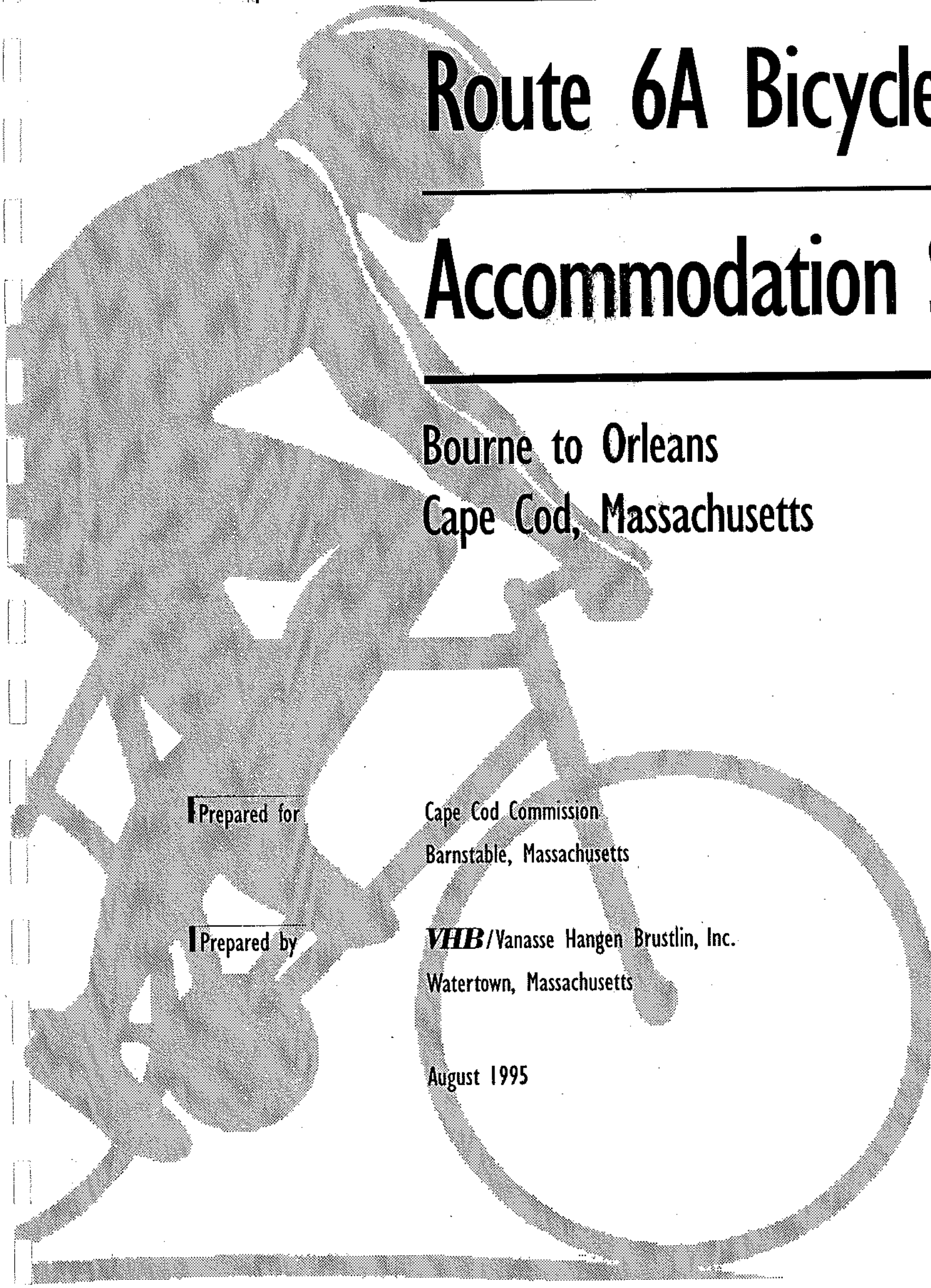
Final Report



Route 6A Bicycle Accommodation Study

Bourne to Orleans
Cape Cod, Massachusetts

Prepared for

Cape Cod Commission
Barnstable, Massachusetts

Prepared by

VHB/Vanasse Hangen Brustlin, Inc.
Watertown, Massachusetts

August 1995

ROUTE 6A BICYCLE ACCOMMODATION STUDY

Prepared for:

Cape Cod Commission
3225 Main Street
P.O. Box 226
Barnstable, MA 02630

Prepared by:

Vanasse Hangen Brustlin, Inc.
Transportation, Land Development, and Environmental Services
101 Walnut Street
P.O. Box 9151
Watertown, MA

August 1995

Spock\Windows\
04259\Rte6A2.doc

CONTENTS

INTRODUCTION

BACKGROUND

Vanasse Hangen Brustlin, Inc. (VHB) was retained by the Cape Cod Commission to identify and analyze both structural and non-structural measures to better accommodate bicycling within the Route 6A corridor while maintaining the scenic and historical characteristics for which the corridor is nationally known. Route 6A is generally a winding, two-lane roadway traversing many historical towns and villages along the bay side of Cape Cod. The study area is approximately 35 miles long connecting the Sagamore Bridge to the west with the Orleans Rotary to the east. Route 6A's roadway and traffic characteristics, such as, cross-section, speed limits, traffic volumes, and truck percentages, vary throughout the entire corridor.

Route 6A is also known as the Old King's Highway and is nationally recognized as one of the most scenic and historical roadways in the country. According to the Route 6A corridor plan, the route is believed to have begun as an Indian trail from Plymouth to Provincetown and was enhanced as the major east-west thoroughfare for early settlers on Cape Cod during the 1600's. The corridor continued to develop over the years and is currently lined with historic properties, scenic opportunities, mature shade trees and many other unique features that add to the corridor's attractiveness. For these reasons, the roadway is a major tourist attraction and recreational resource for surrounding communities and provides access to numerous visitor attractions, both on and off the corridor. In 1992, the roadway was designated a Scenic Road by the Massachusetts State Legislature.

Over recent years, Route 6A has been facing steadily increasing congestion due to increases in visitor and local traffic. Route 6A is one of two east-west routes (the other being Route 6) that provide direct access from the Sagamore Bridge to the northeastern portions of Cape Cod. Route 6 is a four-lane limited access highway (bicycles are not allowed) located in the center of Cape Cod, running somewhat parallel to Route 6A. During peak traffic periods, Route 6A is often used as an alternative route because of congestion experienced on Route 6. This exacerbates the congestion problems that Route 6A is already experiencing.

STUDY ISSUES

There is a great deal of controversy surrounding the development of roadway improvements that could be implemented to improve the safety of traffic operations on Route 6A and better accommodate bicyclists. The following are some of the key issues which were highlighted at the public meeting held on January 5, 1995 at the Sandwich Public Library to kick off this study:

- The current roadway cross-section varies from 20 feet to 24 feet with intermittent shoulders. This width leaves little room for motorists and bicyclists to safely co-exist on the road.

- Many sections of the roadway are in need of structural improvements. There is a difference of opinion as to what level of improvement should be pursued (i.e., what cross-section should be in place).

- Bicyclists, and others, argue that space should be provided on the roadway for their use.

- Some residents along the corridor are concerned that structural improvements will impact the historical and environmental character of the corridor.

- Other residents support some type of structural improvement but are concerned that widening the roadway will increase vehicle travel speeds making the corridor more unsafe for both bicyclists and motorists.

- An increasing number of elderly drivers using the corridor may influence potential improvements because of their unique operating characteristics.

- High volumes of recreational vehicles and commercial trucks using the corridor need to be considered when addressing the needs of bicyclists within the corridor.

- Varying speed limits and high motor vehicle travel speeds need to be considered when addressing the needs of bicyclists within the corridor.

VHB approached this study in two phases. The first phase of the study: researched strategies being used throughout the country on similar corridors to better accommodate bicyclists; identified different physical treatments which could improve bicycle access and operation within the corridor; explored non-structural approaches which could improve bicycle access and operation within the corridor; and investigated issues raised by the Cape Cod Commission (CCC) and the public regarding potential effects of roadway improvements on the operational characteristics of motor vehicles in the corridor.

The second phase of the study concentrated on applying the information gathered in the first phase of the study and data from the Route 6A Corridor Management Plan and field reconnaissance to develop an alternative analysis matrix to help identify the best applications to better accommodate bicyclists along Route 6A. This part of the study provides the types of data necessary for informed decision making regarding future improvements along the corridor.

POLICY REGARDING BICYCLES

There is a need to accommodate bicycles along Route 6A. Efforts to better accommodate bicyclists within the Route 6A corridor are consistent with state and federal transportation policies. The Intermodal Surface Transportation Efficiency Act of 1991, also known as ISTEA, recognizes the transportation value of bicycling and walking, and offers mechanisms, primarily through funding, to increase consideration of bicyclists' and pedestrians' needs within the National Intermodal Transportation System.

Route 6A has also been officially designated a Scenic Road by the Commonwealth of Massachusetts and has therefore qualified for funding under the Scenic Byways Program of ISTEA. The Scenic Byways Program provides funding for roadways that are in need of highway improvements which enhance recreational access, protect historical, cultural and scenic resources and provide pedestrian and bicycle access through facilities, rest areas, overlooks, shoulder improvements, turnouts, passing lanes and other facilities.[1] Improvements to better accommodate bicycling within the Route 6A corridor are, therefore, also consistent with the Scenic Byways Program of ISTEA.

1 "A Summary: The Intermodal Surface Transportation Efficiency Act of 1991," Highway Users Federation and the Automotive Safety Foundation, 1991.

CURRENT UTILIZATION

Route 6A attracts motorists and other modes such as pedestrians and bicyclists because of its scenic and historical characteristics and its directness as one of the only continuous east-west routes on Cape Cod. The Route 6A corridor is considered a destination in and of itself because of its resources. Route 6A is promoted in bicycling publications as a scenic bicycle route providing bicyclists with an opportunity to experience the history of Cape Cod as they travel through the corridor.

Despite the roadway condition of the corridor, bicycling is generally encouraged along Route 6A. Route 6A is a highly publicized bicycle route attracting bicyclists as part of long distance rides, event rides and local trips. Portions of Route 6A are part of the internationally known bicycle route commonly referred to by bicyclists as "Cape in a Day or Two".[2] This bicycle route was inaugurated the Claire Saltonstall Bikeway in 1978 and is approximately 135 miles long beginning in Boston and ending in Provincetown. The Massachusetts Highway Department has produced and installed signs along the route which indicate the name of the route ("Claire Saltonstall Bikeway") and direction ("Boston to Provincetown" or "Provincetown to Boston) and, also signs which refer to Route 6A as Massachusetts "Bicycle Route 1."

In addition to the bicycle route signage, the American Youth Hostels have produced a detailed bicycle map for the entire length of the Claire Saltonstall Bikeway[3]. Event bicycle rides are commonly planned along Route 6A because of its status as an established bicycle route. Two of the well known event rides along this route include: The Pan Mass Challenge sponsored by the Dana Farber Cancer Institute; and the Century Bicycling Weekend sponsored by the American Youth Hostels.

The designation of an established bicycle route along portions of Route 6A, event rides using the designated route, local bicyclists running errands or recreating, and the lack of an alternative east-west roadway, create a significant level of bicycle activity within and around the Route 6A corridor. This high level of bicycle activity has prompted the Cape Cod Commission and the Massachusetts Highway Department to look into methods to improve bicycling conditions within the Route 6A corridor.

The Cape Cod Commission has conducted bicycle counts along the entire Route 6A corridor and portions of Route 6A for 1993 and 1994, respectively. In 1993, it was

2 Thomas, Paul; The Best Bike Rides in New England., The Globe Pequot Press, 1990.
3 "Claire Saltonstall Bikeway Map," Boston to Cape Cod, American Youth Hostels, 1992.

found that bicycle volumes for the entire corridor were approximately 30 bicycles per hour (bph) on a typical summer weekday. According to the data, Brewster and Barnstable recorded the highest average volumes of bicycles per hour, at 12 bph and 5 bph, respectively. It was also noted that the highest concentration of bicyclists were found near Nickerson State Park in Brewster and the playground in Yarmouthport. In 1994, Route 6A bicycle counts were only taken in Barnstable. It was found that approximately 8 bph typically use this portion of Route 6A during a typical summer weekday. These volumes represent an average weekday summer condition and do not indicate bicycle volumes under weekend summer or special event conditions. Weekend bicycle use is probably much higher because of the increase of residents and tourists on Cape Cod during the summer and group tours utilizing the corridor.

TYPES OF USERS

When discussing the requirements and implications of different bicycle facilities for Route 6A, it is important to keep in mind the varying skill levels and needs of different bicycling groups. The 1992 FHWA manual, "Selecting Roadway Design Treatments to Accommodate Bicycles,"[4] divides bicyclists into three distinct user groups:

- Group A—Advanced Bicyclists: experienced bicyclists who can operate under most traffic conditions;
- Group B—Basic Bicyclists: casual or new adult and teenage bicyclists who are less confident of their ability to operate in traffic without special provisions for bicycles; and,
- Group C—Pre-teen bicyclists whose roadway use is initially monitored by parents and who are eventually accorded independent access to the system.

Group A bicyclists ride under most traffic conditions and are comfortable interacting with adjacent street traffic. Bicyclists in this group often use bicycles strictly as a mode of transportation and seek the most direct route to their destination. When riding adjacent to motor vehicle traffic this group is more concerned with roadway (surface) conditions than traffic characteristics. These bicyclists typically do not mind mixing with motor vehicle traffic and require minimal structural roadway improvements; however, maintenance of the roadway edge to provide a consistent and smooth operating surface is critical.

Group B bicyclists have the ability to ride under moderate traffic conditions , but are not comfortable interacting with heavy adjacent street traffic and/or adjacent traffic traveling at high speeds. Under these conditions, this group typically requires additional roadway pavement width with bicycle pavement markings, separating motorists from bicyclists and reducing the amount of interaction between the two modes. Bicyclists in this group are typically recreational riders that will avoid undesirable roadway conditions and traffic characteristics.

---

4 FHWA, "Selecting Roadway Design Treatments to Accommodate Bicycles," Publication No. FHWA-RD-92-073, January 1994.

Group C bicyclists are beginner bicyclists who may not have an understanding of potential safety concerns of bicycling adjacent to motor vehicle traffic. This group, which often includes young families (referred to as B/C bicyclists), is typically more comfortable riding on separate bicycle facilities and residential streets.

Input from the public meeting held for this study on who uses Route 6A focused predominantly on Group A and B bicyclists. Most people felt that Route 6A could never be improved to the extent necessary to accommodate Group C bikers and that this user group should be discouraged from using the road. The decision to focus the bicycle accommodation strategies on Group A and more experienced Group B bicyclists was supported by the Route 6A Corridor Management Plan.

STATE-OF-THE-PRACTICE

INTRODUCTION

The first phase of the Route 6A Bicycle Accommodation Study researched strategies being used throughout the country on similar corridors and innovations in bicycle planning and design. This work was accomplished through an extensive literature search, telephone interviews with industry experts, and access to various bicycle bulletin boards and user groups via the Internet.

Since the implementation of ISTEA in 1991, bicycling and walking has been recognized as an important link in a comprehensive intermodal transportation system. As part of the ISTEA legislation, all metropolitan planning organizations (MPO) are required to develop transportation plans and programs that include pedestrian and bicycle facilities that are consistent with state plans and programs. ISTEA also requires that each state establish and fund a Bicycle and Pedestrian Coordinator position in its Department of Transportation for promoting and facilitating increased bicycling and pedestrian activity, including developing bicycling and pedestrian facilities, public education, promotions, and safety programs for using these facilities.[5] These actions have inspired transportation officials and special interest groups to pursue new and innovative techniques and policies to accommodate pedestrians and bicyclists within a comprehensive transportation system. These programs focus on the Engineering, Education, Encouragement, and Enforcement aspects of bicycle planning and accommodation. These topics, commonly referred to as the 4E's, are discussed in the following sections of this report.

ENGINEERING

There are generally three distinct types of bicycle treatments. The first, a bicycle path, is a bikeway physically separated from motorized vehicular traffic by an open space or a barrier. A bicycle path can be located either within the highway right-of-way or within an independent right-of-way. The second, a bicycle lane, is a portion of the roadway which has been designated by striping, signing, and pavement markings for preferential or exclusive use by bicyclists. The third, a shared roadway, is any roadway which may be legally used by bicycles but does not provide additional space for them, and may, or may not, be specifically designated as a bikeway by the use of signage. Since this study is intended to evaluate treatments to

5 "A Summary: Bicycle and Pedestrian Provisions under the Intermodal Transportation Efficiency Act (ISTEA) of 1991," U.S. DOT, December 1992.

better accommodate bicycles within the existing Route 6A corridor, separate bikepaths were not considered as part of this research.

There are primarily four engineering approaches (structural improvements) typically used in the United States to better accommodate bicycles within existing roadways: bicycle lanes, wide curb lanes, hybrid bicycle lanes and improved roadway shoulders. The following section describes these cross-sections and discusses the associated advantages and disadvantages of each.

Bicycle Lanes

According to AASHTO[6], bicycle lanes are considered when it is desirable to delineate available road space for preferential use by bicyclists and motorists, and to provide for more predictable movements by each. Bicycle lanes should always be one-way facilities and carry bicycle traffic in the same direction as adjacent motor vehicle traffic. Two-way bicycle lanes on one side of the roadway are unacceptable because they promote riding against the flow of motor vehicle traffic. Wrong-way riding is a major cause of bicycle accidents and violates the Rules of the Road stated in the Uniform Vehicle Code.

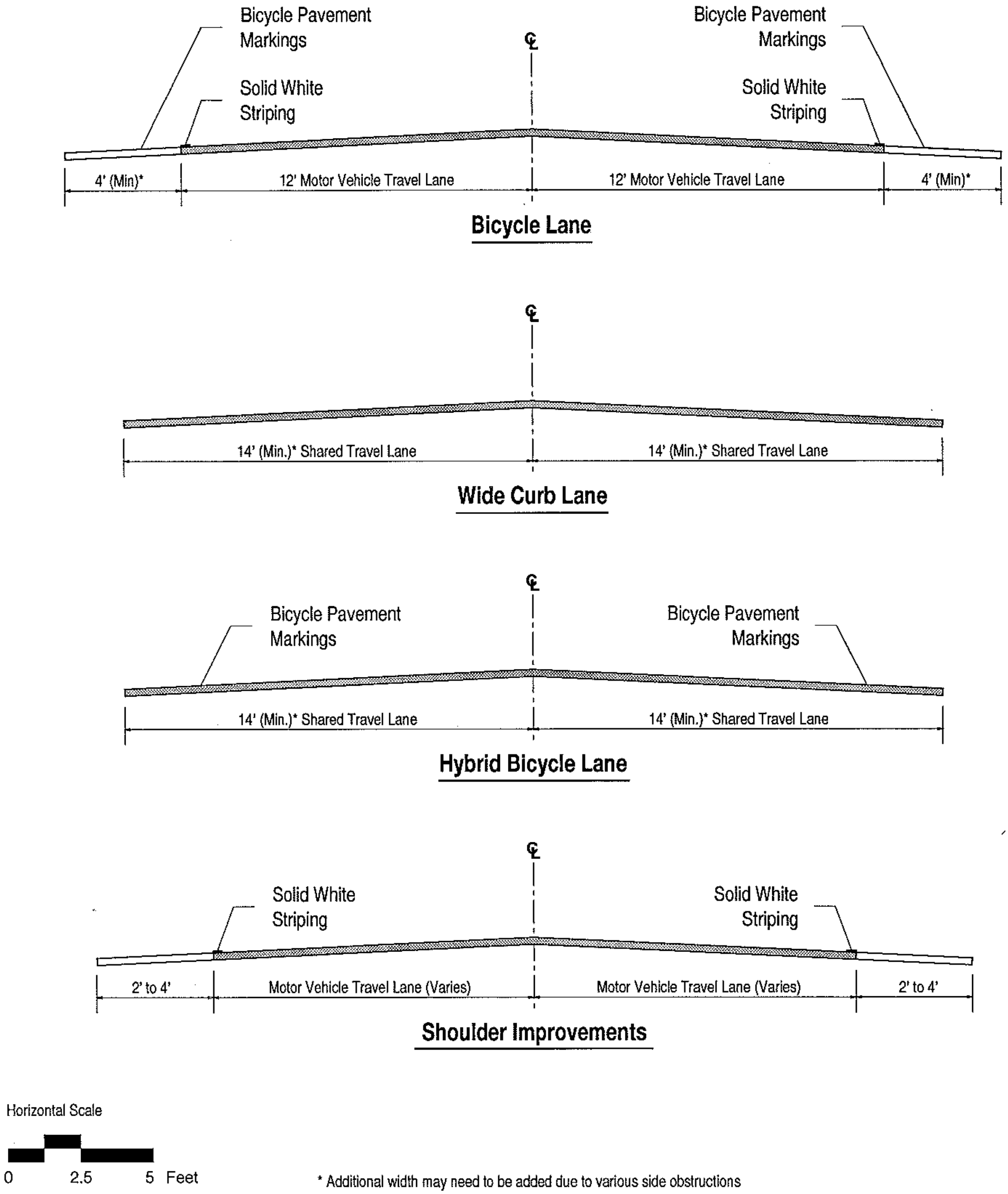
Bicycle lanes are striped lanes that are generally delineated with pavement symbols and signage. Because of their pavement markings, bicycle lanes can also be an effective means of encouraging bicyclists to use particular corridors in lieu of others. This can help consolidate bicyclists within certain corridors, creating a higher awareness of bicycling within the corridor. Under ideal conditions, the minimum bicycle lane width is 4 feet. This provides for comfortable separation between motorists and bicyclists, appealing to both Class A, B and, under certain conditions, B/C bicycle groups. However, certain edge conditions, such as on-street parking, curbing and longitudinal joints, dictate additional desirable bicycle lane width. Additional width is also desirable when the width of the adjacent traffic lane is less than 12 feet. Therefore, under ideal conditions, the total pavement width needs to be at least 32 feet to accommodate two 12-feet travel lanes and two 4-feet bicycle lanes providing desirable separation between the two modes (see Figure 1).

Wide Curb Lanes

An alternative to the full bicycle lane is provision of a wide curb lane. The desirable width of a motor vehicle lane on a typical roadway is 12 feet. On roadways without bicycle lanes, a right travel lane wider than 12 feet can better accommodate both bicyclists and motor vehicles in the same lane and thus is beneficial to both.[7] Wide curb lanes are considered a good alternative to striped bicycle lanes where environmental or other structural constraints prohibit widening for a separate lane. Wide curb lanes are generally preferred in urban environments rather than rural environments because rural roads tend to have higher posted speed limits and heavier truck traffic, both of which require additional clearance between bicyclists and the adjacent motor vehicle stream. The additional lane width required because

6 "Guide for the Development of Bicycle Facilities," American Association of State Highway and Transportation Officials, 1991.

7 "Guide for the Development of Bicycle Facilities," American Association of State Highway and Transportation Officials, 1991.



* Additional width may need to be added due to various side obstructions

Vanasse Hangen Brustlin, Inc.

Typical Roadway Cross Sections Used to Accomodate Bicyclists

Figure 1

of these roadway characteristics may result in a recommended lane width which could encourage the undesirable operation of two motor vehicles in the same lane.[8] As a result, shoulders are used in rural settings.

Wide curb lanes have no stripes to delineate a separate lane for bicycles and, therefore, require bicyclists and motorists to be more aware and attentive of each other, promoting safer interaction between the two modes. According to AASHTO, a wide curb lane width of 14 feet of usable width is desired. Usable width would normally be from the curb face to center lane stripe, or from the edge line stripe to the center line stripe, but adjustments need to made for drainage grates, parking, and longitudinal joints between pavement and gutter sections. The North Carolina Department of Transportation recommends an extra 1 foot of "shy distance" be added for flush or depressed obstructions, such as longitudinal joints or soft shoulders and an extra 2 feet of "shy distance" be added for raised obstructions such as curbing or gutters.[9] Under ideal conditions, the total pavement width needs to be at least 28 feet, not including any adjustments for "shy distances," to accommodate two 14-foot wide curb lanes (see Figure 1). If pavement widths greater than 14 feet are available, consideration should be given to striping a shoulder, as discussed below.

Wide curb lanes are generally acceptable to Group A and some Group B users since they provide a place for bicyclists to ride out of high-speed and high-volume traffic. In addition, wide curb lanes do not offer bicyclists a false sense security similar to bicyclists operating within striped bicycle lanes. According to the Colorado Bikeways Standards and Design Guidelines, wide curb lanes are often the only improvement that is needed to accommodate bicyclists, but striped bike lanes and designated facilities tend to encourage more bicycle use because they tend to attract more Group B and Group C bicyclists in those areas.[10]

However, adjacent motor vehicle speeds and traffic volumes are important determinants when considering wide curb lanes. Depending on the Groups of bicyclists that are anticipated to use the facility, wide curb lanes are appropriate bicycle facilities where traffic speeds and volumes are tolerable for shared roadway facilities. In general, wide curb lane facilities are acceptable for roadway facilities where speeds are not more than 45 mph and volumes are not higher than 20,000 vehicles per day.[11] Research is currently being funded by the Federal Highway Administration to identify other roadway characteristic thresholds for different structural improvements to better accommodate bicyclists.

Hybrid Bicycle Lanes

A hybrid bicycle lane tries to combine the assets of both bicycle lanes and wide curb lanes. Hybrid bicycle lanes have the same pavement cross-section width as wide curb lanes (see Figure 1). In addition, bicycle symbol and directional arrow

---

8 FHWA, "The Effects of Bicycle Accommodations on Bicycle/Motor Vehicle Safety and Traffic Operations, Publication No. FHWA-RD-92-069, July 1994.

9 North Carolina Department of Transportation, "North Carolina Bicycle Facilities, Planning and Design Guidelines," 1994.

10 FHWA, "Current Planning Guidelines and Design Standards Being Used by State and Local Agencies for Bicycle and Pedestrian Facilities," National Bicycling and Walking Study, Case Study No. 24, FHWA-PD-93-006, August 1992.

11 Ibid.

pavement markings are placed in the center of the portion of roadway intended for use by bicyclists. Lane striping separating the two modes is not needed for this approach.[12] The absence of lane striping requires bicyclists and motorists to be more aware and attentive of each other. In addition, bicycle symbol and directional arrow pavement markings help establish the presence of bicyclists within the corridor. This treatment accommodates Group A bicyclists and some of Group B bicyclists depending on the adjacent traffic characteristics. Hybrid bicycle lanes share many of the advantages of bicycle lanes but require bicyclists to be more skilled in interacting with motorists. One key advantage to hybrid bicycle lanes is that they make motorists keenly aware of the presence of bicycles. A disadvantage is that bicycle pavement markings may lure less experienced bicyclists to use the road.

Shoulders

In rural areas, or on roadways with relatively few driveways and intersections, smoothly paved and consistent shoulders are preferred by many bicyclists. Shoulders can reduce the amount of interaction between the two modes by providing bicyclists with a separate area within the roadway to operate. This treatment most often accommodates Group A bicyclists and Group B bicyclists, depending on the adjacent traffic characteristics and the uniformity of the treatment. Where it is intended that bicyclists operate on roadway shoulders, smooth and well maintained shoulders need to be provided.

According to AASHTO, shoulder widths should be a minimum of 4 feet when intended to accommodate bicycle travel. Roadways with shoulders less than 4 feet wide normally should not be signed as bikeways. If travel speeds exceed 35 mph, if the percentage of trucks, buses and recreational vehicles is high, or if fixed side obstructions exist, then additional width is desirable. Under ideal conditions, the total pavement width needs to be approximately 32 feet to accommodate two 12-foot travel lanes and two 4-foot shoulders to accommodate bicyclists through the use of roadway shoulders (see Figure 1). However, any shoulder improvements will benefit Group A bicyclists and many state and regional bicycle planners have stated that even a 2-foot shoulder, if maintained, helps bicyclists.

In many instances, motorists perceive roadway shoulders as the portion of roadway dedicated for bicycling, regardless of whether the shoulders are adequate by AASHTO standards or even signed for bicycle use. However, shoulders are not always adequate for bicycling due to available width, inconsistencies in pavement conditions, and built up debris. For these reasons bicyclists may choose to or need to ride on the edge of the travel lane, utilizing the shoulder as a "bail-out" area. Adjacent motorists may be unaware of shoulder conditions and can become agitated when bicyclists creep from the shoulder onto the travel lane. This behavior promotes conflicts between the two modes and creates a potential safety hazard for bicyclists and can be of particular concern for Group B bicyclists using this type of facility. It has been reported that, overtaking accidents on two-lane rural roadways are the major cause of fatal accidents involving bicycles and motor vehicles.[13] Most of this

12 FHWA, "Measures to Overcome Impediments to Bicycling and Walking," National Bicycling and Walking Study, Case Study No. 4, August 1993.

13 Jones, Gregory M., "On-Road Improvements for Bicyclists in Maryland," Transportation Research Record 739.

concern can be mitigated by an aggressive program to maintain the shoulder and pavement edge.

Summary

Bicycle lanes and adequate shoulders limit mode interaction by physically separating the two modes through pavement markings, bicycle lane striping and edge striping, respectively. Because of the wide separation and lack of interaction, motorists tend not to reduce speeds when bicyclists are present, creating a safety concern for some bicyclists. This separation may also result in a false sense of security and attract bicycling groups that may not possess the abilities to safely operate a bicycle under particular roadway conditions. This is an important concern for Route 6A, because this condition is more likely to occur in areas that are saturated with tourists/recreational bicyclists that may be more accustomed to riding on separate bicycle paths. However, on roadways with low traffic volumes and travel speeds, where safety is not compromised, bicycle lanes may be advantageous to encourage bicyclists by offering the security of separation.

Wide curb lanes work best where the intent is to accommodate Group A bicyclists. Bicycle lanes work better where the intent is to encourage more bicycle use by Group B/C bicyclists. Wide curb lanes and hybrid bicycle lanes encourage interaction between bicyclists and motorists allowing bicyclists to establish themselves within the roadway. This reduces conflicts created by perceived or implied lane designations for the two modes and allows bicyclists to be more visible to the motorists. The hybrid bicycle lane establishes the presence of bicyclists within the roadway through pavement markings. These pavement marking, however, do not create a false sense of security, because separate travel lanes are not designated for the two modes. These two cross-sectional treatments, because of the implied interaction, both tend to reduce motor vehicle speeds when bicyclists are present.

Roadway shoulders designated for bicycle use can be an effective structural improvement to better accommodate bicyclists. Wide shoulders can provide a viable alternative to wide curb lanes, and in some instances may be preferable; for example, on roadways with higher speeds and traffic volume or rural routes with restricted sight distances,[14] conditions similar to Route 6A. Adequate roadway shoulders need to have a consistent width and be maintained to ensure a smooth operating surface clear of debris when intended for bicycle use. Wide shoulders may be inviting to Group A and some Group B bicyclists, however, Group B bicyclists may not have the ability to interact with heavy traffic volumes if portions of the shoulder are inaccessible due to debris or structural conditions. This can create a safety concern for both the bicyclists and the adjacent motorists. If enough room is available to obtain the AASHTO minimum of 4-foot shoulders and high bicycle volume exists in the corridor, then bicycle lanes may be preferred. If the 4-foot minimum is not obtainable, minor shoulder improvements to increase the roadway's overall safety will, at a minimum, improve bicycling for Group A and Group B bicyclists within the corridor.

---

14 FHWA, "The Effects of Bicycle Accommodations on Bicycle/Motor Vehicle Safety and Traffic Operations, Publication No. FHWA-RD-92-069, July 1994.

Engineering considerations, discussed above, address structural changes that could be implemented to better accommodate bicycling on Route 6A. There are also non-structural considerations such as education, encouragement, and enforcement programs which enhance a roadway's ability to properly accommodate bicycles.

Education Programs

Motorists and bicyclists are not always aware of each others needs when sharing a roadway. Many states are focusing on education programs for both motorists and bicyclists to ensure safe interaction between the modes. Motorists should be educated during driver education programs and tested during the driver licensing exams on laws and commonly accepted operating techniques involving bicycles.

Proper interaction between motorists and bicyclists also needs to be taught to bicyclists. Bicycling does not require any formal licensing or testing. Anyone who is physically able to operate a bicycle may do so on any bicycle facility. Because of the lack of formal licensing or testing, bicyclists may not be familiar with bicycle laws and/or commonly accepted operating practices. This can lead to confusion between bicyclists and motorists and can create unsafe operating conditions. Bicyclists should be educated on bicycle laws, bicycle riding techniques and motor vehicle operations to help increase safety for both modes. The education process for bicyclists should begin at a young age and be a continual process. Again, there is strong movement across the United States to improve past efforts in this area.

Education programs need to target not only bicyclists and motorists but also police and lawmakers responsible for enforcing and developing motor vehicle and bicycle laws. Police officers need to be informed of bicycle laws so they can be properly enforced.

Encouragement

Measures need to be taken to encourage the use of bicycle facilities in pursuing a comprehensive intermodal transportation system. Education and enforcement programs can play an important role in promoting bicyclists. There are also encouragement measures that can be pursued to better accommodate bicyclists within a roadway corridor including, "Share the Road" programs, spot maintenance programs and route information.

One of the most successful encouragement techniques being implemented are "Share the Road" programs. These programs inform motorists that bicyclists may be present on the roadway through the use of warning signs, leaflets, bumper stickers, and other efforts. This program is typically not intended to encourage bicyclists to use a particular bicycle route, but rather to encourage cooperation between motorists and bicyclists in sharing congested roadways under less than desirable operating conditions.

Spot maintenance programs are also being included in community bicycle plans to help ensure safe bicycling conditions throughout the community. These programs are established to identify minor roadway repairs, such as pot hole patching, street sweeping, drainage grate replacement and sight distance improvements that can help create a safer environment for bicyclists. Spot maintenance programs can also establish an interactive process between roadway maintenance departments and bicycling groups. This process can educate both groups of practical needs of the other.

Keeping bicyclists and motorists informed of anticipated roadway characteristics and traffic conditions is an effective technique in encouraging cooperation between motorists and bicyclists in sharing congested roadways. On roadways with high levels of bicycle traffic, both the bicyclists and motorists should be made aware of traffic conditions, such as roadway width, traffic volumes, truck volumes and travel speeds. Perhaps in the case of Route 6A, bicyclists should be warned to avoid certain heavy traffic times. Other pertinent information that could be provided includes pavement conditions, roadway grades, mileage, important services, bicycle repair shops, bicycle laws, etc. This information enables bicyclists to self evaluate their own ability to safely bicycle along a corridor. Information, such as this, can be provided on bicycle maps and/or general information leaflets regarding Route 6A.

ENFORCEMENT PROGRAMS

Enforcement programs need to be implemented to ensure that bicyclists and motorists comply with motor vehicle and bicycle laws. Enforcement and information on bicycling safety can help make bicyclists and motorists function together in the same environment, enabling them to share the road. Sometimes illegal, careless, and inappropriate bicyclist behavior is a primary cause of automobile-bicycle accidents. These faults contribute heavily to the bad image of bicyclists, and the poor relations between motorists and bicyclists. Bicyclists that ride recklessly also set a dangerous example for children learning how to ride a bicycle.[15]

Enforcement does not necessarily have to be negative in character, since it constitutes education. Highly visible enforcement campaigns can focus on giving warning citations towards the beginning of the campaign as a means of educating bicyclists in the area. As the campaign continues, bicyclists should eventually be fined for violating traffic laws.

Motor vehicle traffic laws, especially speed limits, should be aggressively enforced on roadways that are expected to have high bicycle use. This is particularly applicable to Route 6A High motor vehicle speeds increase the likelihood of a bicyclist fatality in a bicycle/motor vehicle collision.[16] "Zero tolerance" enforcement programs should be implemented on these roadways to reduce travel speeds. "Zero tolerance" enforcement programs aggressively monitor particular corridors through saturation speed patrols, aerial speed enforcement and public information to effectively eliminate speeding within the corridor.[17]

15 FHWA, "Measures to Overcome Impediments to Bicycling and Walking," National Bicycling and Walking Survey, Case Study No. 4, August 1993.

16 Gardner, Per., "Bicycle Accidents in Maine: An analysis," Transportation Research Record 1438.

17 National Highway Traffic Safety Administration, "Off-Limits—A Reference Guide for Improving Compliance with Posted Speed Limits," 1988.

CURRENT APPLICATIONS AND INNOVATIONS

As part of the research conducted for this study, VHB surveyed bicycle activities throughout the United States to learn what innovations and success bicycle planners are having in better accommodating bicycles within our transportation system. This research was particularly focused on what is being done along corridors where major structural improvements are not possible due to environmental or other land use constraints. The following pages offer a brief snapshot of what is going on elsewhere for innovations.

- The North Carolina Department of Transportation has developed a subplate relaying the "share the road" message to both motorists and bicyclists. This subplate, when combined with the bicycle warning sign (W11-1) is intended to increase a bicyclists visibility without designating the signed roadway as a preferred bicycle route. These signs are intended for use on roadways with high levels of bicycle traffic, but relatively hazardous conditions for bicyclists and are not intended to encourage inexperienced bicyclists to bicycle on the roadway as a preferred route. North Carolina considers this an interim solution.

- The Maryland Department of Transportation is in the process of approving signage criteria for "share the road" programs throughout the State. This program is geared towards educating motorists that bicycling is a legitimate highway vehicle with equal rights and responsibilities. For this program blue and white information signs are used instead of a yellow warning signs whether poor bicycle conditions exist on the roadway or not. The Department of Transportation also distributes "share the road" bumper stickers to increase the exposure of the program. Maryland approaches this as an education/encouragement program and plans to potentially install these signs on roadways throughout the State.

- The Florida Department of Transportation installs "share the road" warning signs where high bicycle use is expected on roadways with less than adequate cross-section or roadway conditions.

- The Maine Department of Transportation and Bicycle Coalition of Maine are jointly running a "bike spot improvement" program to fix relatively minor defects that affect bicyclists in the state. The Bicycle Coalition distributes printed, post paid request cards to bike clubs, shops and other appropriate locations and the public sends completed forms straight back to the Department of Transportation.

- The City of London, Canada has initiated a "Spot Improvement Program," to reduce hazards along popular bicycle routes through small scale, low-cost improvements. Hazards include street debris, dangerous potholes, sewer grates and railway crossings. The City of London recommends that the program could be funded through the existing road maintenance budget depending on whether the roadway is a local or state maintained road.

- District 1 of the California Department of Transportation publishes and distributes a "Bicycle Touring Guide" that describes what bicyclists can anticipate along popular bicycle routes within the District. The guide includes descriptions of traffic and truck volumes, roadway widths, vehicle speeds, roadway elevations, attractions and bicycle services for these popular routes.

- Route 101 and 1 from the Oregon border along the entire coast of Northern California is a nationally and internationally known bicycle route. This route was at one time designated "The Pacific Coast Bicentennial Bicycle Route" and was signed such along its entire length. After a few years of the signed bicycle route being in place the California Department of Transportation removed the signs because of undesirable roadway widths, traffic volumes, truck percentages and associated liability issues. It was felt that if optimum conditions did not exist along the route then the route should not be officially designated a safe bicycle route by the Department of Transportation.

- The North Carolina Department of Transportation (NCDOT) has implemented a "share the road" program on a similar corridor to Rout 6A on the outer banks of North Carolina. The corridor is approximately 30 miles long with a pavement cross-section of 22 feet. Similar to Route 6A, this corridor attracts many bicyclists during the summer months. Environmental constraints on both sides of the road restrict potential widenings. Since the implementation of this program there has been no reported bicycle/motor vehicle accidents within the corridor. The Share the Road program is simply installation of bicycle warning signs with the message "share the road" to make motorists more aware of the presence of bicyclists within the corridor. However, sight distance restrictions on this corridor are not present and wide, sandy shoulders are present on both sides of the road.

- In Wenham, Massachusetts the Police Department has implemented aggressive speed reduction programs. These programs have been very successful for some roadway corridors in the town.

- The Florida DOT has recently altered its policy of providing wide curb lanes on all new highways in Urban areas in favor of providing designated bike lanes. Accommodation of Group B and C bicyclists was a key determinant in this decision.[18]

- The Lake County, Florida bicycle and pedestrian plan recommends sidewalks and wide curb lanes be developed to 1 mile beyond the corporate limits of municipalities. After that, there should be at least a 4-foot shoulder added to the county roads to 3 miles beyond the city limits, and shoulders should be given a lower priority 5 miles from the city limits.[19]

- The Lexington Bicycle Safety Program, Inc., located in Lexington, MA, is a non-profit organization devoted to promoting safer riding by bicyclists. It organizes bicycle safety events, coordinates media campaigns promoting bicycle safety throughout Massachusetts, and produces a variety of educational materials for national distribution, some of which include:

---

18 FHWA, "The Effects of Bicycle Accommodations on Bicycle/Motor Vehicle Safety and Traffic Operations, Publication No. FHWA-RD-92-069, July 1994.

19 FHWA, "The Effects of Bicycle Accommodations on Bicycle/Motor Vehicle Safety and Traffic Operations, Publication No. FHWA-RD-92-069, July 1994.

-- "A Two-Lesson Elementary School Bicycle Safety Curriculum Kit." The kit presents bicycle safety to students in kindergarten through grade two and students in grade three to grade five.

-- "Video Public Service Announcements Starring NBA Players." The 30-second announcements have appeared on television stations throughout the United States. The videos include Robert Parish, a Boston Celtic's legend, talking about knowing the rules of the road, and Sherman Douglas and Dee Brown of the Boston Celtics, talking to adults about setting a good example when cycling and about the importance of wearing a bicycle helmet, respectively.

- Broward County, Florida has developed a bicycle education program for elementary schools as part of the physical education curriculum. The County has purchased three sets of bicycles and helmets to be used for the program. The County received funding for this program through a grant sponsored by the Florida Department of Transportation.

- The League of American Wheelmen offers a three-hour training course entitled "Effective Cycling". This course targets adult bicycle riders and covers topics including bicycling in traffic, road hazards, laws pertaining to bicyclists and riding techniques.

- The National Highway Safety Administration has developed a forth-grade level bicycle education course which is currently being used by schools throughout the country.

- The Massachusetts Department of Public Health distributes a "Bicycle Packet" that provides bicycle safety information. This information includes; bicycle laws, bicycle fact sheets, bicycle safety curricula, audiovisual resources, community bike safety kits and other educational material.

- The American Automobile Association has a developed a bicycle guidebook entitled "Teacher's Guide to Bicycle Safety, Kindergarten to Grade 8". The guidebook has been developed to assist teachers in ways to implement bicycle safety into daily classroom programs.

- The Kiwanis Foundation of New England and the Kiwanis Affiliated Pediatric Trauma Centers organize annual New England wide bicycle rodeos to promote safe bicycle riding techniques to families.

- Massachusetts, Washington, D.C., Michigan and other states, currently have driver education programs emphasizing proper motor vehicle operation in the presence of bicyclists and include this as part of the testing requirements for licensing.

- The American Trucking Association has an active education program educating truck drivers of the needs of bicycles and trucks when sharing the road. The American Trucking Association has also developed a video tape entitled "Trucks and Bicycles Sharing the Road" to illustrate these needs. These can both be effective education programs targeting motorists.

Defining a bicycle improvement program for Route 6A requires a complete understanding of the factors which affect bicycling along Route 6A and the impacts of potential alternatives to better accommodate bicycling within the corridor. The following section discusses roadway geometric and traffic flow characteristics of Route 6A and evaluates the impacts to the Route 6A corridor of two structural roadway improvement alternatives.

EXISTING BICYCLIST STRESS RATING

When evaluating the Route 6A corridor for its ability to accommodate bicycling, it is important to develop an understanding of the existing roadway geometric and traffic flow characteristics and the effects of these characteristics on bicycling.

There is currently limited information available to guide engineers and planners in the evaluation of existing roadways to determine whether a roadway facility can safely accommodate different types of bicyclists. The Traffic Institute of Northwestern University has developed an "Urban/Suburban Street Compatibility Evaluation"[20] which quantifies bicyclist stress levels in relation to various traffic flow and roadway geometric characteristics. The key traffic flow characteristics evaluated in this study include peak hour traffic volumes, 85th percentile speed, and truck percentages. The key roadway geometric characteristics included curb lane width, parking turnover and driveway frequency. Each traffic flow and roadway geometric characteristic were divided into stress level rating parameters. The Northwestern study based the stress level parameters on professional judgment and limited research. The stress level ratings for each traffic flow and roadway geometric characteristic are then averaged to determine an overall stress level rating that can be applied to a particular roadway segment. This overall stress rating can then be used to help identify potential problem areas that may hinder safe bicycle operation on a roadway segment and to test the effectiveness of strategies to address them.

The Federal Highway Administration (FHWA) has recently funded the Traffic Institute to further develop the stress level rating approach for evaluating bicycle compatibility on existing roadways. The Traffic Institute will concentrate on developing a comprehensive database to statistically define traffic flow and roadway geometric threshold parameters and their associated stress levels.

20 Sorten, Alex and Walsh, Thomas, Urban and Suburban Bicycle Compatibility Street Evaluation Using Bicycle Stress Level, Paper Presented at the 73rd Annual TRB Meeting, Washington, D.C, 1994.

Route 6A Stress Rating

VHB has built on the limited research of the Traffic Institute's approach to develop a stress level rating system that appears reasonable for evaluating bicycle compatibility on the existing roadway segments of the Route 6A corridor. VHB has identified four key traffic flow and roadway geometric characteristics that have a significant impact on bicycle travel within the Route 6A corridor:

- peak hour traffic volumes,
- motor vehicle speeds,
- curb lane width, and
- number of trucks or recreational vehicles.

These four variables have been selected to reflect critical elements of traffic flow and roadway geometrics affecting the level of comfort (or stress) of bicycle travel within the Route 6A roadway corridor. The inclusion of these factors came from experience riding Route 6A and our reaction to the conditions which most contribute to the corridor's friendliness toward bicyclists All factors were weighted equally with the exception of width, which was given double weight. Details of the parameters and their associated stress levels are provided in the Appendix to this report. The traffic flow and roadway geometric data collected for the Route 6A Corridor Management Plan by the Cape Cod Commission were primarily used for this analysis.

Vehicles Per Hour Per Lane (Curb Lane)

Peak summer average daily traffic (ADT) volumes from 1993 for representative locations along Route 6A were obtained from the Cape Cod Commission. A growth rate of 0.9 percent per year was then applied to the ADT's to represent 1995 existing traffic volumes. Peak hour traffic volumes were then derived by applying a peak hour factor of 9.89 percent to the daily traffic volumes. The peak hour curb lane traffic volumes were determined by using an even (50/50) directional distribution. The growth rate, peak hour, and directional distribution factors were also provided by the Cape Cod Commission. The resulting peak hour curb lane traffic volumes are presented in Table 1. The peak hour curb lane traffic volumes were then assigned a corresponding stress rating as discussed in the Appendix of this report.

Traffic volumes vary considerably over the length of the corridor. The highest traffic demands are experienced in the Bourne/Sandwich area, in the vicinity of Union Street in Yarmouth, and from the Brewster/Orleans town line to the Orleans rotary. The lowest volumes along the corridor are in Barnstable.

Curb Lane Width

Roadway widths for half mile intervals along Route 6A were provided by the Cape Cod Commission. Curb lane widths were then developed by dividing the roadway widths in half. The average curb lane width per section are provided in Table 1. The curb lane widths were also assigned associated stress ratings. The roadway width of Route 6A generally ranges from 21 to 24 feet. The roadway is narrowest through Barnstable and Yarmouth.

Traffic Speed

The 85th percentile speed was not readily available for the numerous speed limit changes throughout the corridor. However, a field inventory of existing posted speed limits throughout the corridor by VHB was used to supplement available 85th percentile speeds and demonstrate the speeds within the corridor. The average speed limits per section are summarized in Table 1. The traffic speeds were then be assigned an associated stress ratings as discussed in the Appendix of this reports. The highest average speed limits along the corridor are in sections of Sandwich, through Dennis, and in Orleans. The lowest speeds are found in Barnstable.

Truck Frequency

Peak hour truck volumes in the curb lane were determined by reviewing truck counts provided by the Cape Cod Commission for particular intersections along the Route 6A corridor. These data are generally correlated to traffic volumes, although there is slightly higher truck activity in the eastern portion of the corridor. This information, however, was based on limited data and should be viewed as such. The average truck frequencies per section are presented in Table 1. The truck frequency data were also assigned associated stress ratings, as discussed in the Appendix of this report.

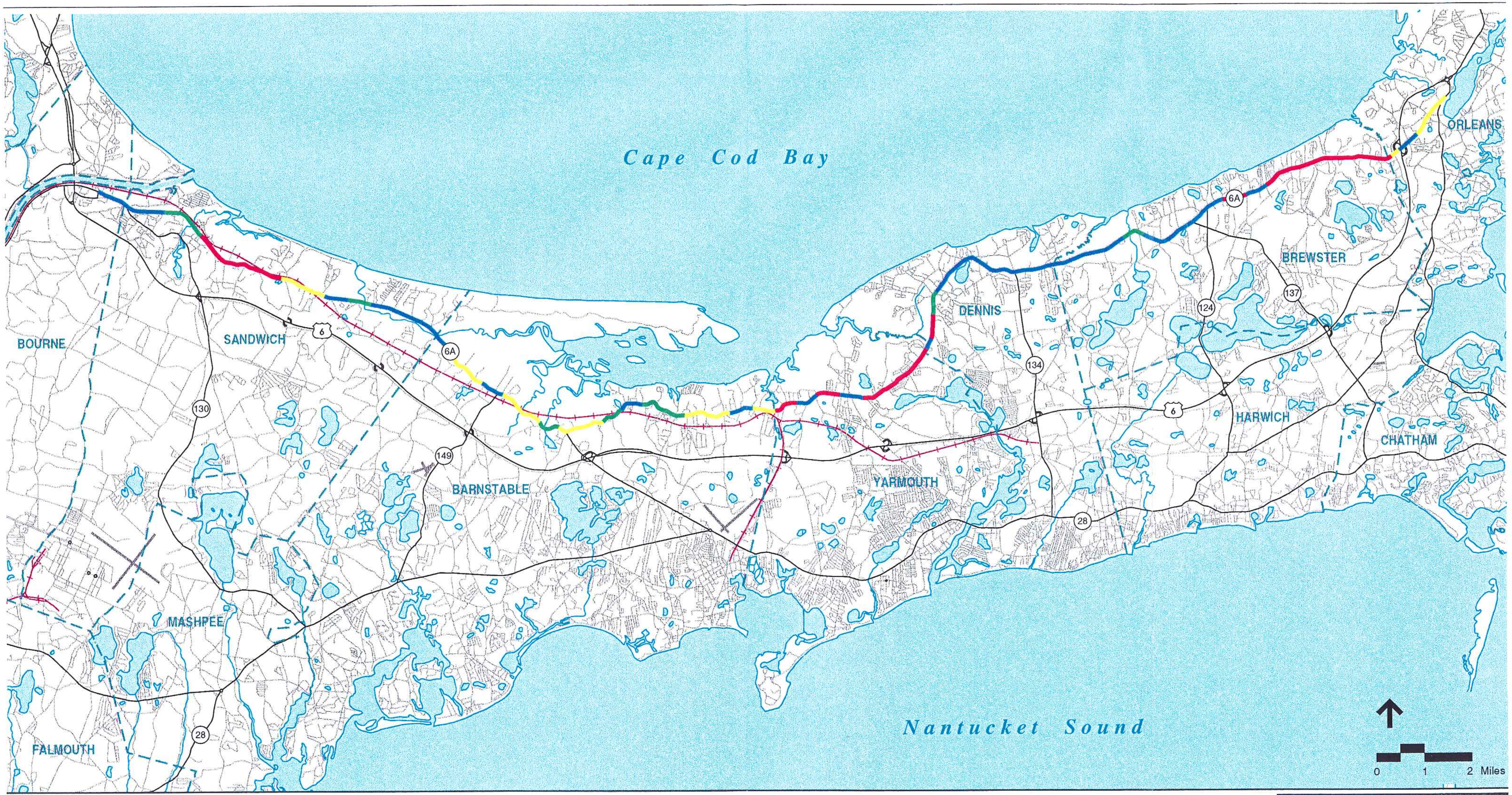
Results

Table 1 presents an overall average stress rating for each section of Route 6A. This rating is simply a derived average of the stress ratings associated with each section's curb lane traffic volume, average posted speed limit, average curb lane width and truck frequency. Again, in calculating the average, the curb lane factor was given twice the weight, since the available roadway width is fundamental to safe bicycle operations. Figure 2 graphically presents the average stress ratings for each section of Route 6A.

The stress ratings, as defined, can range from 1 to 5, with 1 being excellent (low to no stress for bicyclists) and 5 being poor (extremely high stress for bicyclists). The ratings that were calculated for Route 6A range from 3.16 to 4.35. In other words, the corridor rates well worse than "average" for accommodating bicyclists.

From inspection of Table 1 and Figure 2, it becomes apparent that the segment of roadway that has the least bicycle stress is (perhaps surprisingly) Barnstable. This is attributable to the lower traffic volumes, lower posted speed limits.and lower truck frequency. It also is apparent that the sections of Route 6A that have higher traffic volumes, higher posted speed limits and higher truck frequency, and narrower pavement width, such as Yarmouth and portions of Brewster, have the highest bicycle stress rating. The other conclusion which is evident in reviewing Figure 2, is the variability in the corridor's conditions for accommodating bicycles. This factor also detracts from a bicyclist's experience in traveling Route 6A.

Accepting the factors which contribute to bicycle stress, one can also clearly see what actions might improve bicycle accommodation along the Route 6A corridor. The first set of actions to investigate are structural improvements. These might include minor widening to provide some shoulder space, or more extensive widening to provide a full bicycle lane. A key consideration here is to provide a consistent and



Bicycle Stress Ratings

- 0 - 3.00
- 3.01 - 3.50
- 3.51 - 4.00
- 4.01 - 5.00

Vanasse Hangen Brustlin, Inc.

Figure 2

Existing Bicycle Stress Ratings

well maintained surface for bicyclists, since bicycle stress is also related to user expectancy and the inconsistency of corridor conditions.

If structural improvement opportunities are limited because of historical, environmental, or financial constraints, it is important to explore the potential of non-structural improvements to affect other factors within the corridor that impact bicyclist stress, such as speeds, traffic volumes and truck frequency. These issues are discussed in more detail later in this report.

Table 1 FACTORS AFFECTING ROUTE 6A BICYCLE STRESS

	Mile Markers		1995 Curbside* Traffic	Average Posted	Average Curb Lane	Truck	Average Stress
	Begin	End	Volume	Speed**	Width***	Frequency+	Rating
	0.00	0.63	875	40	12.5	8	3.80
Sandwich	0.63	2.00	651	37	14.2	9	3.37
	2.00	4.50	785	39	11.0	9	4.00
	4.50	8.12	360	43	11.6	5	3.45
Barnstable	8.12	11.50	355	37	11.0	5	3.33
	11.50	14.00	310	30	11.3	6	3.16
	14.00	16.53	561	32	11.8	6	3.30
Yarmouth	16.53	19.50	806	39	10.9	8	4.20
	19.50	20.25	697	40	10.8	11	4.35
Dennis	20.25	21.50	697	43	13.7	12	3.73
	21.50	24.51	527	40	12.1	12	3.77
Brewster	24.51	27.50	438	38	12.2	12	3.57
	27.50	30.50	854	37	11.9	12	4.10
	30.50	32.29	933	41	12.0	12	4.25
Orleans	32.29	33.00	720	40	12.5	17	3.20
	33.00	34.00	814	38	13.8	17	3.30

* One-way peak hour traffic volumes, derived from 1993 ADT traffic volume data provided by the Cape Cod Commission.
** Based on posted speed limits.
*** From roadway center to edge of pavement, excluding Cape Cod berm. Data provided by Cape Cod Commission.
+ Number of trucks in one direction of travel during the peak hour. Based on limited data provided by Cape Cod Commission.

STRUCTURAL IMPROVEMENT ALTERNATIVES

Two levels of structural improvements were tested as part of this study to provide the Cape Cod Commission and the Massachusetts Highway Department with some planning level guidance on future roadway improvements to better accommodate bicycles along the Route 6A corridor. A "minimum", or low-end, structural improvement was defined as a 26-foot cross-section featuring an 11-foot travel lane with a 2-foot shoulder in each direction. This is the same cross-section that is being proposed by the Massachusetts Highway Department for a section of Route 6A in Sandwich. A "maximum", or high-end, structural improvement was defined as a 32-foot cross-section, featuring a 12-foot travel lane and 4-foot bicycle lane in each direction. The impacts associated with each of these cross-sectional treatments were evaluated and are discussed in the subsequent sections of this report. To determine the impacts associated with a cross-section in between the two alternative defined (ie. for a 28-foot roadway with wide curb lanes and no shoulders), one should simply interpolate the impacts between the low and high-end treatments.

Physical Impacts

The assessment of the physical impacts that would result from the alternative structural improvements to Route 6A was completed largely through the use of the Cape Cod Commission's existing Geographic Information System (GIS) database. This database was supplemented by field inspection, where appropriate. Field notes of key design issues are also provided in the Appendix to this report . The data presented in this section of report should be used for planning purposes only. Progressing the design of a defined improvement program, with recent survey and base mapping, is necessary to provide a more detailed and accurate assessment of the location and magnitude of the physical impacts.

Table 2 presents a summary of the potential corridor impacts for the two structural improvements defined for the corridor. This section of the report discusses and compares the order of magnitude impacts for the two alternatives.

Wetland Impacts

The Critical Environmental Features database provided by the Cape Cod Commission was utilized to assess the implications on wetlands of the two structural alternatives considered for Route 6A.[21] The square footage of wetland impact was calculated approximately for each alternative by taking the linear footage of wetlands along Route 6A and multiplying it by the width of the widening. As is common with many roads on Cape Cod, wetlands are adjacent to the roadway in many areas. The result is that there will be some degree of wetlands impact with any level of widening to the corridor. As an order of magnitude estimate, a low-end structural improvement for the entire 34 mile corridor would impact approximately 1.5 acres of wetlands. Provision of a full bicycle lane under the 32-foot cross-section alternative would impact over 6 acres of wetlands.

With respect to drainage impacts, the 26-foot cross-section would not significantly increase runoff or require extensive drainage improvements. The 32-foot cross-section would increase runoff by more than 50 percent in some locations and would most likely require extensive drainage improvements along the corridor.

Historic Impacts

Route 6A is strongly valued for its many historic resources. Most of the Route 6A corridor under study is within the Old King's Highway Regional Historic District. In addition, the corridor contains many areas and properties which are on or are eligible for the National Register. The total land area affected by the widening

21 The data sources referenced for the wetlands data include the MacConnell wetlands map and Massachusetts Department of Environmental Protection (DEP) wetland restrictions map.

alternatives was calculated for the areas eligible to be on the National Register and areas defined by the CCC "of moderate historic integrity".

In general, the low-end (26-foot) structural improvement to Route 6A will have modest impacts on the historic features within the corridor. Over the 34 mile study area, approximately 5 acres outside the current roadway limits will be affected; however, essentially all of the roadway's historic points of interest and special features are set back sufficiently from the roadway edge and would not be physically impacted by a 26-foot cross-section. On the other hand, the 32-foot full cross-section would have significant impact, especially on adjacent stonewalls and fences in areas where the right-of-way is limited. This is particularly true in Barnstable, Yarmouth and Brewster. In terms of historic resource areas, the high-end structural treatment would affect a little over 2 acres of land of moderate historic integrity and over 17 acres of land in areas where properties are either on or eligible for the National Register of Historic Places.

Tree Impacts

Route 6A is lined with mature trees along most of its corridor. There are sections of the corridor with limited tree coverage or with trees that are set back at a reasonable distance from the roadway. However, there are other areas that have trees only a few feet from the edge of the road, such as the sections of Route 6A entering and exiting Barnstable Village and in Brewster. Many of the trees that are very close to the edge of the roadway are in poor condition from being hit by motor vehicles, pruned by the utility companies, or affected by roadway salts and other pollutants. A low-end structural treatment (26-foot cross-section) would have some impacts on adjacent trees. On average, this treatment would impact about 7 trees per mile of improvements. The high-end structural treatment (a 32-foot cross-section) would have significant impacts on adjacent trees. Although it varies widely by location, this type of structural improvement along Route 6A would affect, on average, 52 trees per mile. Along sections of the corridor, minor roadway realignment could help avoid the removal of some trees under both conditions.

Table 2 CONCEPTUAL CORRIDOR IMPACTS BY BICYCLE TREATMENT ALTERNATIVE

	Mile Markers		Physical Impact by Alternative											
					Historic Areas++									
			Wetlands (sf)+		Moderate Integrity (sf)		National Register (sf)		Trees (#)+++		Utility Poles(#)*		Sidewalks (lf)	
	Begin	End	Low**	High***	Low	High	Low	High	Low*	High**	Low	High**	Low	High
	0.00	0.63	--	--	3,200	12,800	--	--	--	--	--	30	--	2,850
Sandwich	0.63	2.00	--	--	--	--	--	--	0	39	--	70	--	--
	2.00	4.50	2,100	8,400	--	--	16,800	67,200	13	70	--	130	--	5,525
	4.50	8.12	3,600	14,400	--	--	3,200	12,800	22	100	--	175	--	--
Barnstable	8.12	11.50	16,300	65,200	--	--	35,600	142,400	20	382	--	165	--	2,450
	11.50	14.00	3,200	12,800	--	--	26,400	105,600	37	172	--	120	--	13,750
	14.00	16.53	--	--	--	--	26,800	107,200	35	167	--	125	--	14,875
											--		--	
Yarmouth	16.53	19.50	3,700	14,800	--	--	20,800	83,200	17	104	--	145	--	13,625
	19.50	20.25	--	--	--	--	--	--	3	17	--	40	--	--
Dennis	20.25	21.50	1,100	4,400	--	--	10,600	42,400	19	94	--	60	--	200
	21.50	24.51	9,500	38,000	7,400	29,600	19,200	76,800	8	147	--	145	--	9,475
											--		--	
Brewster	24.51	27.50	25,400	101,600	7,400	29,600	10,400	41,600	46	242	--	145	--	1,450
	27.50	30.50	600	2,400	--	--	21,100	84,400	27	155	--	145	--	14,775
	30.50	32.29	1,500	6,000	--	--	--	--	6	68	--	90	--	--
											--		--	
Orleans	32.29	33.00	200	800	7,400	29,600	--	--	--	--	--	35	--	475
	33.0	34.00	200	800	--	--	--	--	--	--	--	50	--	12,250

\+ Based on Cape Cod Commission provided GIS data and limited field inspection (square feet).
++ Based on Cape Cod Commission GIS data. Includes properties and/or eligible for the National Register.
+++ Defined as trees greater than approximately 8" in diameter. Based on windshield surveys and corridor field inspection (square feet).
* Based on one utility pole per 110 feet throughout entire corridor, only effected by maximum improvement.
** Based on a 26-foot roadway cross-section for entire corridor.
*** Based on a 32-foot roadway cross-section for entire corridor.

Utility Impacts

Overhead utility poles are present on one side of Route 6A through most of the corridor. The position of these poles detract from the corridor's scenic and historic value. In many areas, the utility poles and lines compete with the corridor's tree canopy. Under the low-end alternative, the utilities will not be significantly impacted. The minor widening necessary to accommodate a 26-foot cross-section can be moved from one side of the road to the other to avoid any major utility relocation. However, the high-end alternative will require relocating the majority of the utility poles in the corridor to accommodate the 32-foot cross-section. If this improvement were made, it may be appropriate to investigate the possibilities of relocating these utilities underground for portions of the corridor.

Sidewalk Impacts

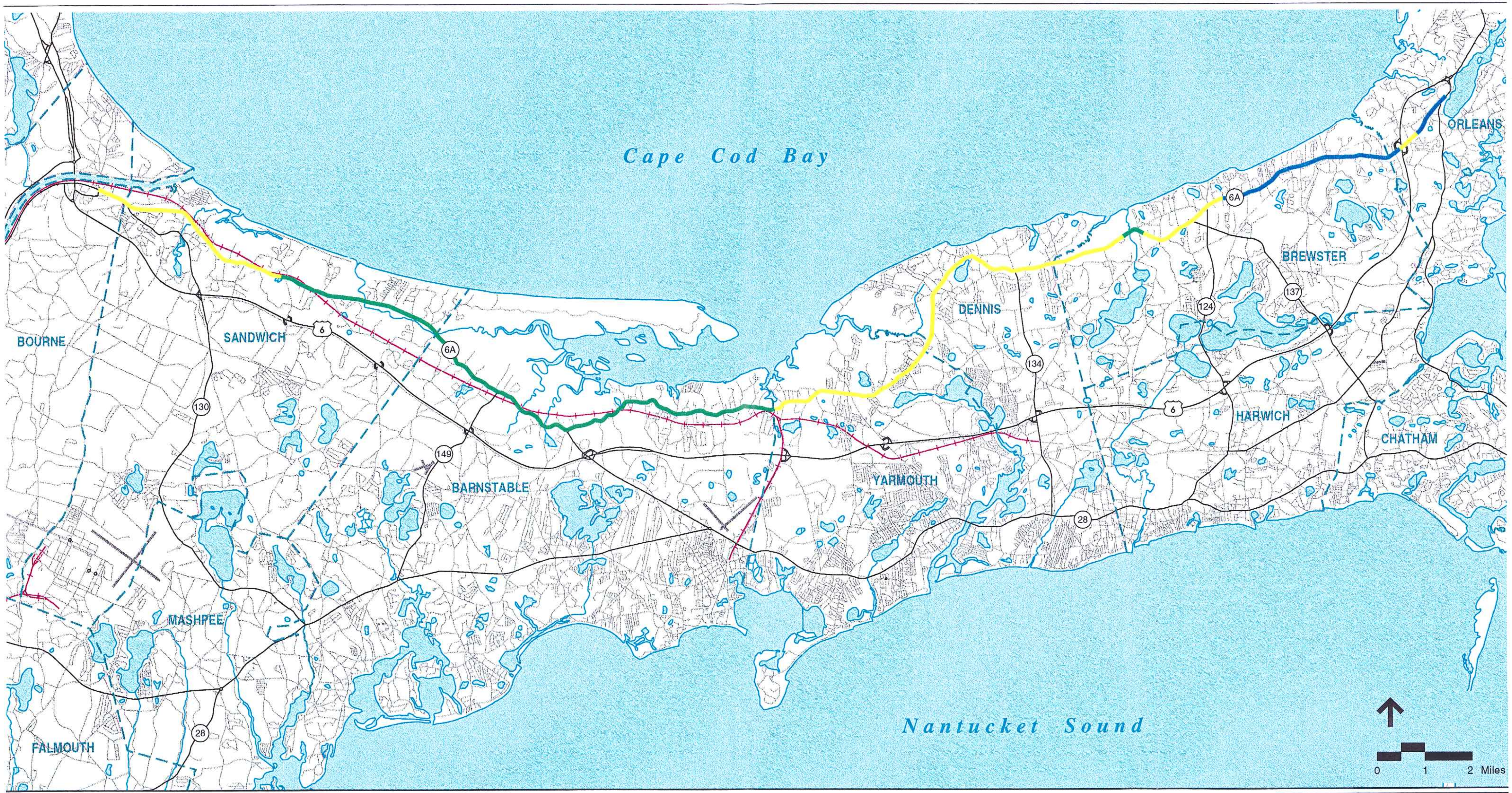
Sidewalk impacts were also calculated for each of the structural improvement alternatives. In the case of the 26-foot cross-section, there will be minimal impact on existing adjacent sidewalks. However, many of the adjacent sidewalks are in disrepair or are overgrown with vegetation and consideration should be given to reconstructing all sidewalks with any roadway improvement alternative. The Route 6A Corridor Management Plan also suggested completing missing pedestrian links, wherever feasible. To accommodate the wider 32-foot cross-section, it was assumed that all adjacent sidewalks would have to be reconstructed. In total, this improvement alternative would affect approximately 17.5 miles of existing sidewalks.

Operational Impacts

Stress Ratings

As part of this evaluation, the two structural improvement alternatives were also factored in to the bicycle stress analysis to quantify the resulting improvement in the conditions for bicyclists along the corridor. The results of this analysis are summarized in Table 3. A third alternative was also considered which evaluates the 26-foot cross-section with reduced speeds along Route 6A. This alternative assumed that speed limits are posted at 35 miles per hour or less throughout the corridor.

As one would expect, there is increasing improvement in the bicycle stress rating at most locations as one moves from the existing roadway geometry toward the 32-foot cross-section. With the full structural improvement to a 32-foot cross-section, Route 6A would be rated as average or better than average in terms of bicycle comfort along most of the corridor. Measurable improvement in the bicycle stress rating is also found with the 26-foot cross-section, although bicycle stress factors are still in the 2.5 to 3.85 range. This improvement is enhanced under the third alternative which involves a reduction in speeds along the corridor. Assuming posted speeds along the corridor of 35 mph or less, the stress ratings would range from 2.48 to 3.60. The stress ratings for the 26-foot cross-sectioned treatment with reduced speeds are illustrated in Figure 3. As evident by the graphic when compared with existing conditions (Figure 2), both the stress ratings and the variability of corridor conditions



Bicycle Stress Ratings

- 0 - 3.00
- 3.01 - 3.50
- 3.51 - 4.00
- 4.01 - 5.00

Vanasse Hangen Brustlin, Inc.

Figure 3

Bicycle Stress Ratings with 26 Foot Cross Section and Reduced Speed Limits are improved under this type of treatment. Other non-structural type improvements, as discussed later in this report, would further improve the experience for bicyclists along the corridor with little or no physical impacts.

Table 3 COMPARISON OF RESULTING ROUTE 6A BICYCLE STRESS

	Mile Markers Begin	Mile Markers End	Existing Stress Rating*	Improvement Alternatives Stress Ratings: With 26-Foot Cross-Section	With 32-foot Cross-Section	With 26-Foot Cross-Section and Reduced Speed
	0.00	0.63	3.80	3.60	2.80	3.40
Sandwich	0.63	2.00	3.37	3.37	2.57	3.30
	2.00	4.50	4.00	3.56	2.76	3.40
	4.50	8.12	3.45	2.90	2.10	2.60
Barnstable	8.12	11.50	3.33	2.64	1.84	2.53
	11.50	14.00	3.16	2.52	1.72	2.48
	14.00	16.53	3.30	2.82	2.02	2.78
Yarmouth	16.53	19.50	4.20	3.43	2.63	3.27
	19.50	20.25	4.35	3.55	2.75	3.35
Dennis	20.25	21.50	3.73	3.73	2.93	3.40
	21.50	24.51	3.77	3.40	2.60	3.20
Brewster	24.51	27.50	3.57	3.25	2.43	3.07
	27.50	30.50	4.10	3.67	2.87	3.53
	30.50	32.29	4.25	3.85	3.05	3.60
Orleans	32.29	33.00	3.20	3.20	3.20	3.20
	33.00	34.00	3.30	3.30	2.80	3.30

* See Table 1 and the accompanying text for factors contributing to the existing corridor bicycle stress rating.

Roadway Speeds

Several people who live along Route 6A expressed concern that widening the roadway might encourage motorists to travel faster. According to the Highway Capacity Manual[22] narrow travel lanes force motorists to drive closer to vehicles in the opposing lane than they would normally desire. Restricted or narrow shoulders have much of the same effect, as drivers "shy" away from roadside obstructions or point restrictions perceived to be close enough to the roadway to pose a hazard. Motorists tend to compensate for these conditions by reducing their travel speeds, in effect, also reducing the capacity of the roadway. In the same manner, providing wider travel lanes and increased shoulder widths might encourage increased travel speeds. However, the speed that motorists are comfortable driving is also dependent on the horizontal and vertical alignment of the roadway, sight distance restrictions and shoulder widths. This is particularly true on Route 6A where the alignment is constrained at many points along the corridor. In the case of the 26-foot

22 Highway Capacity Manual, Special Report 209, Transportation Research Board, Washington, D.C. (1992).

restrictions and shoulder widths. This is particularly true on Route 6A where the alignment is constrained at many points along the corridor. In the case of the 26-foot cross-section, the roadway would be striped for an 11-foot lane and 2-foot shoulder in each direction (as is currently proposed by the MHD in Sandwich). The travel lane is close to the same width today and, with no significant change in the alignment, this improvement should have a negligible effect on speeds through the corridor. Speeds would most likely increase, however, with the 32-foot cross-section, since this improvement would also improve the alignment of the road and reduce the effect on motorists of roadside obstructions.

The expected increase in travel speeds due to increasing the roadway width may be countered by the added presence of bicyclists which cause motorists to reduce speeds and "shy" away from the edge of the roadway when overtaking bicyclists. The extent of this reaction often depends on the amount of separation provided by the roadway treatment to accommodate bicyclists. Field observations from Madison, Wisconsin, Eugene, Oregon and Blacksburg, Virginia showed approximately fifty percent of motorists overtaking a bicyclist within a wide curb lane reacted by changing their lateral displacement towards the center of the roadway. In addition, approximately one third of the motor vehicles had either a possible or an obvious travel speed reduction. According to the same study, only eleven percent of motorists overtaking bicyclists using a bicycle lane reacted by changing their lateral displacement towards the center of the roadway. Similarly, only eight percent of the motor vehicles had either a possible or an obvious travel speed reduction when overtaking a bicyclists in a bicycle lane.[23] This study suggests that roadway improvements requiring motorists and bicyclists to interact, such as wide curb lanes or narrow shoulders, also require the two modes to be more aware and react to each others' presence and needs when sharing the roadway. A separate bicycle lane is less effective in counteracting any potential travel speed increases due to roadway widening.

Safety

A wider and uniform cross-section on Route 6A should enhance overall safety along the corridor. Highway research has shown that increasing travel lane widths and/or shoulder widths not only increases the capacity of a roadway but also tends to increase the safety of the roadway. A recent Federal study showed that travel lane width widening of 1 foot (e.g., from 11-foot to 12-foot lanes) will be expected to reduce related accidents, such as collisions with side obstructions and vehicles running off the road, by 12 percent, and 2 feet of widening (e.g., from 10 feet to 12 feet) should result in a 23 percent reduction in related accident types. Similarly, reductions in related accidents due to increasing the travel lane width by 1 foot and widening paved shoulders by 2 feet should result in an overall reduction in related accidents by 26 percent.[24] Therefore, if an increase in travel speed is realized by increasing a road's pavement width, it does not degrade the safety of the roadway. Instead, the roadway should realize a reduction in accidents. This study did not specifically address bicycles; however, as discussed above, any potential increase in travel speeds may be offset by a presence and general awareness of bicyclists within

23 FHWA, "The Effects of Bicycle Accommodations on Bicycle/Motor Vehicle Safety and Traffic Operations, Publication No. FHWA-RD-92-069, July 1994.

24 FHWA, "Safety Effectiveness of Highway Design Features, Volume III: Cross-sections," Publication No. FHWA-RD-91-046, November 1992.

the corridor. A presence and general awareness of bicyclists within the corridor can be achieved through non-structured means which will be discussed towards the end of the report.

Other safety concerns along Route 6A have to do with the number of older drivers using the corridor. Motorists, especially older motorists, tend to track towards the edge line of the roadway. Because of Route 6A's winding nature, constrained travel lane widths, and poor sight distance, motorists rely heavily on the edge line. Motorists tracking the edge line of a roadway can disrupt bicyclists' use of wide curb lanes or the edge of the roadway if no shoulder exists, creating a safety concern. Constantly changing roadway characteristics can often lead to confusion for older motorists and motorists that are not familiar with the corridor. Changing roadway characteristics are often heavily signed with regulatory, warning and information signs which can lead to information overloading for motorists within the corridor and in some instances add to unnecessary sign clutter. Measures to reduce the amount of information motorists must react to should be considered to provide a more manageable driving experience for older motorists and new motorists within the corridor. One method could be to reduce the amount of physical and regulatory changes, such as cross-section widths and speed limits within the corridor, creating a corridor that has relatively the same characteristics throughout its entire length.

NON-STRUCTURAL ALTERNATIVES

Along corridors where there is limited roadway pavement width due to environmental, historical, right-of-way and/or fiscal constraints, such as the Route 6A corridor, many jurisdictions are implementing non-structural improvements to enhance bicycle access and safety. A program for Route 6A might include speed limit reductions, special signage, an education program, improved maintenance, and enhanced enforcement. Developing this type of a program to better accommodate bicycles within a roadway corridor such as Route 6A should be comprehensive and include the entire length of the corridor. Non-structural improvements for Route 6A could include:

A Share-the-Road Program - There are two important messages to convey to motorists and bicyclists along Route 6A: 1) Route 6A is a by-way not a thru-way, and 2) the corridor is a place for motorists, pedestrians, and bicyclists alike. The key strategy to convey these messages in the development of a unique image for Route 6A that lets everyone know that they have arrived at a special destination and are traveling on a special road. This corridor theme should start with the gateways leading to Route 6A and continue with a consistent signage program to remind travelers along the way. The signage should alert motorists to the presence of both pedestrians and bicyclists and reinforce a slow, safe and scenic philosophy.

A Speed Reduction and Enforcement Program - Safety concerns for bicyclists are exacerbated with higher posted speed limits and speed limits that significantly change throughout a roadway corridor. Route 6A's posted speed limits vary from 25 to 45 mph and change approximately forty two times through the study area. Over sixty five percent of the corridor is posted at or above 40 mph. As a result, bicyclists comfortably traveling in the corridor where the speed limit is 25 mph can easily be exposed to motor vehicle speeds in excess of 45 mph. These higher travel speeds can be stressful and pose safety concerns for the bicyclists. A viable alternative to better accommodate bicyclists on Route 6A would be to provide a lower and uniform speed limit. A precedence for reduced speed limits on scenic roadways in Massachusetts has been set by the Metropolitan District Commission (MDC), on its parkways throughout the metropolitan Boston area. It has also been done through state law for scenic roads in Rhode Island. This type of action would have to be implemented with an aggressive enforcement program.

An Educational Program - Educating motorists and bicyclists on proper operating techniques and the share-the-road concepts are essential to safe and efficient multimodal operations along Route 6A in the future. Many states are implementing programs through their school systems, registry of motor vehicles, and local community groups. In the case of Route 6A, bicycle education should also be incorporated into chamber of commerce and tourist marketing materials and distributed at all visitor information booths.

A Maintenance Program - Spot maintenance programs are also being included in community and corridor bicycle plans extensively to help ensure safe and consistent bicycling conditions. These programs are established to identify minor roadway repairs, such as pot hole patching, street sweeping, drainage grate replacement and sight distance improvements that can help create a safer environment for bicyclists. Spot maintenance programs can improve communications and cooperation between roadway maintenance departments and bicycling groups. A spot maintenance program for Route 6A would require a partnership between the MHD and local communities to ensure a quick and responsive program to address identified deficiencies.

A Traffic Management Program - Speed limit restrictions and enforcement along the corridor will likely have a secondary effect of discouraging traffic from using Route 6A as a by-pass route for other congested locations (ie. Route 6). Development of projects to enhance the capacity and management of Route 6 traffic, through local and regional support, will help to minimize the impact of overflow traffic onto Route 6A. Furthermore, alternate truck routes should be developed and promoted to reduce the volume of truck traffic within the corridor, to the extent possible. Both the reduction in total traffic and truck activity will provide for a better environment for bicycles and pedestrians.

APPENDIX

- Stress Rating Parameters and Calculations
- Field Notes
- Bibliography
- Research Contacts

Stress Rating Parameters

STRESS RATING PARAMETERS

BICYCLIST STRESS LEVELS ASSOCIATED WITH PEAK HOUR TRAFFIC VOLUMES

A roadway's peak hour traffic volume dictates the maximum number of motor vehicles passing a bicyclist in one hour. In addition, potential conflict points for bicyclists and motorists substantially increase as traffic volumes approach capacity. As discussed in the Traffic Institute's study, the Highway Capacity Manual[1] (HCM) recommends enough roadway lanes be provided at an urban intersection approach receives approximately 50 percent of the signal green time. However, in an area with limited number of signalized intersections, a single lane will conservatively be able to accommodate 900 vphpl. Traffic flow of 900 vphpl equates to approximately 15 vehicles per minute or one vehicle passing a stationary point every four seconds. This relatively high frequency of bicycle/motor vehicle interaction will tend to create a stressful environment for the bicyclist and motorist. Therefore, the peak hour traffic volume stress level parameters were derived incrementally using a stress level factor of one for 150 or less vphpl and a stress level factor of five for more than 850 vphpl. Table 1 displays the relationship between peak hour traffic volumes and stress level factors.

Table 1 **PEAK HOUR TRAFFIC VOLUMES RELATED TO STRESS LEVEL FACTORS**

Peak Hour Traffic Volume (vph)	Stress Level Factor
x <= 150	1.0
150 < x <= 250	1.5
250 < x <= 350	2.0
350 < x <= 450	2.5
450 < x <= 550	3.0
550 < x <= 650	3.5
650 < x <= 750	4.0
750 < x <= 850	4.5
X <= 850	5.0

1 Highway Capacity Manual, Special Report 209; Transportation Research Board, Washington, DC, 1992.

BICYCLIST STRESS LEVEL ASSOCIATED WITH MOTOR VEHICLE SPEED

High motor vehicle speeds can cause bicyclists to become unstable and lose control. Turbulence caused by air displacement of large motor vehicles (referred to as truck blast) begins to affect the stability of a bicyclist when passing vehicles are traveling at speeds greater than 45 miles per hour (mph).[2] High speeds also cause additional discomfort in inclement weather. Therefore, the speed of motor vehicle traffic adjacent to a bicyclist on a shared roadway facility can be translated into bicyclist stress levels. For these reasons, 45 mph can be considered the threshold parameter for a stress level factor of five for motor vehicle speeds. The remaining stress level parameters for speed were derived incrementally using a stress level factor of one for speeds including and below 30 mph and a stress level factor of five for speeds greater than 45 mph. It is recommended that the 85th percentile speed for each roadway link be used to determine the bicyclist stress factor for adjacent motor vehicle speed. However, if these data are not available, the posted speed limit can be used as is or modified based on general perception of actual speeds. Table 2 displays the relationship between motor vehicle speeds and stress level factors.

Table 2 **MOTOR VEHICLE SPEEDS RELATED TO STRESS LEVEL FACTORS**

Motor Vehicle Speeds (mph)	Stress Level Factor
x <= 30	1.0
30 < x <= 35	2.0
35 < x <= 40	3.0
40 < x <= 45	4.0
x > 45	5.0

BICYCLIST STRESS LEVEL ASSOCIATED WITH CURB LANE WIDTH

Curb lane width is the distance between the edge of the first full travel lane and the adjacent curb line or the outside edge of curbside parked vehicles. A roadway's curb lane width dictates the available operating space for bicyclist. According to the Traffic Institute study, research by the Maryland Department of Transportation suggested that a curb lane width of 15 feet or greater can accommodate bicyclists and motor vehicles in the same lane for speeds of 40 mph and lower. According to the HCM, bicyclists are not expected to have any impact on motor vehicle traffic where curb lane widths exceed 14 feet. Curb lane widths of 11 feet or less will have some impact on motor vehicle traffic; however, further research is needed to quantify these impacts. For these reasons, 11 feet can be considered the threshold parameter for a stress level factor of five for curb lane widths. The remaining stress level parameters were derived incrementally using a stress level of one for curb lane widths of 15 feet and a stress level factor of five for curb lane widths of 11 feet or less. It should be noted that curb lane widths greater than 14 feet may encourage the undesirable

2 De Leuw, Cather and Co., Safety and Location Criteria For Bicycle Facilities - Final Report, US Department of Transportation, FHWA, DOT - FH-11-8134, Washington, DC, 1975.

operation of two motor vehicles in one lane, especially in urban areas, and consideration should be given to striping as a bicycle lane when wider widths exist.[3] Table 3 displays the relationship between curb lane widths and stress level factors.

Table 3 **CURB LANE WIDTH RELATED TO STRESS LEVEL FACTORS**

Curb Lane Width (feet)	Stress Level Factor
x >= 15.0	1.0
15.0 > x >= 14.5	1.5
14.5 > x >= 14.0	2.0
14.0 > x >= 13.5	2.5
13.5 > x >= 13.0	3.0
13.0 > x >= 12.5	3.5
12.5 > x >= 12.0	4.0
12.0 > x >= 11.5	4.5
x <= 11.0	5.0

BICYCLIST STRESS LEVEL ASSOCIATED WITH TRUCK FREQUENCY

Truck traffic within the curb lane affects bicyclists safety and comfort as a result of instability created by localized turbulence (truck blast), wheel tracking, blind spots in the operator's field of vision, and increased lane width occupied by trucks. According to Van Valkenberg[4] bicycle riding with 10 percent trucks on a roadway with an AADT of 2000 vehicles per day (vpd) or 10 trucks per hour is very uncomfortable. For this reason 10 trucks per hour on a roadway segment can be considered the threshold parameter for a stress level factor of five. The remaining stress level parameters for truck frequency were derived incrementally using a stress level factor of one for two or less trucks per hour and a stress level factor of five for ten or more trucks per hour. Table 4 displays the relationship between truck frequencies and stress level factors.

3 Guide for Development of Bicycle Facilities, AASHTO, Washington, DC, 1991.

4 Van Valkenberg, P., Methodology for Evaluating the Suitability of Two-Lane Two-Way Paved Rural Roads for the Shared Bicycle/Motor Vehicle Use, Wisconsin Division of Tourism, Madison, Wisconsin, 1982.

Table 4 **TRUCK FREQUENCY RELATED TO STRESS LEVEL FACTORS**

Truck Frequency (Trucks Per Hour)	Stress Level Factor
x <= 2	1.0
x = 3	1.5
x = 4	2.0
x = 5	2.5
x = 6	3.0
x = 7	3.5
x = 8	4.0
x = 9	4.5
x >= 10	5.0

Corridor break down for Matrix of Existing Conditions

BEGIN	END	LENGTH	CRBWIDT	CRBRATE	SPDLIMIT	SPDRATE	CRBVOL	VOLRATE	CRBTRK	TRKRATE	AVERATE	CURB_ID	
0.00	0.63	0.63	12.50	3.50	40	3.00	875	5.00	8	4.00	3.80	1	
0.63	1.00	0.37	12.00	4.00	40	3.00	651	4.00	9	4.50	3.90	1	
1.00	1.50	0.50	12.00	4.00	35	2.00	651	4.00	9	4.50	3.70	1	
1.50	2.00	0.50	18.50	1.00	35	2.00	651	4.00	9	4.50	2.50	1	
			14.17		**37**		**651**		**9**		**3.37**		
2.00	2.50	0.50	22.50	1.00	35	2.00	785	4.50	9	4.50	2.60	1	
2.50	3.00	0.50	11.00	5.00	40	3.00	785	4.50	9	4.50	4.40	1	
3.00	3.50	0.50	11.50	4.50	40	3.00	785	4.50	9	4.50	4.20	1	
3.50	4.00	0.50	11.00	5.00	40	3.00	785	4.50	9	4.50	4.40	1	
4.00	4.50	0.50	11.00	5.00	40	3.00	785	4.50	9	4.50	4.40	1	
			13.40		**39**		**785**		**9**		**4.00**		
4.50	5.00	0.50	11.50	4.50	40	3.00	360	2.50	5	2.50	3.40	1	
5.00	5.50	0.50	11.50	4.50	40	3.00	360	2.50	5	2.50	3.40	1	
5.50	6.00	0.50	11.00	5.00	45	4.00	360	2.50	5	2.50	3.80	1	
6.00	6.50	0.50	15.00	1.00	45	4.00	360	2.50	5	2.50	2.20	1	
6.50	7.00	0.50	11.00	5.00	45	4.00	360	2.50	5	2.50	3.80	1	
7.00	7.50	0.50	11.00	5.00	40	3.00	360	2.50	5	2.50	3.60	1	
7.50	8.00	0.50	11.00	5.00	45	4.00	360	2.50	5	2.50	3.80	1	
8.00	8.12	0.12	11.00	5.00	40	3.00	360	2.50	5	2.50	3.60	1	
			11.63		**43**		**360**		**5**		**3.45**		**Sandwich / Barnstable**
8.12	8.50	0.38	11.00	5.00	40	3.00	360	2.50	5	2.50	3.60	1	
8.50	9.00	0.50	10.50	5.00	30	1.00	360	2.50	5	2.50	3.20	1	
9.00	9.50	0.50	10.50	5.00	35	2.00	360	2.50	5	2.50	3.40	1	
9.50	10.00	0.50	11.00	5.00	40	3.00	360	2.50	5	2.50	3.60	1	
10.00	10.50	0.50	10.50	5.00	40	3.00	349	2.00	5	2.50	3.50	1	
10.50	11.00	0.50	12.00	4.00	40	3.00	349	2.00	5	2.50	3.10	1	
11.00	11.50	0.50	12.00	4.00	35	2.00	349	2.00	5	2.50	2.90	1	
			11.07		**37**		**355**		**5**		**3.33**		
11.50	12.00	0.50	11.00	5.00	25	1.00	310	2.00	6	3.00	3.20	1	
12.00	12.50	0.50	11.00	5.00	35	2.00	310	2.00	6	3.00	3.40	1	
12.50	13.00	0.50	12.00	4.00	25	1.00	310	2.00	6	3.00	2.80	1	
13.00	13.50	0.50	10.50	5.00	40	3.00	310	2.00	6	3.00	3.60	1	
13.50	14.00	0.50	12.00	4.00	25	1.00	310	2.00	6	3.00	2.80	1	
			11.30		**30**		**310**		**6**		**3.16**		
14.00	14.50	0.50	12.50	3.50	25	1.00	553	3.50	6	3.00	2.90	1	
14.50	15.00	0.50	12.50	3.50	35	2.00	563	3.50	6	3.00	3.10	1	
15.00	15.50	0.50	11.50	4.50	30	1.00	563	3.50	6	3.00	3.30	1	
15.50	16.00	0.50	11.50	4.50	40	3.00	563	3.50	6	3.00	3.70	1	
16.00	16.50	0.50	11.00	5.00	30	1.00	563	3.50	6	3.00	3.50	1	
			11.80		**32**		**561**		**6**		**3.30**		
16.50	16.53	0.03	10.50	5.00	40	3.00	806	4.50	6	3.00	4.10	1	
													Barnstable / Yarmouth
16.53	17.00	0.47	11.00	5.00	40	3.00	806	4.50	7	3.50	4.20	1	
17.00	17.50	0.50	11.00	5.00	35	2.00	806	4.50	7	3.50	4.00	1	
17.50	18.00	0.50	11.00	5.00	40	3.00	806	4.50	7	3.50	4.20	1	
18.00	18.50	0.50	11.50	4.50	40	3.00	806	4.50	7	3.50	4.00	1	
18.50	19.00	0.50	10.50	5.00	40	3.00	806	4.50	9	4.50	4.40	1	
19.00	19.50	0.50	10.50	5.00	40	3.00	806	4.50	9	4.50	4.40	1	
			10.92		**39**		**806**		**8**		**4.20**		
19.50	20.00	0.50	10.50	5.00	40	3.00	697	4.00	9	4.50	4.30	1	
20.00	20.25	0.25	11.00	5.00	40	3.00	697	4.00	12	5.00	4.40	1	
			10.75		**40**		**697**		**11**		**4.35**		**Yarmouth / Dennis**
20.25	20.50	0.25	12.00	4.00	40	3.00	697	4.00	12	5.00	4.00	1	
20.50	21.00	0.50	12.00	4.00	45	4.00	697	4.00	12	5.00	4.20	1	
21.00	21.50	0.50	17.00	1.00	45	4.00	697	4.00	12	5.00	3.00	1	
			13.67		**43**		**697**		**12**		**3.73**		
21.50	22.00	0.50	12.00	4.00	35	2.00	532	3.00	12	5.00	3.60	1	
22.00	22.50	0.50	12.00	4.00	40	3.00	532	3.00	12	5.00	3.80	1	
22.50	23.00	0.50	12.00	4.00	45	4.00	532	3.00	12	5.00	4.00	1	
23.00	23.50	0.50	12.00	4.00	40	3.00	532	3.00	12	5.00	3.80	1	
23.50	24.00	0.50	12.00	4.00	40	3.00	516	3.00	12	5.00	3.80	1	
24.00	24.50	0.50	12.50	3.50	40	3.00	516	3.00	12	5.00	3.60	1	
			12.08		**40**		**527**		**12**		**3.77**		**Dennis / Brewster**
24.50	24.51	0.01	12.00	4.00	40	3.00	516	3.00	11.5	5.00	3.80	1	
24.51	25.00	0.49	12.00	4.00	40	3.00	438	2.50	12	5.00	3.70	1	
25.00	25.50	0.50	12.00	4.00	40	3.00	438	2.50	12	5.00	3.70	1	
25.50	26.00	0.50	12.00	4.00	40	3.00	438	2.50	12	5.00	3.70	1	
26.00	26.50	0.50	13.00	3.00	30	1.00	438	2.50	12	5.00	2.90	1	
26.50	27.00	0.50	12.00	4.00	40	3.00	438	2.50	12	5.00	3.70	1	
27.00	27.50	0.50	12.00	4.00	40	3.00	438	2.50	12	5.00	3.70	1	
			12.17		**38**		**438**		**12**		**3.57**		
27.50	28.00	0.50	12.00	4.00	30	1.00	854	5.00	12	5.00	3.80	1	
28.00	28.50	0.50	11.50	4.50	30	1.00	854	5.00	12	5.00	4.00	1	
28.50	29.00	0.50	12.00	4.00	40	3.00	854	5.00	12	5.00	4.20	1	
29.00	29.50	0.50	13.00	3.00	40	3.00	854	5.00	12	5.00	3.80	1	
29.50	30.00	0.50	11.50	4.50	40	3.00	854	5.00	12	5.00	4.40	1	
30.00	30.50	0.50	11.50	4.50	40	3.00	854	5.00	12	5.00	4.40	1	
			11.92		**37**		**854**		**12**		**4.10**		
30.50	31.00	0.50	12.00	4.00	40	3.00	933	5.00	12	5.00	4.20	1	
31.00	31.50	0.50	12.00	4.00	40	3.00	933	5.00	12	5.00	4.20	1	
31.50	32.00	0.50	12.00	4.00	40	3.00	933	5.00	12	5.00	4.20	1	
32.00	32.29	0.29	12.00	4.00	45	4.00	933	5.00	12	5.00	4.40	1	
			12.00		**41**		**933**		**12**		**4.25**		**Brewster / Orleans**
32.29	32.50	0.21	16.50	1.00	45	4.00	933	5.00	12	5.00	3.20	1	
32.50	33.00	0.50	25.00	1.00	40	3.00	1199	5.00	17	5.00	3.00	1	
33.00	33.50	0.50	14.50	1.50	40	3.00	814	4.50	17	5.00	3.10	1	
33.50	34.00	0.50	13.00	3.00	35	2.00	814	4.50	17	5.00	3.50	1	
			13.75		**38**		**814**		**17**		**3.30**		

EXISTING STRESS FACTORS

Corridor breakdown for Matrix--26 foot cross-section
MAIN SPREADSHEET (26 foot cross section)

BEGIN	END	LENGTH	CRBWIDT	CRBRATE	SPDLIMIT	SPDRATE	CRBVOL	VOLRATE	CRBTRK	TRKRATE	AVERATE	CURB_ID	
0.00	0.63	0.63	13.00	3.00	40	3.00	875	5.00	8	4.00	3.60	1	
0.63	1.00	0.37	13.00	3.00	40	3.00	651	4.00	9	4.50	3.50	1	
1.00	1.50	0.50	13.00	3.00	35	2.00	651	4.00	9	4.50	3.30	1	
1.50	2.00	0.50	13.00	3.00	35	2.00	651	4.00	9	4.50	3.30	1	
					37		**651**		**9**		**3.37**		
2.00	2.50	0.50	13.00	3.00	35	2.00	785	4.50	9	4.50	3.40	1	
2.50	3.00	0.50	13.00	3.00	40	3.00	785	4.50	9	4.50	3.60	1	
3.00	3.50	0.50	13.00	3.00	40	3.00	785	4.50	9	4.50	3.60	1	
3.50	4.00	0.50	13.00	3.00	40	3.00	785	4.50	9	4.50	3.60	1	
4.00	4.50	0.50	13.00	3.00	40	3.00	785	4.50	9	4.50	3.60	1	
					39		**785**		**9**		**3.56**		
4.50	5.00	0.50	13.00	3.00	40	3.00	360	2.50	5	2.50	2.80	1	
5.00	5.50	0.50	13.00	3.00	40	3.00	360	2.50	5	2.50	2.80	1	
5.50	6.00	0.50	13.00	3.00	45	4.00	360	2.50	5	2.50	3.00	1	
6.00	6.50	0.50	13.00	3.00	45	4.00	360	2.50	5	2.50	3.00	1	
6.50	7.00	0.50	13.00	3.00	45	4.00	360	2.50	5	2.50	3.00	1	
7.00	7.50	0.50	13.00	3.00	40	3.00	360	2.50	5	2.50	2.80	1	
7.50	8.00	0.50	13.00	3.00	45	4.00	360	2.50	5	2.50	3.00	1	
8.00	8.12	0.12	13.00	3.00	40	3.00	360	2.50	5	2.50	2.80	1	
					43		**360**		**5**		**2.90**		**Sandwich/Barnstable**
8.12	8.50	0.38	13.00	3.00	40	3.00	360	2.50	5	2.50	2.80	1	
8.50	9.00	0.50	13.00	3.00	30	1.00	360	2.50	5	2.50	2.40	1	
9.00	9.50	0.50	13.00	3.00	35	2.00	360	2.50	5	2.50	2.60	1	
9.50	10.00	0.50	13.00	3.00	40	3.00	360	2.50	5	2.50	2.80	1	
10.00	10.50	0.50	13.00	3.00	40	3.00	349	2.00	5	2.50	2.70	1	
10.50	11.00	0.50	13.00	3.00	40	3.00	349	2.00	5	2.50	2.70	1	
11.00	11.50	0.50	13.00	3.00	35	2.00	349	2.00	5	2.50	2.50	1	
					37		**355**		**5**		**2.64**		
11.50	12.00	0.50	13.00	3.00	25	1.00	310	2.00	6	3.00	2.40	1	
12.00	12.50	0.50	13.00	3.00	35	2.00	310	2.00	6	3.00	2.60	1	
12.50	13.00	0.50	13.00	3.00	25	1.00	310	2.00	6	3.00	2.40	1	
13.00	13.50	0.50	13.00	3.00	40	3.00	310	2.00	6	3.00	2.80	1	
13.50	14.00	0.50	13.00	3.00	25	1.00	310	2.00	6	3.00	2.40	1	
					30		**310**		**6**		**2.52**		
14.00	14.50	0.50	13.00	3.00	25	1.00	553	3.50	6	3.00	2.70	1	
14.50	15.00	0.50	13.00	3.00	35	2.00	563	3.50	6	3.00	2.90	1	
15.00	15.50	0.50	13.00	3.00	30	1.00	563	3.50	6	3.00	2.70	1	
15.50	16.00	0.50	13.00	3.00	40	3.00	563	3.50	6	3.00	3.10	1	
16.00	16.50	0.50	13.00	3.00	30	1.00	563	3.50	6	3.00	2.70	1	
					32		**561**		**6**		**2.82**		
16.50	16.53	0.03	13.00	3.00	40	3.00	806	4.50	6	3.00	3.30	1	
													Barnstable/Yarmouth
16.53	17.00	0.47	13.00	3.00	40	3.00	806	4.50	7	3.50	3.40	1	
17.00	17.50	0.50	13.00	3.00	35	2.00	806	4.50	7	3.50	3.20	1	
17.50	18.00	0.50	13.00	3.00	40	3.00	806	4.50	7	3.50	3.40	1	
18.00	18.50	0.50	13.00	3.00	40	3.00	806	4.50	7	3.50	3.40	1	
18.50	19.00	0.50	13.00	3.00	40	3.00	806	4.50	9	4.50	3.60	1	
19.00	19.50	0.50	13.00	3.00	40	3.00	806	4.50	9	4.50	3.60	1	
					39		**806**		**8**		**3.43**		
19.50	20.00	0.50	13.00	3.00	40	3.00	697	4.00	9	4.50	3.50	1	
20.00	20.25	0.25	13.00	3.00	40	3.00	697	4.00	12	5.00	3.60	1	
					40		**697**		**11**		**3.55**		**Yarmouth/Dennis**
20.25	20.50	0.25	13.00	3.00	40	3.00	697	4.00	12	5.00	3.60	1	
20.50	21.00	0.50	13.00	3.00	45	4.00	697	4.00	12	5.00	3.80	1	
21.00	21.50	0.50	13.00	3.00	45	4.00	697	4.00	12	5.00	3.80	1	
					43		**697**		**12**		**3.73**		
21.50	22.00	0.50	13.00	3.00	35	2.00	532	3.00	12	5.00	3.20	1	
22.00	22.50	0.50	13.00	3.00	40	3.00	532	3.00	12	5.00	3.40	1	
22.50	23.00	0.50	13.00	3.00	45	4.00	532	3.00	12	5.00	3.60	1	
23.00	23.50	0.50	13.00	3.00	40	3.00	532	3.00	12	5.00	3.40	1	
23.50	24.00	0.50	13.00	3.00	40	3.00	516	3.00	12	5.00	3.40	1	
24.00	24.50	0.50	13.00	3.00	40	3.00	516	3.00	12	5.00	3.40	1	
					40		**527**		**12**		**3.40**		**Dennis/Brewster**
24.50	24.51	0.01	13.00	3.00	40	3.00	516	3.00	12	5.00	3.40	1	
24.51	25.00	0.49	13.00	3.00	40	3.00	438	2.50	12	5.00	3.30	1	
25.00	25.50	0.50	13.00	3.00	40	3.00	438	2.50	12	5.00	3.30	1	
25.50	26.00	0.50	13.00	3.00	40	3.00	438	2.50	12	5.00	3.30	1	
26.00	26.50	0.50	13.00	3.00	30	1.00	438	2.50	12	5.00	2.90	1	
26.50	27.00	0.50	13.00	3.00	40	3.00	438	2.50	12	5.00	3.30	1	
27.00	27.50	0.50	13.00	3.00	40	3.00	438	2.50	12	5.00	3.30	1	
					38		**438**		**12**		**3.23**		
27.50	28.00	0.50	13.00	3.00	30	1.00	854	5.00	12	5.00	3.40	1	
28.00	28.50	0.50	13.00	3.00	30	1.00	854	5.00	12	5.00	3.40	1	
28.50	29.00	0.50	13.00	3.00	40	3.00	854	5.00	12	5.00	3.80	1	
29.00	29.50	0.50	13.00	3.00	40	3.00	854	5.00	12	5.00	3.80	1	
29.50	30.00	0.50	13.00	3.00	40	3.00	854	5.00	12	5.00	3.80	1	
30.00	30.50	0.50	13.00	3.00	40	3.00	854	5.00	12	5.00	3.80	1	
					37		**854**		**12**		**3.67**		
30.50	31.00	0.50	13.00	3.00	40	3.00	933	5.00	12	5.00	3.80	1	
31.00	31.50	0.50	13.00	3.00	40	3.00	933	5.00	12	5.00	3.80	1	
31.50	32.00	0.50	13.00	3.00	40	3.00	933	5.00	12	5.00	3.80	1	
32.00	32.29	0.29	13.00	3.00	45	4.00	933	5.00	12	5.00	4.00	1	
					41		**933**		**12**		**3.85**		**Brewster/Orleans**
32.29	32.50	0.21	13.00	3.00	45	4.00	933	5.00	12	5.00	4.00	1	
32.50	33.00	0.50	13.00	3.00	40	3.00	1199	5.00	17	5.00	3.80	1	
33.00	33.50	0.50	13.00	3.00	40	3.00	814	4.50	17	5.00	3.70	1	
33.50	34.00	0.50	13.00	3.00	35	2.00	814	4.50	17	5.00	3.50	1	
					38		**814**		**17**		**3.60**		

STRESS FACTORS WITH 26-FOOT CROSS-SECTION

Corridor breakdown for Matrix--32 foot cross-section
MAIN SPREADSHEET (32 foot cross section)

BEGIN	END	LENGTH	CRBWIDT	CRBRATE	SPDLIMIT	SPDRATE	CRBVOL	VOLRATE	CRBTRK	TRKRATE	AVERATE	CURB_ID	
0.00	0.63	0.63	16.00	1.00	40	3.00	875	5.00	8	4.00	2.80	1	
0.63	1.00	0.37	16.00	1.00	40	3.00	651	4.00	9	4.50	2.70	1	
1.00	1.50	0.50	16.00	1.00	35	2.00	651	4.00	9	4.50	2.50	1	
1.50	2.00	0.50	16.00	1.00	35	2.00	651	4.00	9	4.50	2.50	1	
					37		**651**		**9**		**2.57**		
2.00	2.50	0.50	16.00	1.00	35	2.00	785	4.50	9	4.50	2.60	1	
2.50	3.00	0.50	16.00	1.00	40	3.00	785	4.50	9	4.50	2.80	1	
3.00	3.50	0.50	16.00	1.00	40	3.00	785	4.50	9	4.50	2.80	1	
3.50	4.00	0.50	16.00	1.00	40	3.00	785	4.50	9	4.50	2.80	1	
4.00	4.50	0.50	16.00	1.00	40	3.00	785	4.50	9	4.50	2.80	1	
					39		**785**		**9**		**2.76**		
4.50	5.00	0.50	16.00	1.00	40	3.00	360	2.50	5	2.50	2.00	1	
5.00	5.50	0.50	16.00	1.00	40	3.00	360	2.50	5	2.50	2.00	1	
5.50	6.00	0.50	16.00	1.00	45	4.00	360	2.50	5	2.50	2.20	1	
6.00	6.50	0.50	16.00	1.00	45	4.00	360	2.50	5	2.50	2.20	1	
6.50	7.00	0.50	16.00	1.00	45	4.00	360	2.50	5	2.50	2.20	1	
7.00	7.50	0.50	16.00	1.00	40	3.00	360	2.50	5	2.50	2.00	1	
7.50	8.00	0.50	16.00	1.00	45	4.00	360	2.50	5	2.50	2.20	1	
8.00	8.12	0.12	16.00	1.00	40	3.00	360	2.50	5	2.50	2.00	1	
					43		**360**		**5**		**2.10**		**Sandwich/Barnstable**
8.12	8.50	0.38	16.00	1.00	40	3.00	360	2.50	5	2.50	2.00	1	
8.50	9.00	0.50	16.00	1.00	30	1.00	360	2.50	5	2.50	1.60	1	
9.00	9.50	0.50	16.00	1.00	35	2.00	360	2.50	5	2.50	1.80	1	
9.50	10.00	0.50	16.00	1.00	40	3.00	360	2.50	5	2.50	2.00	1	
10.00	10.50	0.50	16.00	1.00	40	3.00	349	2.00	5	2.50	1.90	1	
10.50	11.00	0.50	16.00	1.00	40	3.00	349	2.00	5	2.50	1.90	1	
11.00	11.50	0.50	16.00	1.00	35	2.00	349	2.00	5	2.50	1.70	1	
					37		**355**		**5**		**1.84**		
11.50	12.00	0.50	16.00	1.00	25	1.00	310	2.00	6	3.00	1.60	1	
12.00	12.50	0.50	16.00	1.00	35	2.00	310	2.00	6	3.00	1.80	1	
12.50	13.00	0.50	16.00	1.00	25	1.00	310	2.00	6	3.00	1.60	1	
13.00	13.50	0.50	16.00	1.00	40	3.00	310	2.00	6	3.00	2.00	1	
13.50	14.00	0.50	16.00	1.00	25	1.00	310	2.00	6	3.00	1.60	1	
					30		**310**		**6**		**1.72**		
14.00	14.50	0.50	16.00	1.00	25	1.00	553	3.50	6	3.00	1.90	1	
14.50	15.00	0.50	16.00	1.00	35	2.00	563	3.50	6	3.00	2.10	1	
15.00	15.50	0.50	16.00	1.00	30	1.00	563	3.50	6	3.00	1.90	1	
15.50	16.00	0.50	16.00	1.00	40	3.00	563	3.50	6	3.00	2.30	1	
16.00	16.50	0.50	16.00	1.00	30	1.00	563	3.50	6	3.00	1.90	1	
					32		**561**		**6**		**2.02**		
16.50	16.53	0.03	16.00	1.00	40	3.00	806	4.50	6	3.00	2.50	1	
													Barnstable/Yarmouth
16.53	17.00	0.47	16.00	1.00	40	3.00	806	4.50	7	3.50	2.60	1	
17.00	17.50	0.50	16.00	1.00	35	2.00	806	4.50	7	3.50	2.40	1	
17.50	18.00	0.50	16.00	1.00	40	3.00	806	4.50	7	3.50	2.60	1	
18.00	18.50	0.50	16.00	1.00	40	3.00	806	4.50	7	3.50	2.60	1	
18.50	19.00	0.50	16.00	1.00	40	3.00	806	4.50	9	4.50	2.80	1	
19.00	19.50	0.50	16.00	1.00	40	3.00	806	4.50	9	4.50	2.80	1	
					39		**806**		**8**		**2.63**		
19.50	20.00	0.50	16.00	1.00	40	3.00	697	4.00	9	4.50	2.70	1	
20.00	20.25	0.25	16.00	1.00	40	3.00	697	4.00	12	5.00	2.80	1	
					40		**697**		**11**		**2.75**		**Yarmouth/Dennis**
20.25	20.50	0.25	16.00	1.00	40	3.00	697	4.00	12	5.00	2.80	1	
20.50	21.00	0.50	16.00	1.00	45	4.00	697	4.00	12	5.00	3.00	1	
21.00	21.50	0.50	16.00	1.00	45	4.00	697	4.00	12	5.00	3.00	1	
					43		**697**		**12**		**2.93**		
21.50	22.00	0.50	16.00	1.00	35	2.00	532	3.00	12	5.00	2.40	1	
22.00	22.50	0.50	16.00	1.00	40	3.00	532	3.00	12	5.00	2.60	1	
22.50	23.00	0.50	16.00	1.00	45	4.00	532	3.00	12	5.00	2.80	1	
23.00	23.50	0.50	16.00	1.00	40	3.00	532	3.00	12	5.00	2.60	1	
23.50	24.00	0.50	16.00	1.00	40	3.00	516	3.00	12	5.00	2.60	1	
24.00	24.50	0.50	16.00	1.00	40	3.00	516	3.00	12	5.00	2.60	1	
					40		**527**		**12**		**2.60**		**Dennis/Brewster**
24.50	24.51	0.01	16.00	1.00	40	3.00	516	3.00	12	5.00	2.60	1	
24.51	25.00	0.49	16.00	1.00	40	3.00	438	2.50	12	5.00	2.50	1	
25.00	25.50	0.50	16.00	1.00	40	3.00	438	2.50	12	5.00	2.50	1	
25.50	26.00	0.50	16.00	1.00	40	3.00	438	2.50	12	5.00	2.50	1	
26.00	26.50	0.50	16.00	1.00	30	1.00	438	2.50	12	5.00	2.10	1	
26.50	27.00	0.50	16.00	1.00	40	3.00	438	2.50	12	5.00	2.50	1	
27.00	27.50	0.50	16.00	1.00	40	3.00	438	2.50	12	5.00	2.50	1	
					38		**438**		**12**		**2.43**		
27.50	28.00	0.50	16.00	1.00	30	1.00	854	5.00	12	5.00	2.60	1	
28.00	28.50	0.50	16.00	1.00	30	1.00	854	5.00	12	5.00	2.60	1	
28.50	29.00	0.50	16.00	1.00	40	3.00	854	5.00	12	5.00	3.00	1	
29.00	29.50	0.50	16.00	1.00	40	3.00	854	5.00	12	5.00	3.00	1	
29.50	30.00	0.50	16.00	1.00	40	3.00	854	5.00	12	5.00	3.00	1	
30.00	30.50	0.50	16.00	1.00	40	3.00	854	5.00	12	5.00	3.00	1	
					37		**854**		**12**		**2.87**		
30.50	31.00	0.50	16.00	1.00	40	3.00	933	5.00	12	5.00	3.00	1	
31.00	31.50	0.50	16.00	1.00	40	3.00	933	5.00	12	5.00	3.00	1	
31.50	32.00	0.50	16.00	1.00	40	3.00	933	5.00	12	5.00	3.00	1	
32.00	32.29	0.29	16.00	1.00	45	4.00	933	5.00	12	5.00	3.20	1	
					41		**933**		**12**		**3.05**		**Brewster/Orleans**
32.29	32.50	0.21	16.00	1.00	45	4.00	933	5.00	12	5.00	3.20	1	
32.50	33.00	0.50	16.00	1.00	40	3.00	1199	5.00	17	5.00	3.00	1	
33.00	33.50	0.50	16.00	1.00	40	3.00	814	4.50	17	5.00	2.90	1	
33.50	34.00	0.50	16.00	1.00	35	2.00	814	4.50	17	5.00	2.70	1	
					38		**814**		**17**		**2.80**		

STRESS FACTORS WITH 32-FOOT CROSS-SECTION

Corridor Breakdown for Matrix--26 foot cross-section and 35 mph

MAIN SPREADSHEET (26 foot cross section with 35mph)

BEGIN	END	LENGTH	CRBWIDT	CRBRATE	SPDLIMIT	SPDRATE	CRBVOL	VOLRATE	CRBTRK	TRKRATE	AVERATE	CURB_ID	
0.00	0.63	0.63	13.00	3.00	35	2.00	875	5.00	8	4.00	3.40	1	
0.63	1.00	0.37	13.00	3.00	35	2.00	651	4.00	9	4.50	3.30	1	
1.00	1.50	0.50	13.00	3.00	35	2.00	651	4.00	9	4.50	3.30	1	
1.50	2.00	0.50	13.00	3.00	35	2.00	651	4.00	9	4.50	3.30	1	
							651		**9**		**3.30**		
2.00	2.50	0.50	13.00	3.00	35	2.00	785	4.50	9	4.50	3.40	1	
2.50	3.00	0.50	13.00	3.00	35	2.00	785	4.50	9	4.50	3.40	1	
3.00	3.50	0.50	13.00	3.00	35	2.00	785	4.50	9	4.50	3.40	1	
3.50	4.00	0.50	13.00	3.00	35	2.00	785	4.50	9	4.50	3.40	1	
4.00	4.50	0.50	13.00	3.00	35	2.00	785	4.50	9	4.50	3.40	1	
							785		**9**		**3.40**		
4.50	5.00	0.50	13.00	3.00	35	2.00	360	2.50	5	2.50	2.60	1	
5.00	5.50	0.50	13.00	3.00	35	2.00	360	2.50	5	2.50	2.60	1	
5.50	6.00	0.50	13.00	3.00	35	2.00	360	2.50	5	2.50	2.60	1	
6.00	6.50	0.50	13.00	3.00	35	2.00	360	2.50	5	2.50	2.60	1	
6.50	7.00	0.50	13.00	3.00	35	2.00	360	2.50	5	2.50	2.60	1	
7.00	7.50	0.50	13.00	3.00	35	2.00	360	2.50	5	2.50	2.60	1	
7.50	8.00	0.50	13.00	3.00	35	2.00	360	2.50	5	2.50	2.60	1	
8.00	8.12	0.12	13.00	3.00	35	2.00	360	2.50	5	2.50	2.60	1	
							360		**5**		**2.60**		**Sandwich/Barnstable**
8.12	8.50	0.38	13.00	3.00	35	2.00	360	2.50	5	2.50	2.60	1	
8.50	9.00	0.50	13.00	3.00	30	1.00	360	2.50	5	2.50	2.40	1	
9.00	9.50	0.50	13.00	3.00	35	2.00	360	2.50	5	2.50	2.60	1	
9.50	10.00	0.50	13.00	3.00	35	2.00	360	2.50	5	2.50	2.60	1	
10.00	10.50	0.50	13.00	3.00	35	2.00	349	2.00	5	2.50	2.50	1	
10.50	11.00	0.50	13.00	3.00	35	2.00	349	2.00	5	2.50	2.50	1	
11.00	11.50	0.50	13.00	3.00	35	2.00	349	2.00	5	2.50	2.50	1	
							355		**5**		**2.53**		
11.50	12.00	0.50	13.00	3.00	25	1.00	310	2.00	6	3.00	2.40	1	
12.00	12.50	0.50	13.00	3.00	35	2.00	310	2.00	6	3.00	2.60	1	
12.50	13.00	0.50	13.00	3.00	25	1.00	310	2.00	6	3.00	2.40	1	
13.00	13.50	0.50	13.00	3.00	35	2.00	310	2.00	6	3.00	2.60	1	
13.50	14.00	0.50	13.00	3.00	25	1.00	310	2.00	6	3.00	2.40	1	
							310		**6**		**2.48**		
14.00	14.50	0.50	13.00	3.00	25	1.00	553	3.50	6	3.00	2.70	1	
14.50	15.00	0.50	13.00	3.00	35	2.00	563	3.50	6	3.00	2.90	1	
15.00	15.50	0.50	13.00	3.00	30	1.00	563	3.50	6	3.00	2.70	1	
15.50	16.00	0.50	13.00	3.00	35	2.00	563	3.50	6	3.00	2.90	1	
16.00	16.50	0.50	13.00	3.00	30	1.00	563	3.50	6	3.00	2.70	1	
							561		**6**		**2.78**		
16.50	16.53	0.03	13.00	3.00	35	2.00	806	4.50	6	3.00	3.10	1	
													Barnstable/Yarmouth
16.53	17.00	0.47	13.00	3.00	35	2.00	806	4.50	7	3.50	3.20	1	
17.00	17.50	0.50	13.00	3.00	35	2.00	806	4.50	7	3.50	3.20	1	
17.50	18.00	0.50	13.00	3.00	35	2.00	806	4.50	7	3.50	3.20	1	
18.00	18.50	0.50	13.00	3.00	35	2.00	806	4.50	7	3.50	3.20	1	
18.50	19.00	0.50	13.00	3.00	35	2.00	806	4.50	9	4.50	3.40	1	
19.00	19.50	0.50	13.00	3.00	35	2.00	806	4.50	9	4.50	3.40	1	
							806		**8**		**3.27**		
19.50	20.00	0.50	13.00	3.00	35	2.00	697	4.00	9	4.50	3.30	1	
20.00	20.25	0.25	13.00	3.00	35	2.00	697	4.00	12	5.00	3.40	1	
							697		**11**		**3.35**		**Yarmouth/Dennis**
20.25	20.50	0.25	13.00	3.00	35	2.00	697	4.00	12	5.00	3.40	1	
20.50	21.00	0.50	13.00	3.00	35	2.00	697	4.00	12	5.00	3.40	1	
21.00	21.50	0.50	13.00	3.00	35	2.00	697	4.00	12	5.00	3.40	1	
							697		**12**		**3.40**		
21.50	22.00	0.50	13.00	3.00	35	2.00	532	3.00	12	5.00	3.20	1	
22.00	22.50	0.50	13.00	3.00	35	2.00	532	3.00	12	5.00	3.20	1	
22.50	23.00	0.50	13.00	3.00	35	2.00	532	3.00	12	5.00	3.20	1	
23.00	23.50	0.50	13.00	3.00	35	2.00	532	3.00	12	5.00	3.20	1	
23.50	24.00	0.50	13.00	3.00	35	2.00	516	3.00	12	5.00	3.20	1	
24.00	24.50	0.50	13.00	3.00	35	2.00	516	3.00	12	5.00	3.20	1	
							527		**12**		**3.20**		**Dennis/Brewster**
24.50	24.51	0.01	13.00	3.00	35	2.00	516	3.00	12	5.00	3.20	1	
24.51	25.00	0.49	13.00	3.00	35	2.00	438	2.50	12	5.00	3.10	1	
25.00	25.50	0.50	13.00	3.00	35	2.00	438	2.50	12	5.00	3.10	1	
25.50	26.00	0.50	13.00	3.00	35	2.00	438	2.50	12	5.00	3.10	1	
26.00	26.50	0.50	13.00	3.00	30	1.00	438	2.50	12	5.00	2.90	1	
26.50	27.00	0.50	13.00	3.00	35	2.00	438	2.50	12	5.00	3.10	1	
27.00	27.50	0.50	13.00	3.00	35	2.00	438	2.50	12	5.00	3.10	1	
							438		**12**		**3.07**		
27.50	28.00	0.50	13.00	3.00	30	1.00	854	5.00	12	5.00	3.40	1	
28.00	28.50	0.50	13.00	3.00	30	1.00	854	5.00	12	5.00	3.40	1	
28.50	29.00	0.50	13.00	3.00	35	2.00	854	5.00	12	5.00	3.60	1	
29.00	29.50	0.50	13.00	3.00	35	2.00	854	5.00	12	5.00	3.60	1	
29.50	30.00	0.50	13.00	3.00	35	2.00	854	5.00	12	5.00	3.60	1	
30.00	30.50	0.50	13.00	3.00	35	2.00	854	5.00	12	5.00	3.60	1	
							854		**12**		**3.53**		
30.50	31.00	0.50	13.00	3.00	35	2.00	933	5.00	12	5.00	3.60	1	
31.00	31.50	0.50	13.00	3.00	35	2.00	933	5.00	12	5.00	3.60	1	
31.50	32.00	0.50	13.00	3.00	35	2.00	933	5.00	12	5.00	3.60	1	
32.00	32.29	0.29	13.00	3.00	35	2.00	933	5.00	12	5.00	3.60	1	
							933		**12**		**3.60**		**Brewster/Orleans**
32.29	32.50	0.21	13.00	3.00	35	2.00	933	5.00	12	5.00	3.60	1	
32.50	33.00	0.50	13.00	3.00	35	2.00	1199	5.00	17	5.00	3.60	1	
33.00	33.50	0.50	13.00	3.00	35	2.00	814	4.50	17	5.00	3.50	1	
33.50	34.00	0.50	13.00	3.00	35	2.00	814	4.50	17	5.00	3.50	1	
							814		**17**		**3.50**		

STRESS FACTORS WITH 26-FOOT CROSS-SECTION AND REDUCED SPEEDS

Field Notes

[redacted]

Vanasse Hangen Brustlin, Inc.

Transportation
Land Development
Environmental
Services

VHB

101 Walnut Street
Post Office Box 9151
Watertown
Massachusetts 02272
617 924 1770
FAX 617 924 2286

Meeting Notes

Attendees:	Steve O'Neill Eric Carlson	Date/Time:	May 15, 1995
		Project No.:	04259
Place:	Field Notes	Re:	Route 6A Bicycle Accommodation Study
		Notes taken by:	Eric Carlson

This field trip began at the 00 mile marker in Sandwich and proceeded along Route 6A west. The focus of this field trip was to identify significant project issues along the project corridor.

- At mile marker 1.9 on the right is the first salt marsh that abuts the project area. The bridge at mile marker 2.1 appears to have adequate access across the bridge as well as existing pedestrian access.

- At mile marker 3.0 there is a cemetery on the left which has a stone wall approximately 6 to 8 feet off the existing edge of the pavement. At this location it appears that a 26 foot section will have very little impacts to the adjacent properties, however, a 32 foot section would likely require a shift of the roadway towards the south side of the road, away from the cemetery. There appears to be adequate space on the south side of the road to accommodate such a shift.

- At mile marker 3.5 on the south side of the road there is a string of approximately one dozen trees which most likely would be impacted with any widenings on the south side of the road at this location. On the north side of the roadway there are intermittent wetlands. At this location, which happens to be at the intersection of Great Island Road, a 26 foot section would likely result in some tree impacts and/or wetland impacts.

- At mile marker 3.9 there are wetlands on both sides of the road with a fairly significant brook running adjacent to roadway. Just beyond at mile marker 4.0 there is a cranberry bog in close proximity to the south side of the roadway.

- At mile marker 3.9 the brook crosses the roadway which is approximately 18 feet wide. Widenings at this location to accommodate a bike path would require filling of the adjacent side slope and some drainage culvert modifications. This location would be considered a point of maximum impact even with a 26 foot section. The length of those impcts would be approximately 500 feet.

- At mile marker 4.1 there is a significant stone wall on the south side at an adjacent property and directly opposite on the north side is a cranberry bog. It appears as though a 32 foot section could be proposed in this area with minimal impacts.

- At mile marker 4.3 the roadway is confined with ponds on either side of the roadway. It appears as though this section could accommodate a 26 foot section with minimal impacts, however, a 32 foot section would likely require filling of the wetlands. The length of those impacts would be approximately 1,000 feet.

- At mile marker 4.9 on the south side of the road in front of the Earl of Sandwich Motel there are 4 significant trees which could be impacted.

- At mile marker 5.3 there is a stretch of roadway with significant trees on the south side, however, they appear to be set back far enough that a 32 foot cross section could be accommodated without impact.

- At mile marker 5.6 there is a minor drainage crossing which would require headwall reconstruction for a 26 foot section. A 32 foot section would impact 3 significant trees opposite the Sandwich Fire Department at this location, on the north side of the road.

- At mile marker 6.1, Route 6A crosses a salt marsh area with an apparent pavement width of 32 feet and from face of guardrail to face of guardrail width of 34 feet. It appears as though the maximum section could be accommodated through this area with no additional impacts.

- From mile marker 6.1 to 6.6 there are intermittent wetland encroachments on the roadway on both sides of the road which would most likely be impacted with a continued 32 foot section. The salt marsh encroachments on the south side of the road continue to approximately mile marker 7.4, whereby they then begin on the north side of the road and extend to mile marker 8.0.

- At mile marker 8.1 there are 2 significant trees on the south side of the road that would likely be impacted with even a 26 foot section.

- At mile marker 8.4 wetlands encroach both sides of the road to mile marker 8.6. A 26 foot section would likely impact these wetlands.

- At mile marker 8.6 to 9.0 there appears to be at least a dozen trees in close to the road which likely would be impacted even with a 26 foot section.

- At mile marker 9.1 to 9.3 wetlands both sides of the road would be impacted with a 26 foot section.

- At mile marker 9.8 trees in close proximity to the roadway. A 26 foot section would impact those trees.

- At mile marker 10.1 railroad signal impacts, a major cross-culvert at salt marsh creek at mile marker 10.2. It appears as though a 26 foot section through here could be accommodated, however, a 32 foot section would have significant impacts.

- At mile marker 11.5 there are significant trees on the north side of the roadway. Approximately a half dozen would likely be impacted with anything greater than a 26 foot section. Significant trees continue on both sides of the roadway intermittently along this stretch into Barnstable center. It should be noted that a 26 foot section along this segment of the roadway will have significant impacts on trees and that a 32 foot section would therefore have substantial impacts to the trees.

- At the Green Bridge there is a 30 foot distance between the faces of abutment and an existing 5 foot sidewalk within that area, on the north side.

- At mile marker 13 area, the mature trees tend to be less frequent, however, the project then enters an area of adjacent stone walls and historic properties.

- At mile marker 13.7 there is an existing section which appears to be a 22 foot travel way within a 40 foot right-of-way, stone walls on both sides at the right-of-way limits with 4 foot sidewalks and 4 - 5 foot grass strips between the sidewalks and the road. It appears as though a 26 foot section could be accommodated within this segment and that perhaps an elimination of one of the sidewalks along this way would be a solution to space problems. It should be noted that a 32 foot section through this area would have significant impacts on the historic character of the area.

- On the approach out of Barnstable Center there are walls on both sides of the roadway. Typically there is a sidewalk on one side. A 32 foot section would have significant impacts to those features, however, a 26 foot section appears possible.

- At mile marker 14.6, which is at Stonehedge Road, the roadway section appears to tighten up a bit with a more narrow right-of-way then previously observed.

- At mile marker 15.1 there appears to be approximately one half dozen trees which would be impacted with the 26 foot cross-section. Tight constraints continue to 15.5 and on, with a 26 foot section impacting significant trees.

- At mile marker 15.6 the expanse appears to open up somewhat with less impacts due to the 26 foot section. However, a 32 foot cross section would have a significant impact on trees and adjacent features such as walls and fences.

- Continuing into Yarmouth a mile marker 16.7 the trend continues with fences and walls at the right-of-way lines, sidewalks on both sides of the street, grass strips with trees planted within those grass strips. It appears as though a 26 foot cross-section could reasonably fit within the corridor, however, a 32 foot section would have significant impacts.

- At mile marker 17.4 there appears to be room for improvements on the south side of the roadway. It appears as though this corridor continuing on would could accommodate a 32 foot section with minimal apparent impact. Should be noted for a significant section of this segment extending beyond mile marker 18 there are very few trees within the right-of-way on the north side of the roadway. Utility poles are along this location on the north side.

- At mile marker 18.3 there is an apparent wetland on the south side of the road and the corridor begins to neck down at this point.

- At mile marker 18.4 the cross-section tightens up with wetlands on both sides with guardrail systems. It appears as though a 26 foot section could be accommodated. However, greater sections would likely have impacts.

- At mile marker 19.4 minor wetlands on the south side. For a station equation vehicles 19.65 odometer reading equals mile marker 20.

- At mile marker 20.3 wetlands on the north side. In general from mile marker 20 to mile marker 21 there appears to be accommodation for a 32 foot section, with very few significant trees or historic impacts evident.

- At mile marker 21.3, Dennis Center, there are park lands apparent on the south side of the roadway.

- At mile marker 21.4 beyond Dennis Center, the significant trees and stone walls features begin to pick up in frequency. A 26 foot section could be accommodated with little impacts. However, the 32 foot section would have significant impacts.

- At mile marker 22.2 there is a major slope constraint on the south side of the roadway.

- At mile marker 22.6, there are wetlands on the south side of the road which then pick up on the northern side of the road and extend to mile marker 22.9. A 26 foot section could be accommodated with minimal impacts however a 32 foot section would have significant wetland impacts.

- At mile marker 23.2 to the intersection of Route 134 there is a typical section on the north side of the road with granite curbing and a sidewalk immediately adjacent thereto, which should be noted.

- At mile maker 23.5 and continuing, there are typically stonewalls on either side of the road with slope conditions on the south side of the roadway.

- At mile marker 23.7 there is a typical section with granite curbing and adjacent sidewalk on the south side and significant trees in close proximity to the edge of the road. On the south side, a 26 foot section would have impacts to those trees.

- At mile marker 24, entering the Town of Brewster, there appears to be wetlands on both sides of the roadway. A 32 foot section would have significant impacts to those wetlands. A 26 foot section may have minor impacts to the wetlands.

- At mile marker 24.6, in general, this segment appears clear for a 32 foot section.

- At mile marker 25.1 there is a pinch point with wetlands on both sides of the road. A 26 foot section would impact those wetlands. Continuing on to mile marker 26 there are significant trees on the north side, planted in a row and they would be impacted with 32 foot section.

- At mile marker 25.7 there are salt marshes on both sides of the roadway. Tight section with guardrail. A 32 foot section would have impacts on those marshes.

- At the 26 mile mark and beyond on the north side of the road are significant trees planted in a row which would be impacted with a 32 foot section. To quantify those trees, there appears to be at least 2 dozen.

- At mile marker 27 and beyond there appears to be clear width for a 32 foot section with minimal impacts. There is a sidewalk on the south side of the road which would have to be incorporated into the section.

- At mile marker 28 on the road equals 27.4 in the car. This location appears to have room for a 32 foot section.

- At mile marker 28.8 roadway section appears adequate for a 32 foot section with minimal tree and other impacts.

- At mile marker 29.1 it appears as though impacts to adjacent trees can be avoided with minor shifts in alignments through this section.

- At mile marker 29.4 there are significant trees and stone walls on the north side of the roadway, which should be avoided.

- At mile marker 29.5 there are significant trees on the south side of the road (approximately 6).

- At mile marker 29.7 and beyond the corridor opens up with minimal trees and adjacent features to be impacted even with the 32 foot section.

- At mile marker 32, it should be noted that there are approximately 2 dozen significant trees planted in a row on the north side which should be avoided. It appears as though much of the widening necessary should be accommodated on the south side.

- At mile marker 30.8 cranberry bog encroaching upon the roadway on the north side for approximately 200 feet.

- At mile marker 30.9 approximately a half of a dozen significant trees are on the north side of the roadway, any widenings on that side would impact those trees. Residences exist on the south side of the roadway through that area. Continuing to mile marker 31.3 which equals mile marker 32 on the road and beyond the significant trees are predominately on the north side of the roadway. At mile marker 31.4 the trend reverses and the significant trees are on the south side of the roadway.

- At mile marker 32.0 is the Town of Orleans, town line.

- At mile marker 31.8 opens up to a 4 lane cross-section with a signalized intersection.

- At mile marker 32.5 the corridor encroaches on both sides with businesses and trees, sidewalks, vertical granite curb.

- At mile marker 32.8 the typical section appears to be 24 - 26 foot roadway with vertical granite curbing on both sides of the road and sidewalks immediately beyond. These conditions continue with a variable width pavement just short of the rotary in Eastham with the sidewalk conditions ceasing on the south side.

Bibliography

BIBLIOGRAPHY

A Synthesis of Existing Bicyclist and Pedestrian Related Laws and Enforcement Programs, Federal Highway Administration, National Bicycling and Walking Study, Case Study No. 13, Publication No. FHWA-PD-93-018, 1993.

Balancing Engineering, Education, Law Enforcement and Encouragement, Federal Highway Administration, National Bicycling and Walking Study, Case Study No. 13, Publication No. FHWA-PD-93-018, 1993.

Betz, Joe, Jim Dustrude and Jill Walker, *Intelligent Bicycle Routing in the United States,* Transportation Research Record 1405.

Bicycling & Walking in the Nineties and Beyond: Applying Scandinavian Experience to America's Challenge, Federal Highway Administration, 1994.

Brilliot, Michael and Julie A. Winterich, *Rails-With-Trails: Sharing Corridors for Recreation and Transportation,* Rails-to-Trails Conservation, 1993.

Brooks, Mary E., *Planning for Urban Trails,* American Society of Planning Officials, Dec. 1996.

California Department of Transportation, *District 1 Bicycle Touring Guide,* 1993.

Claire Saltonstall Bikeway Map - Boston to Cape Cod, American Youth Hostels, 1992.

Conflicts on Multiple-Use Trails: Synthesis of the Literature and State of the Practice, Federal Highway Administration, Publication No. FHWA-PD-94-031, 1994.

Current Planning Guidelines and Design Standards Being Used By State and Local Agencies for Bicycle and Pedestrian Facilities, Federal Highway Administration, National Bicycling and Walking Study, Case Study No. 24, Publication No. FHWA-PD-93-006, August 1992.

Cynecki, Michael J., Grace Perry and George Frangos, *Study of Bicyclist Characteristics in Phoenix, Arizona,* Transportation Research Record 1405.

Epperson, Bruce, *Evaluating Suitability of Roadways for Bicycle Use: Toward a Cycling Level-of-Service Standard,* Transportation Research Record 1438.

FHWA Study Tour for Pedestrian and Bicyclist Safety in England, Germany and the Netherlands, Federal Highway Administration, 1994.

Final Report: The National Bicycling and Walking Study, Transportation Choices for a Changing America, Federal Highway Administration, Publication No. FHWA-PD-94-023, 1994.

Florida Department of Transportation, *Bicycle Facilities Planning & Design Manual*, 1982.

Florida Department of Transportation, *Florida Bicycle Facilities Planning and Design Manual: DRAFT*, 1994.

Garder, Per, *Bicycle Accidents in Maine: An Analysis*, Transportation Research Record 1438.

Granite State Wheelman, *Bicycle Transportation Fundamentals*, October 1993.

Guide for the Development of Bicycle Facilities, American Association of State Highway and Transportation Officials 1991.

Highway Route Designation Criteria for Bicycle Routes, Federal Highway Administration, Report No. FHWA-RD-86\066, April 1986.

Integrating Bicycle and Pedestrian Consideration Into State and Local Transportation Planning, Design, and Operations, Federal Highway Administration, National Bicycling and Walking Study, Case Study No.21, Publication No. FHWA-PD-93-017, 1992.

Jones, Gregory M., *On-Road Improvements for Bicyclists in Maryland*, Transportation Research Record 739.

Krammes, Raymond A. and Stephen W. Glascock, *Geometric Inconsistencies and Accident Experience on Two-Lane Rural Highways*, Transportation Research Record 1356.

Lagerway, Peter and Brian Puncochar, *Evaluation of the Burke-Gilman Trail's Effect on Property Values and Crimes*, Transportation Research Record 1168.

Landis, Bruce W., *Bicycle Interaction Hazard Score: A Theoretical Model*, Transportation Research Record 1438.

Liability Aspects of Bikeway Designation: A Special Report, Bicycle Federation of America, 1986.

Loop, Stephen B. and Robert D. Layton, *Effect of Bicycle Lane Usage on Vehicles in the Adjacent Lane*, Transportation Research Record 629.

Massachusetts Highway Department, *Building Better Bicycling: A Manual for Improving Community Bicycling Conditions*, 1994.

Measures to Overcome Impediments to Bicycling and Walking, Federal Highway Administration, National Bicycling and Walking Study, Case Study No. 4, 1993.

Mitchell, Teresa H., Vincent J. Dee and Chad Dawson, *Suggested Applications by Seaway Trail, Inc., for a National Scenic Byway,* Transportation Research Record 1363.

North Carolina Department of Transportation, *North Carolina Bicycle Facilities, Planning and Design Guidelines,* 1994.

O'Neill, Stephen J., *Application of Planning and Engineering Principles for the Development of Innovation Multi-Use Trail Systems,* A Thesis submitted in Partial Fulfillment of the Requirements for the Degree of Master of Civil and Environmental Engineering, University of Rhode Island, 1993.

Off Limits - A Reference Guide for Improving Compliance with Posted Speed Limits, National Highway Traffic Safety Administration, 1988.

Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas, Federal Highway Administration, National Cooperative Highway Research Program Reports 294 A, June 1987.

Replogle, Michael and Harriet Parcells, *Linking Bicycle/Pedestrian Facilities with Transit* , National Association of Railroad Passengers, September 1992.

Replogle, Michael, *Bicycle Access to Public Transportation: Learning from Abroad,* ITE Journal, December 1992.

Replogle, Michael, *Bicycle and Pedestrian Policies and Programs in Asia, Australia, and New Zealand,* FHWA, April 1992.

Replogle, Michael, *Bicycles and Public Transportation: New Links to Suburban Transit Markets,* The Bicycle Federation, 1983.

Safety Effectiveness of Highway Design Features; Volume III: Cross Sections, Federal Highway Administration, Publication No. FHWA-RD-91-046, 1992.

Selecting and Designing Bicycle Routes: A Handbook, Bicycle Federation of America, 1966.

Selecting Roadway Design Treatments to Accommodate Bicycles, Federal Highway Administration, Publication No. FHWA-RD-92-073, July 1994.

Smith, Bob L. and William L. Smith, *Scenic Byways: Their Selection and Designation,* Transportation Research Record 1363.

Stutts, Jane C., Joseph E. Williamson and Frank C. Sheldon, *Bicycle Accidents: An Examination of Hospital Emergency Room Reports and Comparison with Police Accident Data,* Transportation Research Record 1168.

The Effects of Bicycle Accommodations on Bicycle/Motor Vehicle Safety and Traffic Operations, Federal Highway Administration, Publication No. FHWA - RD-92-069, 1994.

The Impacts of Rail Trails, US Department of the Interior, 1992.

Thomas, Paul., *The Best Bike Rides in New England,* The Globe Pequot Press, 1990.

Torbic, Darren J., *The Planning and Design of Bicycle and Pedestrian Trail Crossings,* A Thesis submitted in Partial Fulfillment of the Requirements for the Degree of Master of Engineering, Pennsylvania State University, 1994.

Traffic Calming, Auto-Restricted Zones and Other Traffic Management Techniques - Their Effects on Bicycling and Pedestrians, Federal Highway Administration, National Bicycling and Walking Study, Case Study No. 19, Publication No. FHWA-PD-93-026, 1994.

Transportation Potential and Other Benefits of Off-Road Bicycle and Pedestrian Facilities, Federal Highway Administration, National Bicycling and Walking Study, Case Study No. 7, Publication No. FHWA-PD-92-040, 1992.

Van Valkenberg, Philip, *Methodology for Evaluating the Suitability of Two-Lane, Two-Way Paved Roadways for Shared Bicycle/Motor Vehicle Use,* 1982.

Wisconsin Department of Transportation, *Facilities Development Manual,* Procedure 11-45-10, 1993.

Research Contacts

Contacts

Contact Name	Address/Phone Number	Comments
Mac Elliott Chair American Society of Civil Engineers Human Powered Transportation Subcommittee	6616 North 14th Street Phoenix, AZ 85014 (602) 265-6712	Motorists track roadway edge lines when oncoming traffic is present. This can create a safety concern for bicyclists in wide curb lanes. Consistant cross-sections need to be provided for bicyclists on roadways that expect high bicycle traffic.
Dave Harkey Transportation Research Engineer Highway Research Center	University of North Carolina 134 1/2 East Franklin Street CB 3430 Chapel Hill, NC 27599-3430 (919) 962-2202	Providing a shoulder or increasing 1-foot shoulders to 2-foot shoulders will improve safety for motorists and bicyclists. Any widening treatment that promotes the separation of bicyclists and motorists on roadways with less than desirable conditions will increase the safety of the roadway. Safety benefits obtained from shoulder improvements will not be negatively impacted by potential increases in travel speeds.
Mark Horowitz Bicycle/Pedestrian Coordinator Broward County, Florida	(305) 357-6661	Florida Department of Transportation has recently passed a roadway policy that all resurfacing projects on state maintained roadways will include bicycle-lanes. Broward County has adopted this policy for county roads. The county will incorporate 14-foot travel lanes or strip 11-foot travel lanes with 4-foot shoulders on roadways where additional pavement width is not available to better accommodate bicycles.

Contact Name	Address/Phone Number	Comments
Mark Horowitz (continued)		On roadways where these application are not possible due to environmental or historical constraints, Broward County will install "share the road" signs to make motorists aware of the pressure of bicyclists.
Tom Huber Bicycle/Pedestrian Coordinator Wisconsin Department of Transportation	Box 7913 Madison, WI 53707-7913 (608) 267-7757	Roadways with less than adequate cross sections and high peak hour traffic volumes should not be signed as bicycle routes. Roadways with these conditions should be upgraded to improve motor vehicle safety, which indirectly benefits bicycle travel within the corridor.
Rick Knapp Acting Director, District 1 California Department of Transportation	P.O. Box 3700 Eureka, CA 95502-3700	Bicyclists and motorists need to be informed of roadway conditions and characteristics. This can be done through "Bicycling Touring Guides" and roadway warning and information signs. Two foot shoulders may create a false sense of security for bicyclists and motorists. CalTrans is concerned with liability issues of signed bicycle routes with inadequate cross sections. It is important to alert visitors of roadways with high volumes of bicyclists. This can be done through signage, flyers, education programs and touring guides.

Contact Name	Address/Phone Number	Comments
Josh Lehman Bicycle/Pedestrian Program Coordinator	10 Park Plaza - Room 4150 Boston, MA 02116-3973 (617) 973-7329	Develop spot maintenance programs to identify problem locations that effect bicycle safety within a corridor. Educate surrounding communities, motorists and bicyclists in regards to operating laws to improve the overall safety of a corridor for all users. Enforce speed limits and bicycle operating laws to create a safer environment for bicyclists.
Harvey Muller Bicycle/Pedestrian Coordinator Maryland State Highway Administration	707 N. Calvert Street P.O. Box 717 Baltimore, MD 21203-0717	Maryland's "share the road" programs are implemented to educate motorists that Maryland Law and Maryland Department of Transportation policy statements regard the bicycle as a legitimate highway vehicle with equal rights and responsibilities.
Tom Norman Bicycle/Pedestrian Coordinator North Carolina Department of Transportation	North Carolina Dept. of Transportation P.O. Box 25201 Raleigh, NC 27611 (919) 733-2804	"Share the Road" programs should be considered "short-term" solutions warning motorists and bicyclists of less desirable roadway conditions. "Share the Road" programs should utilize warning signs not information signs. Information signs can be misinterpreted as route signs designating a safe bicycle route. North Carolina Department of Transportation (NCDOT) is not concerned with potential travel speed increases caused by roadway widenings to better accommodate bicyclists. NCDOT is more concerned with obtaining acceptable laterial separation to increase safety for bicyclists and motorists.

Contact Name	Address/Phone Number	Comments
Tom Norman (Continued)		Shoulder widening programs throughout North Carolina have not encouraged unsafe motor vehicle operation but have instead increased the roadways overall safety Motorists may misinterpret 2-foot shoulders as bicycle lanes and may become overly aggressive in establishing their rights to the "motor vehicle lane".
Pat Pierratte Assistant Pedestrian/Bicycle Coordinate Florida Department of Transportation	605 Suwannee Street MS-82 Tallahassee, FL 32399-0450 (904) 487-1200	Florida Department of Transportation (FLDOT) currently uses "share the road" signs where high bicycle use is expected on roadways with less than adequate cross sections or general roadway conditions. FLDOT reduces travel lane widths to allow for additional operating space for bicyclists.
Charlie Zeeger Associate Director of Roadway Studies Highway Safety Research Center	University of North Carolina 134 1/2 East Franklin Street CB 3430 Chapel Hill, NC 27599-3430 (919) 962-2202	Motor vehicle travel speeds may increase with additional shoulder widths. Reducing travel lane widths and providing a shoulder will possibly reduce travel speeds and better separate bicyclists and motorists.