ROAD SAFETY AUDIT

MAJOR HIGHWAY MEDIAN CROSS-OVER CRASHES

Route 2 Lexington

Prepared for
Massachusetts Highway Department

MASS HIGHWAY

Prepared by
MS Transportation Systems, Inc.
Framingham, Massachusetts

April 2009

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ROUTE 2 LEXINGTON

FINAL REPORT

April 2009

Prepared for

Massachusetts Highway Department

Prepared by

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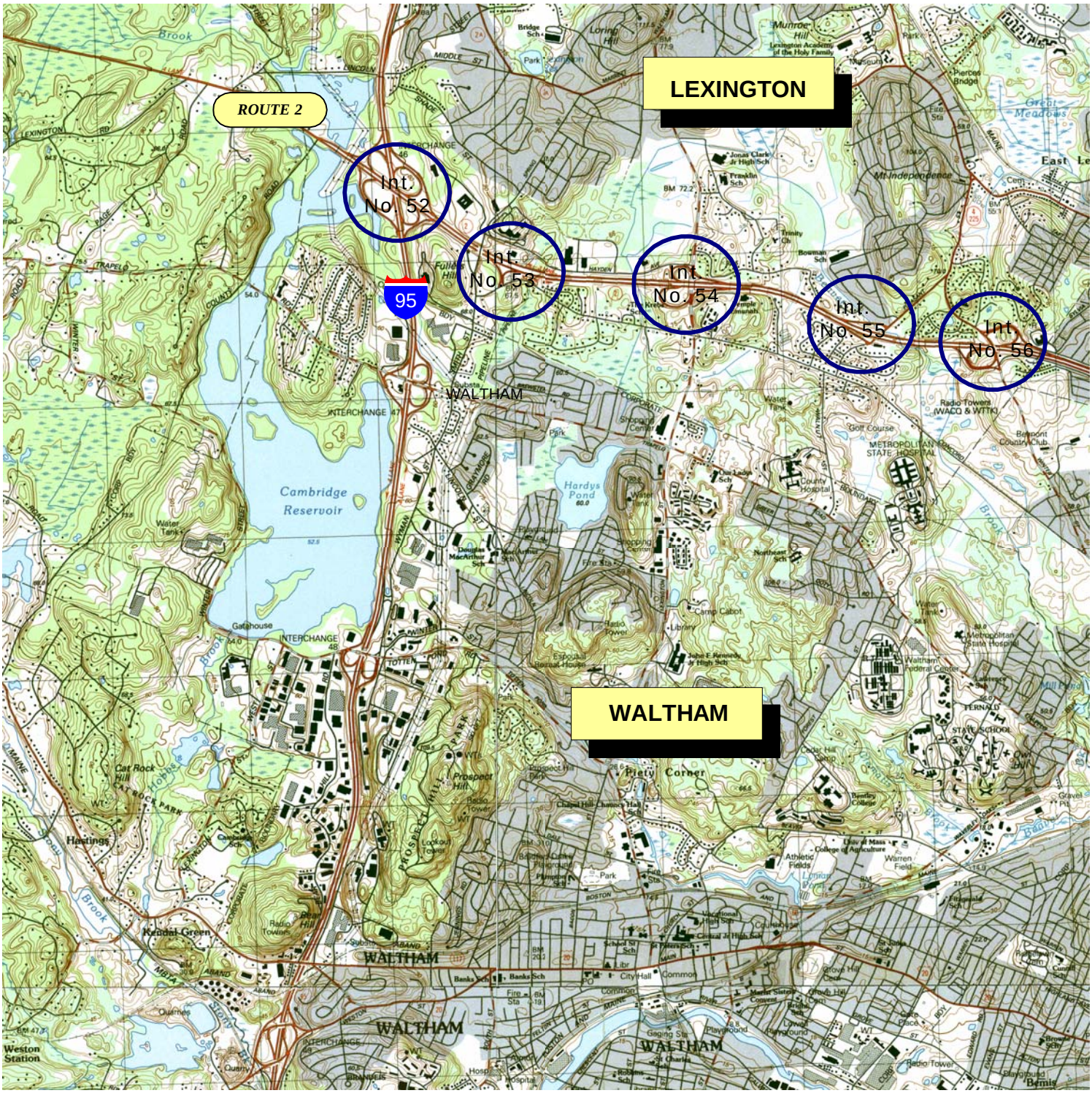
INTRODUCTION

Lane departure crashes are one of the primary fatal crash types in Massachusetts. The Commonwealth exceeds the national average for lane departure crashes and was designated a lead state in lane departure crashes by the American Association of State Highway and Transportation Officials (AASHTO). The Massachusetts Highway Department (MHD) conducted a study of the problem and found that during 2002-2004, lane departure crashes accounted for 25 percent of all injury crashes and nearly half, 46 percent, of all fatal crashes.

As part of the effort in implementing the safety plan and specifically reducing lane departure crashes, the MassHighway is completing a Road Safety Audit (RSA) Review Project specifically focused on median crossing (or median cross-over) crashes on its major highways. Road safety audits are a formal safety performance examination on existing or future roadways by an independent audit team. These specific audits are being conducted in locations where cross-over experience has been or has the potential to be of concern and where the RSA team has judged that factors exist and safety risk could be affected. The team works to identify opportunities for enhancing safety and to recommend specific enhancements that may be implemented to reduce median cross-over crashes and improve the overall safety along the highway.

An RSA was conducted for the Route 2 in Lexington as part of this overall effort. The roadway section under study, shown in Figure 1, was from just west of Interchange No. 52 at Route 128 (I-95) to just east of Interchange No. 56 a distance of approximately 3.8 miles. This study section had experienced a fatal cross-median crash reported in the 2004-2007 data.

The purpose of this Route 2 Lexington RSA was to assess current safety characteristics on the highway section under study and to recommend a set of actions to enhance the safe operation of the highway section under study. Recommendations contained in this report reflect the overall consent of the RSA team and do not necessarily reflect the official views of MassHighway.



Project Location

Route 2 Road Safety Audit
Lexington, Massachusetts

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MS Transportation Systems, Inc. **Framingham, Massachusetts**

FIGURE 1

RSA PROCESS

In conducting the RSA, the overall procedures outlined in the Median Cross-Over RSA Guideline Report[1] with some modifications given the characteristics of the facility being reviewed. The process included identifying RSA team members; conducting field visits; holding a RSA team meeting and then completing an assessment of the data and findings from the field visits and meetings to render recommended actions for MassHighway to consider. Data including recent traffic volume data, summary crash records for the 2004-2007 period, detailed crash reports of cross-over crashes, and available record highway plans were obtained and reviewed by the RSA consultant. Field visits were conducted by the RSA team members. A video recording of the sections under study was taken by the RSA Consultant. The site visits were completed prior to the RSA team meeting that was held on August 28, 2008 at the MassHighway District 4 offices. At that meeting, the RSA consultant provided a brief overview of the RSA purpose, a summary of the roadway section's characteristics and results of the review to date. The RSA team provided input and discussed the key items noted in the field and that were listed on the RSA Median Cross-Over Prompt List. Issues and concerns were noted. Following the RSA meeting, the RSA consultant compiled the information, completed the analysis and circulated the draft report.

- **RSA Team**

The following were members of the Route 2 Lexington Road Safety Audit:

Raj Kulen, MassHighway, District 4 Traffic
Jim Gallagher, MAPC
Erica Grygorcewicz, MassHighway
Brett Loosian, MassHighway, District 4 Maint.
James Baily, Mass State Police
Lisa Schletzbaum, MassHighway, Safety
Jim Alexander, MassHighway, District 4 Projects
Alex Normandin, MassHighway
William J. Scully, MS Transportation systems (RSA Consultant)

- **RSA Team Meeting**

The RSA team meeting took place on August 28, 2008 at the District 4 offices in Arlington. The team included engineers, planners and a representative from the State Police barrack that has jurisdiction of Route 2 in Lexington. Represented were MassHighway (Boston and District), a representative of the Metropolitan Area Planning Council, as well as the State Police. A list of the team members contact information are

[1] MS Transportation Systems, Inc., Road Safety Audits, Median Cross-Over Crashes, Audit Guidelines, Prepared for MassHighway, October 2007.

included in the Appendix. As stated previously, overall characteristics and conditions of the study section were presented. The drive-through video and photographs were reviewed and a discussion of the potential safety opportunities for enhancement followed. Highlights of the discussion include the following:

- Based on the experience of some members of the RSA team in this corridor, it was noted that the roadway surface is noticeably slippery when wet – likely due to the pavement type.

- It was noted that some of Route 2 has been reconstructed but not in this specific section under study. Portions of project area were either crack sealed and/or "micro-surfaced" between Interchanges Nos. 53 and 55 in the early 2000's.

- While posted speeds are for the most part (55 mph) on this highway in the study section, the recently collected data by MassHighway and general observations by the State Police found higher than desired speeds generally occur (exceeded posted speeds by up to 19 mph). Combined with the surface conditions when wet, the high speeds creates a potentially hazardous condition.

- Some sections of the depressed median have steeper side slopes which may be preventing errant motorists from actually crossing the median.

• Analysis Procedures

As previously indicated, the RSA analysis generally followed the procedure described in the previously referenced Guideline with some variations and also took into consideration the methods published by the Federal Highway Administration[2] and those included in training materials[3]. The basic tasks included:

- Obtaining and reviewing crash and other traffic characteristic data and available record plans,

- Conducting site reconnaissance and collecting a current record of condition via photos and video,

[2] Federal Highway Administration, Road Safety Audit Guidelines, Publication No. FHWA SA-06-06, Washington, D.C., 2006.

[3] Federal Highway Administration, Resource Center, Road Safety Audits Mini-Workshop, Jeffrey Shaw, PE, PTOE, presented to New England ITE Section, September 19, 2006.

- Identifying opportunities for enhancement, and
- Identifying and evaluating potential actions to address the noted issues.

In assessing the issues identified by the RSA Team, the relative seriousness and potential risk relative to crash frequency and severity were determined. Using the guidelines of FHWA as input and considering characteristics of this specific RSA, the relative frequency criteria and severity criteria were identified and are presented in Table 1 and Table 2, respectively.

TABLE 1
FREQUENCY RATING

ESTIMATED		EXPECTED CRASH FREQUENCY (PER AUDIT ITEM)	FREQUENCY RATING
Exposure	**Probability**		
high	high	5 or more crashes per year	*Frequent*
medium	high		
high	medium	1 to 4 crashes per year	*Occasional*
medium	medium		
low	high		
high	low	Less that 1 crash per year, but more than 1 crash every 5 years	*Infrequent*
low	medium		
medium	low	Less than 1 crash every 5 years	*Rare*
low	low		

Source: FHWA Road Safety Audit Training Materials

TABLE 2
SEVERITY RATING

Typical Crashes Expected (per audit item)	Expected Crash Severity	Severity Rating
High-speed crashes; head on and rollover crashes	Probable fatality or incapacitating injury	*Extreme*
Moderate-speed crashes; fixed object or off-road crashes	Moderate to severe injury	*High*
Crashes involving medium to low speeds; lane changing or sideswipe crashes	Minor to moderate injury	*Moderate*
Crashes involving low to medium speeds; typical of rear-end or sideswipe crashes	Property damage only or minor injury	*Low*

Source: FHWA Road Safety Audit Training Materials

Taking into consideration both frequency and severity, the relative risk of a particular audit item was rated. The risk ratings are shown in Table 3. For each safety issue identified, the potential seriousness of the issue as well as possible mitigation measures have been indicated.

TABLE 3
CRASH RISK ASSESSMENT

Frequency Rating		**Severity Rating**		
	Low	Moderate	High	Extreme
Frequent	C	D	E	F
Occasional	B	C	D	E
Infrequent	A	B	C	D
Rare	A	A	B	C

Source: FHWA Road Safety Audit Training Materials

Crash Risk Ratings:
A: minimal risk level
B: low risk level
C: moderate risk level
D: significant risk level
E: high risk level
F: extreme risk level

- **RSA Field Audit**

Field audits were conducted by the RSA team members between on or before August 28, 2008. In general, the field visits included "drive-throughs" in each direction of the study section noting physical conditions and the "feel" of the driver. The Prompt List developed as part of the RSA process was used as a guide. The prompt list is included in the appendix for background information. The RSA field audits took place by team members prior to the RSA team meeting and revealed the following:

- There are three travel lanes per direction in the section under study.
- Posted speeds were noted at 55 mph.
- The alignment of the roadway section under study varies with a number of curves and vertical grade changes in study section. Depending on location and direction, some driver discomfort is present at high speeds.
- The inside shoulder appears to be less than 3 feet in width.
- There is no rumble strip in place within the inside shoulder. There is a strip in the outside shoulder.

- No delineation of the median via markers or flexible reflector posts were in place. In addition, there are no markers in the travel lane lines.

- A large portion of the median is open (or unprotected).

- Pavement markings were in average condition at the time of the field audit.

- Median can be generally classified as “depressed” with the median slopes relatively steep in a number of areas.

- Some gore areas at on or off ramps had scored cement concrete in place. There was not consistent application of this within the section.

- The distance between the eastbound on-ramp at Watertown Street (Interchange 56) and the off-ramp (Interchange 57 – in Belmont) is short (approximately 350 feet) to accommodate the weaving.

- Placement of some guide signage seemed to provide shorter than desirable notice to motorists. An example of this was the commuter parking sign in the eastbound direction being placed too close to the exit.

ANALYSIS

In completing the RSA of Route 2 in Lexington, findings were compiled from the field audits, the review of the data, and input provided by team members. The following paragraphs summarize the results from each of the key components of the assessment.

The section of Route 2 under study is approximately 3.8 miles in length with three (3) lanes per direction separated by a median. The section includes five interchanges not including the major interchange at I-95. These are:

- Interchange No. 52 at I-95
- Interchange No. 53 at Concord Avenue and Spring Street
- Interchange No. 54 at Waltham Street
- Interchange No. 55 at Pleasant Street and Concord Avenue
- Interchange No. 56 at Watertown Street

The spacing of the interchanges is relatively close as depicted in Figure 2. As can be seen, the five interchanges within the study area are closely spaced. From I-95 eastward, the next four interchanges are located in 2.5 miles. It is noted that not all the interchanges are fully directional interchanges, which may alleviate to an extent the close spacing.

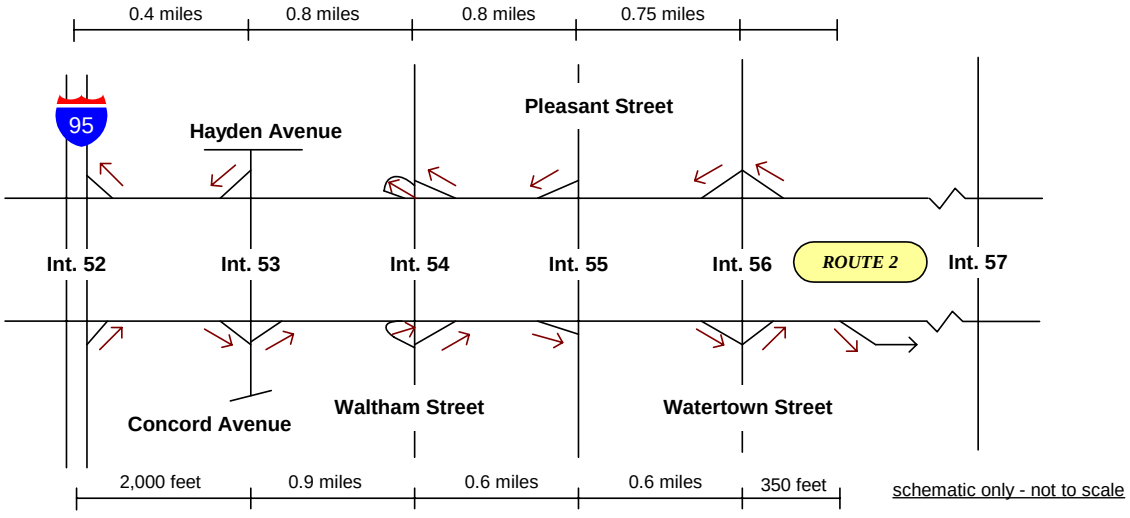


Figure 2
Spacing of Interchanges

The Route 2 alignment in the project area is largely straight and level. Speeds are posted at 55 miles per hour. Recent speed data that was collected indicates actual speeds are averaging between 10 and 15 miles per hour higher. Table 4 summarizes the data.

TABLE 4
SUMMARY OF SPEED OBSERVATIONS

Location	Direction	Posted Speed	85th Perc. Speed
1/4 mile east of Exit 53	Eastbound	55 mph	69 mph
	Westbound	55 mph	69 mph
1/8 mile west of Exit 53	Eastbound	55 mph	61 mph
	Westbound	45 mph	69 mph

The section of highway in the study area for the most part, has an inside shoulder that appears less than 3 feet in width and no rumble strip or recessed reflectors in place at the time of this analysis. There was a noticeable edge drop-off on a number of locations along the study section as well. In addition, this section of Route 2 does not have the reflective delineator posts installed alongside the median. The low level of guidance was cited as a potential contributing factor to median related entries particularly during times of low visibility.

Figure 3 – Eastbound on Route 2 – some areas in study section have elevation difference between the two directions of flow

The pavement surface is in average to below average condition. As noted in the field audit, crack filler is visible throughout the study section. The existing surface does not appear to function well under wet conditions. District personnel have indicated that a resurfacing project is scheduled in the near future.

The width of the median (measured from presumed edge line to edge line) in the project area was primarily between 65 and 70 feet. In total, 2.3 miles of the 3.8 mile section of the median is considered "open" with no barrier present. The Route 2 median is generally clear of trees and other small vegetation.

On the western end of the study section, Route 2 intersects with I-95. In this area, the median is open and begin to narrow as one continues traveling west past the interchange. In this area, which is heavily traveled, Route 2 transitions from 3 lanes per direction to two lanes per direction west of the interchange. Mr. Tabor Road intersects Route 2 on the eastbound direction. A "Authorized Vehicles Only turnaround" (AVOT) is located just east of Mt. Tabor Road. Some factors noted in this particular section that contribute to potentially difficult travel are the merges and lane drops in the westbound direction. The ramp queues observed particularly in the morning peak hour on Route 2 westbound to the I-95 northbound and southbound ramps also contribute to "quick" land changing. The AVOT located near Mt. Tabor Road is in the area of westbound merge and westbound lane drop. At the sametime, an additional travel lane is gained in the eastbound direction. The narrowness of the median and AVOT location in the proximity of Mt. Tabor Road may encourage inappropriate turns into Mt. Tabor Road from the westbound direction of Route 2.

Figure 4 – Median is generally open without vegetation other than grass

Based on the recent MassHighway traffic counts, the roadway section carries an average of 55,875 vehicles per day in the study section. Figure 4 illustrates the directional volume over the course of the day for the sections west of I-95 of Route 2. Higher volumes would tend to exist east of I-95. There are two distinct peak hours (AM and PM commuter periods), with the higher direction flow in the eastbound direction during the morning. Peak hour volumes (two way) are between 4,200 and 4,700 vehicles. The peak volumes occurs in the morning. The peak direction is experiencing in the range of 2,900 to 3,000 vehicles during the peak hour. Truck volume on this section of Route 2 is lower than the interstate highways included in the RSA cross-median program with 3% trucks over the course of the day. Peak hour truck percentage have been observed at 2%.

Figure 5 – Route 2 Eastbound

Figure 6 – Route 2 Westbound

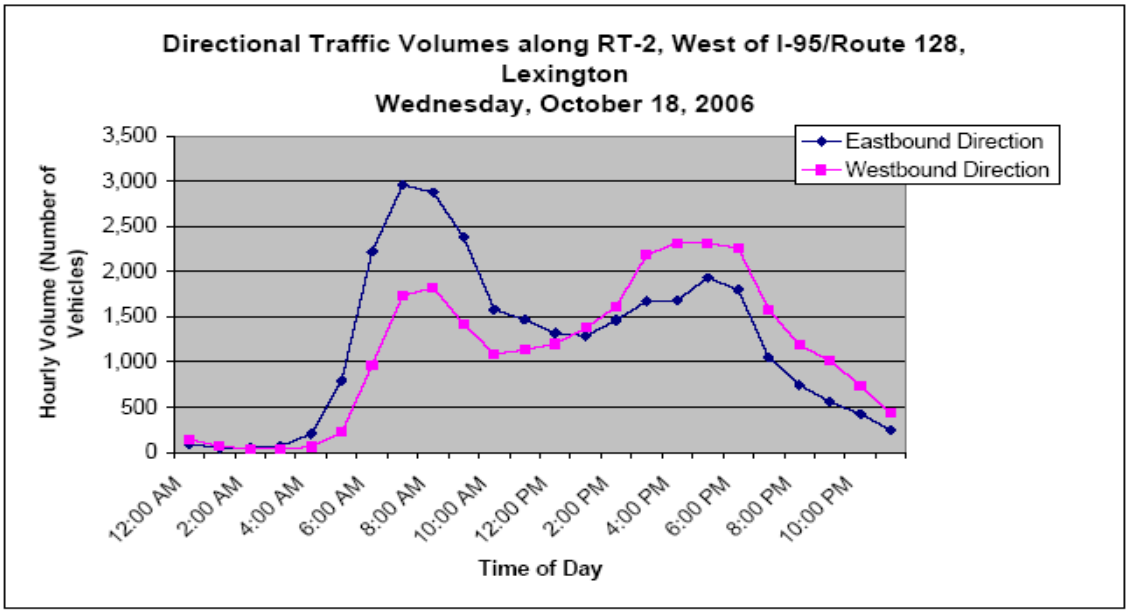


Figure 7 – Route 2 Hourly Traffic Volumes South of Route 2

Another item of note was the condition in the vicinity of the I-95 interchange. It is a significantly high volume interchange. The Route 2 westbound movements to either I-95 northbound or southbound conflict with both movement from I-95 and the high demands on I-95 that slow all the movements and result in long queues. The queues can lead to quick lane changing (by inattentive motorists) or undesirable movements by all.

The District recently installed modified markings on the westbound approach to I-95 to reduce the inappropriate use of the shoulder to bypass queued vehicles. The new markings attempt to give motorists destined for I-95 northbound and southbound separate lanes in approaching the ramps.

Data available as part of the MassHighway crash records system indicated that between 2004 and July 2008, there were 45 reported crashes related to the median. Of the 45, there were five (5) crashes identified as cross-median. There was one cross-median fatal crash and one resulting in a personal injury.

The following highlight the crash characteristics in the study section 2004 to 2008 in addition to the above:

- Of all the median related crashes there were 16 personal injury (36%) related crashes in addition to the cross-median fatal crash.

- A majority of median related crashes were reported to initiate in the westbound direction.

- Approximately 49% of the reported median related crashes occurred on wet or snow/ice surface conditions.

- There were 22% of the reported median related crashes to have occurred during the dark period.

SUMMARY OF RSA FINDINGS/POTENTIAL ACTIONS

Based on the field review, the review of crash data and discussions among the RSA team members, the issues related to the safe operating conditions of the Route 2 in the Lexington area were identified. In essence, the RSA team determined that only a few factors or issues of concern exist at this time that potentially have an effect on the risk. These factors which also consider the crash type (i.e. cross-over median related), are listed in Table 5 along with the assigned risk rating.

TABLE 5
SUMMARY OF FACTORS THAT POTENTIALLY AFFECT
THE RISK OF SAFETY RELATED EVENTS

Factor or Issue	Risk Rating
Open median – perceived narrow and crossable to some extent	E
Inside paved shoulder width is narrow and not consistent	E[1]
Rumble strips do not exist in shoulder	E[1]
Median is not delineated with markers	D[1]
Surface condition including drainage, water ponding and hydroplaning is problem	E[1]
Edge drop is significant in some locations	C
Acceleration lanes appear short and short weave distance exists between Interchanges Nos. 56 and 57 (eastbound)	B
Advance warning for exits and destinations less than ideal	B
Authorized Vehicles Only turnaround location just west of I-95 can create hazard	B
Queuing at I-95 interchange on-ramps combined with demands and weave section creates undesirable maneuvers	B

1 High risk level related to total median entries not solely cross-overs

Although the section of Route 2 under study experienced significantly high traffic volumes (>55,000 ADT), the RSA team felt the drive through the section was generally a "comfortable" drive without any substantive difficulties due to the overall geometry. While there is a substantial length of open median (approx. 2.3 miles), it is approximately 65 to 70 feet in width and as evident by the low percentage (11%) of cross-over crashes, appears to be generally sufficient in "retaining" errant motorists that enter the median – possibly due to depressed characteristics and the median slope.

In general, a major factor in the cross median crashes is having an "open" median – i.e. median without a barrier. As noted above, the study section on Route 2 in Lexington

includes a large portion (approx 2.3 miles) of open median. Based on visual inspection, this median would be largely crossable although having a width of 65 to 70 feet. There was a mixed view by the RSA team, however, in terms of the likelihood of entering and then crossing the median in this section. However, there are several areas along the highway study section where there is a greater probability of cross-median crashes to occur. These were located at Mt. Tabor Road, between Interchange Nos. 53 and 54 and between 54 and 55. These include areas where horizontal curves exist or there is some differential between the directional elevations. In total, these two areas are approximately 4,000 feet in length. A rating of 'E' was assigned to the open median factor.

On the west side of the I-95 interchange, the median narrows east to west in the vicinity of Mt. Tabor Road where a concrete barrier that separates directional exists just west of Mt. Tabor Road. It is a location where a non-fatal cross median crash was reported. There is no barrier in the median east of the concrete barrier. The area is also where an "Authorized Vehicle Only turnaround" is located as shown in Figure 8. A rating of 'B' was assigned in relation to the turnaround as it is close to the I-95 southbound off-ramp to Route 2 westbound and in an area where westbound merging occurs.

Figure 8 - Area Near Mt. Tabor Road

The RSA team identified several factors that pose potentially high risks, more related to median entries and not necessarily cross-over crashes. These include the narrowness of the inside shoulder ('E' Rating), non-existence of a rumble strip ('E' Rating), and the median not being well delineated ('D' Rating).

One of the more significant factors noted by the team related to the pavement surface and its effect on drivers under wet conditions. This was reflected by the ponding and slippery surface. Input by team members pointed to the age and type of pavement. The risk rating assigned for this factor was 'E'. Almost half of the median related crashes occurred under wet surface conditions.

In addition to the sense that the acceleration lanes in general are shorter than desired, there is the condition that the distance between the on-ramp from Interchange 56 to the off-ramp at Interchange 57 in the eastbound direction is also short (approximately 350 feet) making the weaving in this area difficult. This can potentially result in motorists either staying to the left or making "quick" moves to avoid other vehicles entering Route 2. The risk rating for this factor was assigned a 'B'.

Another issue noted by the team included the lower than desirable level of advance warning or information to motorists to aid them in making decisions, particularly in leaving the highway. An example of this is the notice to eastbound motorists for the commuter park and ride lot and the Mass Highway District 4 office exit. The signs are located in close proximity to the exit ramp. If a motorist becomes aware of the exit too late, it may cause inappropriate lane changing and conflicts. This factor was assigned a 'B' as it may have a small to moderate effect on median entries given the 3 travel lane wide section.

The final factor identified that has an effect on driver behavior and the possibility of causing errant motorists was the vehicle queuing that occurs at the I-95 ramps, particularly the westbound movement on Route 2. MassHighway has recognized this condition and recently implemented modified markings and control in this area. A rating of 'B' was assigned for this factor.

Suggested actions identified are intended to reduce the number of and consequences resulting from median related crashes and other types of crashes as well. Given that this RSA program is focused on cross-median crashes, the evaluation of a median barrier was initially completed, other possible actions are discussed later in the report. The subsequent sections include discussion pertaining to the issues and the potential actions to consider for implement.

- **Consideration of a Median Barrier**

One of the more significant actions that could be considered is to install median barriers in the current "open" areas. Although the RSA team concluded that the open median

section did not pose a high risk at this time, the section was evaluated in terms of the median barrier warrants. A barrier can be considered when there is a higher than desirable chance or a greater risk for median cross-over crashes to occur and that have or could result in fatalities and/or a high proportion of injury related crashes. In addition, a barrier could be considered when the consequences or severity of a crash without a barrier are worse than if the barrier were in place.

Factors that generally come into play in deciding on whether a median should be installed involve the following:

- ♦ High volumes and speeds
- ♦ Truck volumes and mix
- ♦ Narrow median
- ♦ History of cross-median crashes
- ♦ High risk of catastrophic event

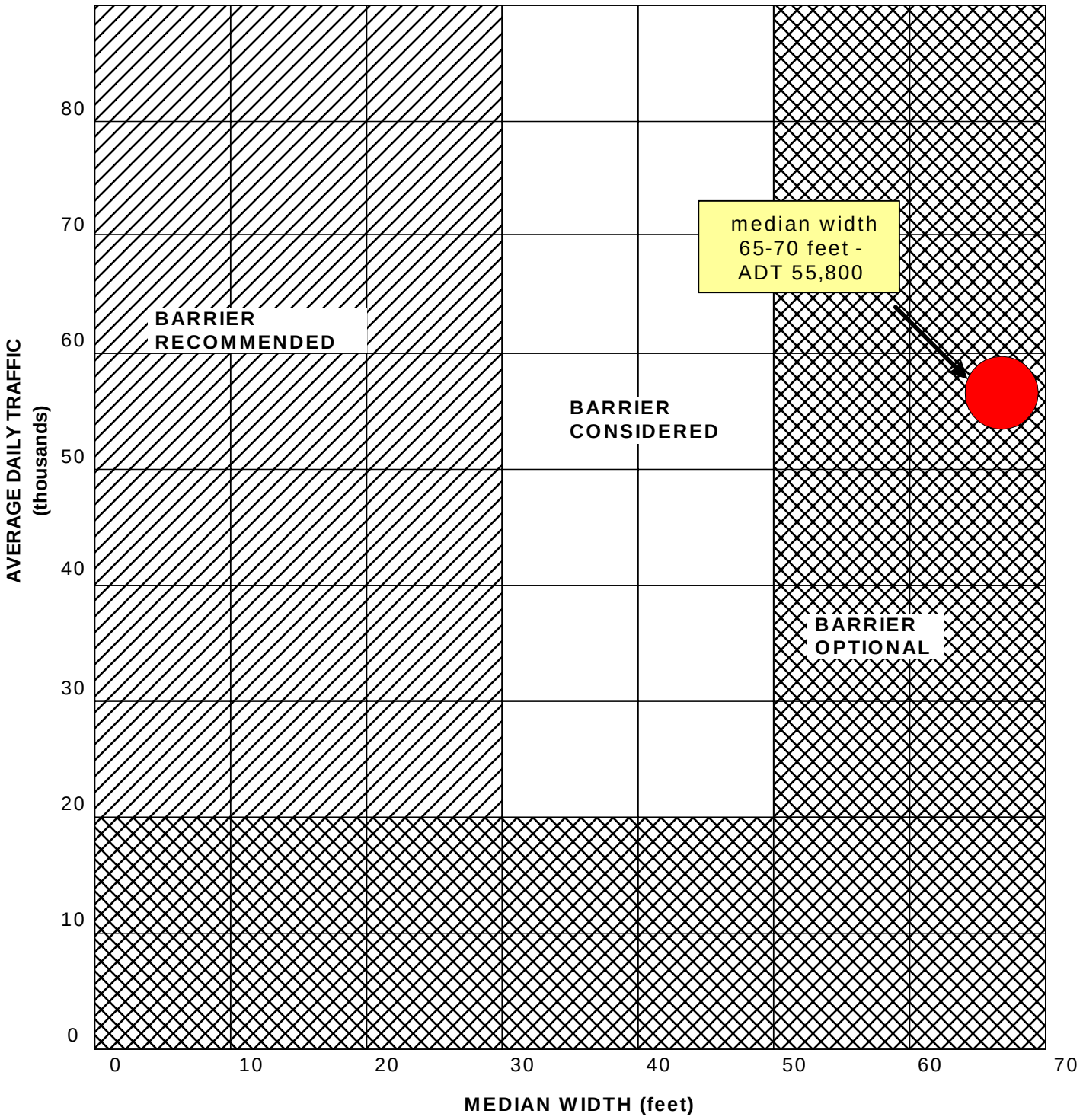
These items have been reviewed relative to the Route 2 section under study. Figure 9 presents a review of the corridor in relation to the median warrant criteria presented in the AASHTO RDG[4]. As can be seen in the diagram, with the median (as measured from edge line to edge line) is approximately 65-70 feet and a volume of over 55,000 vehicles on an average day, the intersection of the two items is in the area of the chart where a barrier can be "optional".

In addition to the analyzed AASHTO warrant criteria, which is a guideline, further consideration was given to the following:

- A small proportion (11%) of the median entries were cross-median crashes over the four (4) year crash period was experienced.
- While the majority of median related crashes have not involved crossing the median, a high proportion (37%) results in injuries.
- Travel speeds are high.
- Certain sections with horizontal curves, depending on the travel direction created some level of driver discomfort.

Consequently, based on the analysis of the data, the field audit and drive-thru and discussion of the conditions by the RSA team members, it was concluded that a median barrier should be considered in some locations along the study section but is not essential for the entire length. As will be discussed in the next section, however, there are a number of other actions recommended as part of this RSA.

[4] American Association of State Highway and Transportation Officials, Roadside Design Guide, Washington, D.C., 2002, Chapter 6 Update 2006.



Median Barrier Warrant Evaluation

Route 2 Road Safety Audit
Lexington, Massachusetts

MS Transportation Systems, Inc. **Framingham, Massachusetts**

FIGURE 9

A. Barrier Selection

Once a decision is made to install a barrier, the type must be determined. There are a number of barrier types that can be considered in addressing the median cross-over crashes. These include the following:

- Weak post W-Beam
- Box Beam
- Generic Low Tension Cable
- High Tension Cable Barrier
- Strong post W-Beam
- Thrie Beam
- Concrete (Jersey)

In deciding on the type of barrier, there are a number of criteria suggested in the AASHTO Roadside Design Guide[5]. These criteria used in selecting a barrier type are included in Table 6.

TABLE 6
CRITERIA FOR BARRIER SELECTION

Criteria	Comments
1. Performance Capability	Barrier must be structurally able to contain and redirect design vehicle.
2. Deflection	Expected deflection of barrier should not exceed available deflection distance.
3. Site Conditions	Slope approaching the barrier and distance from traveled way may preclude use of some barrier types.
4. Compatibility	Barrier must be compatible with planned end anchor and capable of transitioning to other barrier systems (such as bridge railings).
5. Cost	Standard barrier systems are relatively consistent in cost, but high-performance railings can cost significantly more.
6. Maintenance	
A. Routine	Few systems require a significant amount of routine maintenance.
B. Collision	Generally, flexible or semi-rigid systems require significantly more maintenance after a collision than rigid or high-performance railings.
C. Material Storage	The fewer different systems used, the fewer inventory items/storage space required.
D. Simplicity	Simpler designs, besides costing less, are more likely to be reconstructed properly by field personnel.
7. Aesthetics	Occasionally, barrier aesthetics are an important consideration in selection.
8. Field Experience	The performance and maintenance requirements of existing systems should be monitored to identify problems that could be lessened or eliminated by using a difference barrier type.

Source: AASHTO, Roadside Design Guide, 2002, Chapter 5 Roadside Barriers.

[5] American Association of State Highway and Transportation Officials, Roadside Design Guide, Washington, D.C., 2002, Chapter 6 Update 2006.

Based on extensive research and trials over the past five years, the high tension cable barrier system has become more prominent in the U.S. The cable (flexible) barrier has its advantages from a cost and aesthetic perspective, over the various guardrail systems or concrete barrier. The median slope and/or recovery area also affects the use and placement of any barrier including guardrail.

In addition to the cable barrier systems, the alternative types of guardrail were reviewed for potential application on this route. Considerations included the volume of traffic, relative amount of truck traffic and travel speeds. Based on these, the most applicable types of guardrail for this route include the W-beam with strong post or the strong post thrie-beam. These rails are appropriate for high speed highways and high volumes with a relatively high proportion of truck traffic. Costs for each are somewhat similar though the thrie-beam has a higher cost. The weak post W-beam and box beam can be eliminated due to the slope and type of highway. The concrete barrier would generally be applicable in urban sections with limited median widths available. As a result of this review, it was determined that the median barrier options that are most valid for consideration for Route 2 in this section are the cable barrier and strong post guard rail.

Maintenance issues are also an important consideration in decisions regarding median barrier installations. The maintenance issues that are of concern include:

- Barrier hits per mile
- Frequency of hits
- Cost recovery
- Cable downtime
- Repair effect on traffic
- Maintaining tension with cable system
- Mowing median

Final selection of the barrier type should be based on the costs, physical condition of the median, the ability to maintain a recovery zone, likely maintenance or repair requirements, and compatibility with future planned pavement widening. The key points of the cable barrier and guardrail systems are summarized below.

<u>Cable Barrier</u>

While the low tension generic cable system has been in existence for more than 50 years, most of the recent cable system research and installation is focused on the high tension systems. There are currently six (6) manufacturers with systems approved by

the Federal Highway Administration (FHWA) for use under certain conditions. Research on these types of barriers is ongoing. There are 3-rope or 4-rope cable systems as shown in the following two photographs.

3 Cable CASS System on Route 213

4 – Rope Brifen System on I-495

This barrier type can be installed on slopes of 6:1 or flatter with little constraint on placement. There are certain systems (eg. Brifen and Gibraltor 4 rope) that have been approved for slopes as steep as 4:1 as of this writing.

Guardrail

The guardrail could be placed in the median where slopes are 10:1 or flatter as well as at the edge of a steep slope or where minimal recovery zones exist. With the guardrail placed within several feet of the pavement edge, a clear zone (or recovery area) would be eliminated at least on one side of the median if guardrail is applied on only one side of the median. In some locations where the topography of the median is fairly flat, it may be possible to install a single line of double faced barrier a greater distance from the pavement edge in this specific project area.

Estimated per mile costs of the basic types of median barrier treatment to be considered for this route are summarized in Table 7. Shown in the table are estimated per mile costs of installing a cable barrier, a double faced W-beam guardrail and a double faced thrie-beam guardrail. As can be seen, the cable barrier is expected to be the lower cost option. The W-beam rail is a lower cost option compared to the thrie-beam, however, there is slightly greater deflection with the W-beam.

For comparison, installing a cable barrier system in the two sections totaling 4,000 feet on Route 2 would cost approximately $106,500. The thrie-beam guardrail would cost approximately $180,000.

TABLE 7
COMPARISON PER MILE COSTS
Cable vs. Guardrail

	Costs/Mile
Cable	$144,000
W-beam	$171,000
Thrie beam	$213,000

Recommendations

As a result of the RSA analysis and team input, it was concluded that a median barrier be installed at this time in certain locations in the study section. A set of recommendations have been identified and are summarized in Table 8. These actions are intended to eliminate the chance of cross-median crashes as well as reduce the number and severity of all crashes of this section of Route 2 in Lexington. Identified in the table in addition to the risk factor and recommended action are the estimated costs and potential timeframe (i.e. short (0-1 year), medium (1-3 years) and long (>3 years)).

TABLE 8
SUMMARY OF RECOMMENDATIONS

Risk Factor	Risk Rating	Recommended Action	Estimated Cost	Estimated Timeframe
Open median - perceived narrow and crossable to some extent	E	▪ Install barrier in specific locations within study section (see Figure 9)	$106,500	▪ short to medium term
Inside paved shoulder width is narrow	E	▪ Widen shoulder to minimum of 4 feet	TBD	▪ medium to long term or part of rehabilitation project
Rumble strips do not exist in shoulder	E	▪ Install new rumble strips inside shoulder	$13,000	▪ medium to long term requires shoulder widening
Median and travel lanes are not delineated with markers	D	▪ Install flexible, reflective delineator posts ▪ Install recessed markers in lanes	$6,000	▪ short term ▪ do as part of resurfacing
Surface condition including drainage, water ponding and hydroplaning is problem	E	▪ resurface using open graded asphalt	TBD	▪ medium term
Edge drop is significant in some locations	C	▪ correct cross slopes fill and regrade	TBD	▪ short term
Acceleration lanes appear short and short weave distance between Interchange Nos. 56 and 57 (eastbound)	B	▪ lengthen acceleration lanes ▪ Improve markings[1]	TBD	▪ short to medium term depending on if road widening is needed ▪ short term
Advance warning for exits and destinations less than ideal	B	▪ provide new, clear signs in new locations – particularly in eastbound direction	$10,000	▪ short term
Authorized Vehicles Only turnaround location just west of I-95 can create hazard	B	▪ modify turnaround – shift to east	TBD	▪ medium term
Queuing at I-95 interchange on-ramps combined with demands and weave section creates undesirable maneuvers	B	▪ monitor recent changes	TBD	▪ short term

TBD – to be determined

1 – examples of marking plans are included in Appendix and may be able to be incorporated as part of future marking maintenance operation.

In addressing the open median issues, the RSA team further examined the study section to identify the particular areas where it was felt a barrier would be a positive and effective action. The area near Mt. Tabor Road where the wide median section was transitioning to the "no-barrier" section of Route 2 into Lincoln and Concord was one location. The drive-thrus pointed to several areas where the combination of the horizontal alignment together with the elevation difference of the highway directions gave a sense that entering the median and potentially crossing it were more possible. These approximate locations are shown in Figure 10.

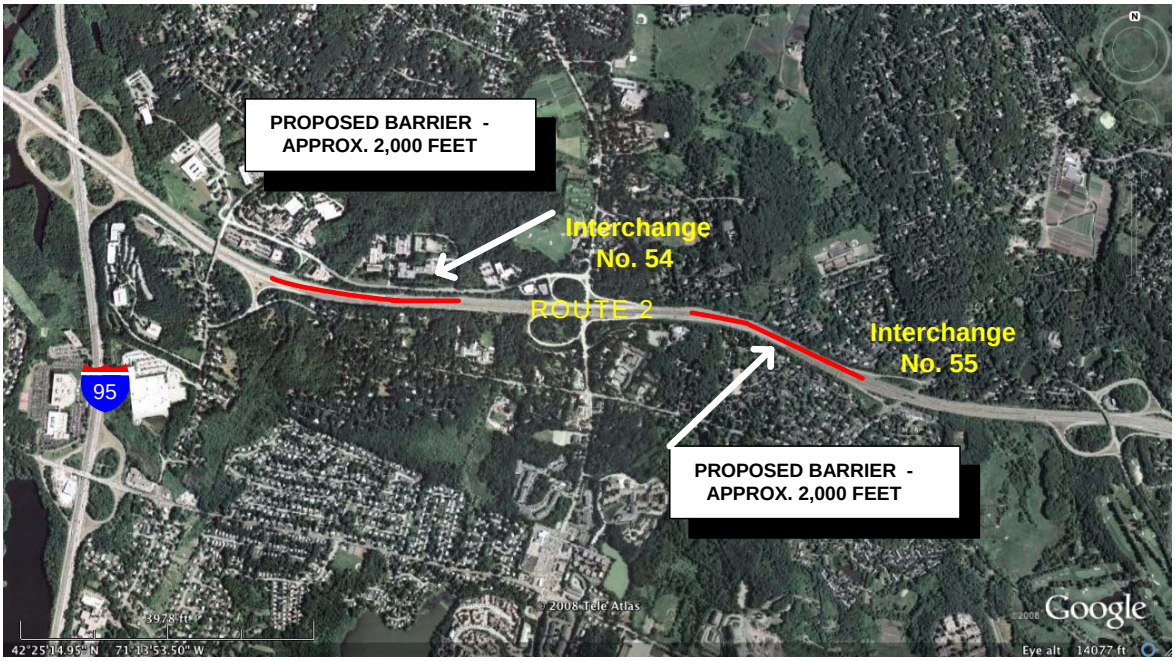


Figure 10 - Proposed Barrier Locations

Regardless of the barrier, it was recommended by the team that the median be highlighted to a much higher degree than at present. Two recommended actions to address this issue are 1) install flexible, reflective posts along both sides of the median, and 2) install a rumble strip in the inside shoulder. For the second action, the inside shoulder will need to be widened to a degree. A recommended action is to widen the inside shoulder to a minimum of 4 feet in width. The widening is proposed as a medium to long term item given its cost. The shoulder widening would be a lower incremental cost if done in conjunction with complete rehabilitation or resurfacing project. This width would effectively accommodate a rumble strip and provide some ability for the errant motorists to be alerted and recover prior to entering the median.

As stated previously, one of the more significant factors noted by the team was related to the pavement surface and the effect on drivers it has under wet conditions. Input by team members pointed to the age and type of pavement. According to the District personnel, the highway section is scheduled for a resurfacing project in the near future. It was recommended by the RSA team that the resurfacing utilize the open-graded asphalt which results in better drainage and maintains a higher skid resistance factor.

To address the factor related to the edge drop off, the specific areas need to be identified and then filled/regraded. It is expected to be a relatively low cost, maintenance action.

Traffic flow in the vicinity of the interchanges is affected by both markings and signage. The issue of "short" acceleration and deceleration lanes can potentially be addressed at least in part by enhanced markings employing dotted stripes. The current MUTCD depicts options with dotted lines for deceleration lanes and weave sections (see Appendix for diagrams). The upcoming revised MUTCD is expected to include dotted lines for acceleration lanes as well. This application applies to the weave section between Interchanges Nos. 56 and 57 in the eastbound direction. If the outside shoulder can be widened, in general, it may be possible to lengthen the acceleration lanes though that would tend to be a longer range project. Improved guide signs including placement are recommended. This is particularly important in the eastbound direction where the interchanges are closely spaced. An example would be a higher visibility sign for the park and ride facility and placed at least ½ miles prior to the exit.

The area near Mt. Tabor road needs attention as the median narrows in this area and the "Authorized Vehicles Only turnaround" exists just east of Mt. Tabor Road. With regard to the turnaround, it is recommended that it be shifted more to the east away from Mt. Tabor Road to establish greater separation and clearly identified in terms of its restricted use.

The driver speeds and lane changing behavior requires additional police presence. It is recommended that sufficient funding be provided to allow for this higher level of presence.

Appendix

- RSA Meeting Agenda
- RSA Attendees List
- Median Crash Diagram
- Crash Data
- Traffic Volume Data
- Speed vs. Volume Chart
- Sample of Lane Markings

Agenda

Road Safety Audit

Lexington – Route 2

Meeting Location: MassHighway District 4 Office
519 Appleton Street, Arlington
Thursday, August 28, 2008
1:30 PM – 3:00 PM

Type of meeting:	**Cross Median – Road Safety Audit**
Attendees:	**Invited Participants to Comprise a Multidisciplinary Team**
Please bring:	**Thoughts and Enthusiasm!!**
1:30 PM	**Welcome and Introductions**
1:45 PM	**Introduction to Road Safety Audits and Cross Median Crashes**
2:00 PM	**Review of Site Specific Material** • Crash, Speed & Volume Summaries– provided in advance • Existing Geometries and Conditions • Video and Images
2:30 PM	**Completion of RSA** • Identification of Safety Concerns – using RSA Prompt List as a guide • Identification of Possible Countermeasures
3:00 PM	**Adjourn for Lunch – but the RSA has not ended**

Instructions for Participants:

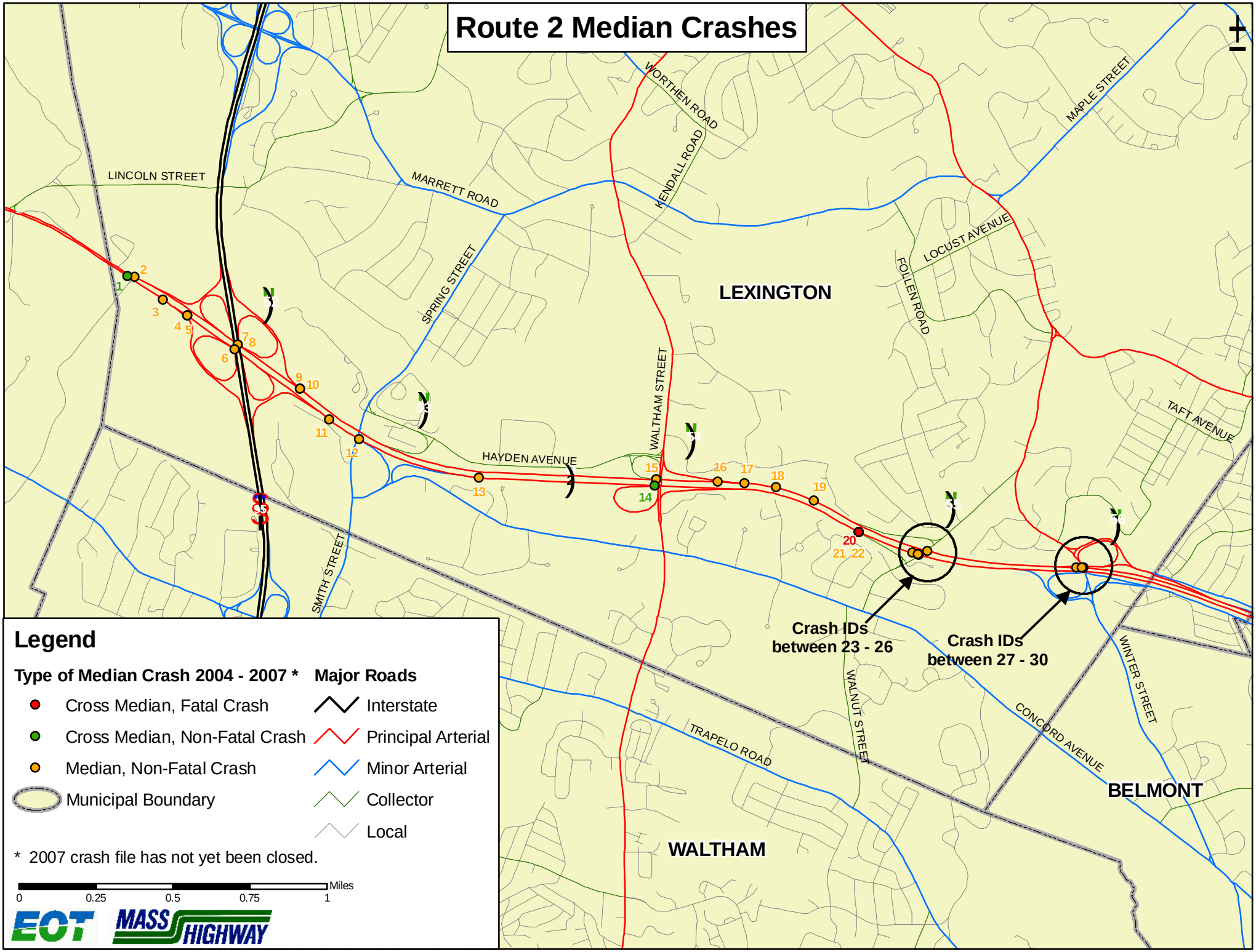
- **Before attending the RSA on August 28th participants are encouraged to drive Route 2 throughout Lexington and complete/consider elements on the RSA Prompt List with a focus on safety factors affecting cross median crashes.**
- **All participants will be actively involved in the process throughout. Participants are encouraged to come with thoughts and ideas, but are reminded that the synergy that develops and respect for others' opinions are key elements to the success of the overall RSA process.**
- **After the initial RSA meeting, participants will be asked to comment and respond to the document materials to assure it is reflective of the RSA completed by the multidisciplinary team.**

ROAD SAFETY AUDIT MEETING

Route 2 Lexington August 28, 2008
MassHighway District 4 Offices, Arlington MA

Attendance List

Name	**Agency/Dept.**	**Email**
Bill Scully	MS Transportation Systems, Inc.	bscullyjr@mac.com
Raj Kylen	MHD, District 4, Traffic	Raj.Kylen@mhd.state.ma.us
Jim Gallagher	MAPC	Jgallagher@mapc.org
Jim Alexander	MHD, District 4, Projects	Jim.Alexander@mhd.state.ma.us
Erica Grygorcewicz	MHD	Erica.Grygorcewicz@mhd.state.ma.us
Alex Normandin	MHD	Alex.Normandin@mhd.state.ma.us
Lisa Schletzbaum	MHD Safety Management Unit	Lisa.Schletzbaum@mhd.state.ma.us
Brett Loosian	MHD, District 4, Maintenance	Brett.Loosian@mhd.state.ma.us
James Baily	Mass State Police	James.Baily@pol.state.ma.us


Route 2 Median Crashes
LINCOLN STREET
MARRETT ROAD
WORTHEN ROAD
KENDALL ROAD
MAPLE STREET
SPRING STREET
LOCUST AVENUE
FOLLEN ROAD
LEXINGTON
WALTHAM STREET
TAFT AVENUE
HAYDEN AVENUE
SMITH STREET
TRAPELO ROAD
WALNUT STREET
CONCORD AVENUE
WINTER STREET
BELMONT
WALTHAM
Crash IDs between 23 - 26
Crash IDs between 27 - 30
Legend
Type of Median Crash 2004 - 2007 *
Cross Median, Fatal Crash
Cross Median, Non-Fatal Crash
Median, Non-Fatal Crash
Municipal Boundary
Major Roads
Interstate
Principal Arterial
Minor Arterial
Collector
Local
* 2007 crash file has not yet been closed.
0
0.25
0.5
0.75
1
Miles
EOT
MASS HIGHWAY

MASSACHUSETTS HIGHWAY SAFETY DIVISION

CRASH SUMMARY

ROADWAY: Route 2 **CITY:** Lexington

STUDY PERIOD: 1/1/2004 **TO** 6/4/2008 **LOCATION:** Mt. Tabor Rd

NO.	CRASH NUMBER	CRASH DATE	CRASH TIME	CRASH DAY	TRAVEL DIRECTION	LIGHT CONDITION	WEATHER CONDITION	ROAD SURFACE	REASON FOR RUNNING OFF ROAD LEFT	VEHICLE MOVEMENT	MEDIAN OR CROSS MEDIAN CRASHES	DRIVER CONTRIBUTING CAUSE	CRASH SEVERITY
1	1721597	3/7/2004	5:15 AM	Sunday	EB	Dawn	Clear	Dry	Driver drove into and across the median into the WB lanes and rolled over	EB right travel lane across median to WB left travel lane	Cross Median	Failure to stay in proper lane	Property Damage only
2	1761535	08/05/04	5:31 AM	Thursday	WB	Dawn	Rain	Wet	Vehicle ran through puddle of water, lost control stricking right guardrail, then spun across all WB lanes through median into EB traffic	Right travel lane across median to travel lane	Cross Median	Disregarded traffic signs, signals, road markings	Fatal Injury
3	1907104	01/26/05	11:20 AM	Wednesday	WB	Daylight	Snow	Slush	Driver lost control on snow covered road, struck another vehicle and ended up in center median	Center travel lane into median	Median	Driving too fast for conditions	Non-fatal injury
4	1913013	01/26/05	1:35 PM	Wednesday	WB	Daylight	Cloudy/Snow	Snow	Vehicle 1 lost control due to snow, sideswiped vehicle 2 and both vehicles skidded into the median strip	Center travel lane into median	Median	Swerving or avoiding due to conditions, traffic	Non-fatal injury
5	2001190	05/07/05	7:17 AM	Saturday	EB	Daylight	Rain	Wet	Vehicle was cut of and spun into left guardrail	Left travel lane into guardrail	Median	Disregarded traffic signs, signals, road markings	Property Damage only
6	2001266	05/31/05	5:30 AM	Wednesday	EB	Daylight	Clear	Dry	Driver choked on coffee and drifted into median striking the guardrail	Left travel lane into median and guardrail	Median	No improper driving	Non-fatal injury
7	2001363	07/13/05	2:54 AM	Wednesday	EB	Dark- lighted	Clear	Dry	Driver swerved to avoid deer, lost control and swerved into the median and then struck the guardrail	Left travel lane into median and guardrail	Median	Distracted	Non-fatal injury
8	2001535	09/04/05	12:10 PM	Sunday	WB	Daylight	Clear	Dry	Vehicle was cut off by another vehicle and spun into the median and rolled over	Center travel lane into median	Median	No improper driving	Property Damage only
9	2002435	10/25/05	10:09 AM	Tuesday	EB	Daylight	Rain/Severe crosswind	Wet	Vehicle traveling too fast and hydroplaned into the median and struck the guardrail	Left lane into median and guardrail	Median	Driving too fast for conditions	Property Damage only
10	2002445	10/29/05	4:35 PM	Saturday	WB	Daylight	Cloudy/snow	Snow	Vehicle went through built up snow, lost control, and spun into the median and struck a concrete barrier	Left travel lane into median	Median	Over-correcting/ over-steering	Non-fatal injury
11	1967930	12/04/05	7:52 AM	Sunday	WB	Daylight	Cloudy/Snow	Snow	Driver hit a slippery patch when trying to change lanes and spun across the median into EB lanes	WB middle lane across median to EB lanes	Cross Median	Driving too fast for conditions	Property Damage only
12	2002877	12/16/05	12:10 PM	Friday	WB	Daylight	Snow	Ice	Driver lost control of vehicle due to snow and it spun into the left guardrail	Left travel lane into left guardrail	Median	Driving too fast for conditions	Property Damage only
13	2013191	01/01/06	3:45 AM	Sunday	WB	Dark- lighted	Cloudy/Snow	Snow	Driver changed gears and lost control due to wet roads and spun into the left guardrail	Center travel lane into left guardrail	Median	Failure to stay in proper lane	Property Damage only
14	2050453	03/31/06	6:50 AM	Friday	WB	Daylight	Clear	Dry	Driver lost control of vehicle and spun into the median strip and rolled over in a ditch	Left travel lane into median ditch	Median	Failure to stay in proper lane	Non-fatal injury
15	2050459	04/05/06	11:20 AM	Wednesday	WB	Daylight	Snow	Snow	Driver was speeding and lost control of the vehicle due to snowy conditions and went into the median and rolled over	Left travel lane into median	Median	Exceeded authorized speed limit	Property Damage only
16	2050481	04/22/06	8:50 PM	Saturday	WB	Dark- not lighted	Rain	Wet	Vehicle merged into lane and cut off another vehicle and then swerved into the median guardrail	Center travel into median guardrail	Media	Failure to stay in proper lane	Non-fatal injury
17	2050521	05/05/06	2:36 AM	Friday	WB	Dark- not lighted	Clear	Dry	Driver swerved to miss something that ran in front of her and turned into the left guardrail	Left travel lane into left guardrail	Median	Failure to stay in proper lane	Property Damage only
18	2050601	05/21/06	11:03 AM	Sunday	EB	Daylight	Clear	Dry	Vehicle swerved to the left into the median due to possible mechanical failure and then rolled over and eventually hit EB guardrail	Left travel lane into median and guardrail	Median	No improper driving	Non-fatal injury
19	2059942	06/16/06	12:00 AM	Friday	WB	Dark-Not lighted	Clear	Dry	Vehicle tire blew out and vehicle swerved into the left guardrail and came to rest in the right shoulder	Left travel lane into guardrail	Median	Failure to stay in proper lane	Property Damage only
20	2114811	06/28/06	1:20 PM	Wednesday	EB	Daylight	Clear	Dry	Vehicle changed lanes and struck vehicle 2 which forced it into the left guardrail	Left travel lane into left guardrail	Median	Followed too closely	Property Damage only
21	2114902	07/12/06	1:15 PM	Wednesday	EB	Daylight	Rain	Wet	Vehicle rolled over into median strip	Left travel lane into median	Median	Failure to stay in proper lane	Property Damage only
22	2114920	07/18/06	5:15 PM	Tuesday	WB	Daylight	Clear	Dry	Unknown vehicle cut off vehicle one which spun into the median then swerved across all WB travel lanes	Left travel lane into median	Median	Over-correcting/ over-steering	Property Damage only
23	2093900	08/12/06	5:00 AM	Saturday	WB	Dawn	Clear	Dry	Driver swerved to avoid hitting small animal, lost control of vehicle, and swerved into the center median strip	Center travel lane into median	Median	Unknown	Property Damage only
24	2130074	11/03/06	1:40 AM	Friday	EB*	Dark-Not lighted	Cloudy	Dry	Driver traveling WB in EB lanes and crossed over the median to correct direction and crashed into the guardrail in the WB lanes	EB lanes, across median into WB left guardrail	Cross Median	Disregarded traffic signs, signals, road markings	Property Damage only
25	2130167	11/15/06	12:00 AM	Wednesday	EB	Dark-Not lighted	Cloudy	Dry	Driver veered to into the center median for unknown reason and struck guardrail	Left travel lane into median and guardrail	Median	Failure to stay in proper lane	Property Damage only
26	2148123	01/01/07	8:08 PM	Monday	EB	Dark- not lighted	Cloudy/Rain	Wet	Driver was attempting to witch from center into left lane and hydroplaned into left guardrail and came to rest in median	Center lane to guardrail and median	Median	No improper driving	Non-fatal injury
27	2155867	01/24/07	7:05 AM	Wednesday	EB	Daylight	Clear	Ice	Unknown vehicle cut off vehicle 1 which swerved to avoid it and lost control rolling over into center median strip	Center lane to median	Median	No improper driving	Non-fatal injury
28	2217948	01/31/07	9:11 PM	Wednesday	WB	Dark-Lighted	Clear	Dry	Unknown vehicle swerved into center lane causing vehicle to lose control and swerve into left guardrail	Center lane to left guardrail	Median	Not reported	Property Damage only
29	2217347	02/21/07	8:13 AM	Wednesday	WB	Daylight	Clear	Dry	Vehicle 1 swerved into left travel lane, hit vehicle 2 and continued into the median guardrail	Center lane into left guardrail	Median	Not reported	Property Damage only
30	2254353	03/11/07	10:47 AM	Sunday	EB	Daylight	Clear	Dry	Vehicle traveled into the center median and while trying to get back onto Rt. 2 hit guardrail and another vehicle	Left travel lane into median into guardrail to EB right shoulder	Median	Not reported	Non-fatal injury
31	2211782	05/30/07	7:15 AM	Wednesday	WB	Daylight	Clear	Dry	Tractor trailer merged onto Rt.2 and cut off vehicle 1 which swerved into the left guardrail/ cement barrier	Center lane into left guardrail	Median	Not reported	Property Damage only
32	2220321	06/13/07	6:10 AM	Wednesday	EB	Daylight	Clear	Dry	Vehicle was forced into median strip by other vehicle changing lanes	Left travel lane into median	Median	Not reported	Property Damage only
33	2258170	11/16/07	5:47 AM	Friday	EB	Dark-Not lighted	Not reported	Wet	Vehicle crossed median from EB lanes into WB lanes for unknown reason striking WB traffic	Left travel lane across median	Cross Median	Not reported	Non-fatal injury
34	2267116	01/11/08	8:45 AM	Friday	EB	Daylight	Rain	Wet	Vehicle hydroplaned and skidded into the left guardrail	Left travel lane into guardrail	Median	Not reported	Property Damage only
35	2310241	01/17/08	2:22 PM	Thursday	WB	Daylight	Clear	Dry	Driver looked at cell phone and then swerved off the road into the median	Left travel lane into median	Median	Not reported	Property Damage only
36	2327919	02/13/08	2:25 PM	Wednesday	EB	Daylight	Rain	Wet	Driver lost control of vehicle and crossed from right lane into left lane, hit guardrail and flipped over it into the median	Right travel lane to guardrail into median	Median	Not reported	Non-fatal injury
37	2323423	02/15/08	3:15 PM	Friday	EB	Daylight	Clear	Dry	Driver entered median for unknown reason and struck tree	Left travel lane into median	Median	Not reported	Property Damage only
38	2327949	02/27/08	10:27 PM	Wednesday	WB	Dark-Not lighted	Snow	Snow	Driver traveling too fast, lost control and struck left guardrail and stopped on top of it	Left travel lane onto guardrail	Median	Not reported	Non-fatal injury
39	2291254	03/04/08	9:40 PM	Tuesday	WB	Dark-Not lighted	Rain	Wet	Driver traveling too fast, lost control and entered median ditch	Middle travel lane into median ditch	Median	Not reported	Property Damage only
40	2321762	04/03/08	11:14 PM	Thursday	WB	Dark-Not lighted	Clear	Dry	Driver lost control entering the roadway and crossed all lanes and struck left guardrail	On-ramp to guardrail	Median	Not reported	Property Damage only
41	2308213	04/14/08	7:16 AM	Monday	WB	Daylight	Clear	Dry	Unknown vehicle cut-off vehicle in middle lane, driver swerved to avoid collision, lost control and hit left guardrail	Center travel lane into guardrail	Median	Not reported	Non-fatal injury
42	2316350	04/20/08	11:33 AM	Sunday	WB	Daylight	Clear	Dry	Unknown vehicle merged into middle lane forcing vehicle into left ravel lane; driver lost control entered the median and rolled over	Center travel lane into median	Median	Not reported	Non-fatal injury
43	2315736	04/29/08	11:46 AM	Tuesday	WB	Daylight	Rain	Wet	Driver hydroplaned and spun into the left guardrail	Left travel lane into guardrail	Median	Not reported	Property Damage only
44	2318284	05/03/08	2:20 PM	Saturday	WB	Daylight	Cloudy	Wet	Driver was entering Rt. 2 and lost control of vehicle and spun across all 3 lanes into median guardrail	On-ramp to guardrail	Median	Not reported	Property Damage only
45	2329961	06/04/08	4:50 PM	Wednesday	WB	Daylight	Rain	Wet	Driver was entering Rt. 2 and lost control of vehicle and spun across all 3 lanes into median guardrail	On-ramp to guardrail	Median	Not reported	Property Damage only

TOTAL NO.	LIGHT CONDITION				ROAD SURFACE			WEATHER CONDITIONS				
	DAYLIGHT	DAWN	DARK - NOT LIGHTED	DARK- LIGHTED	DRY	WET	SNOW, ICE, SLUSH	CLEAR	CLOUDY	RAIN	SNOW	NOT REPORTED
45	29	3	10	3	23	13	9	22	3	11	8	1
100%	64%	7%	22%	7%	51%	29%	20%	49%	7%	24%	18%	2%

TOTAL NO.	MEDIAN OR CROSS MEDIAN		CRASH SEVERITY		
	MEDIAN	CROSS MEDIAN	PROPERTY DAMAGE ONLY	NON-FATAL INJURY	FATAL INJURY
45	40	5	28	16	1
100%	89%	11%	62%	36%	2%

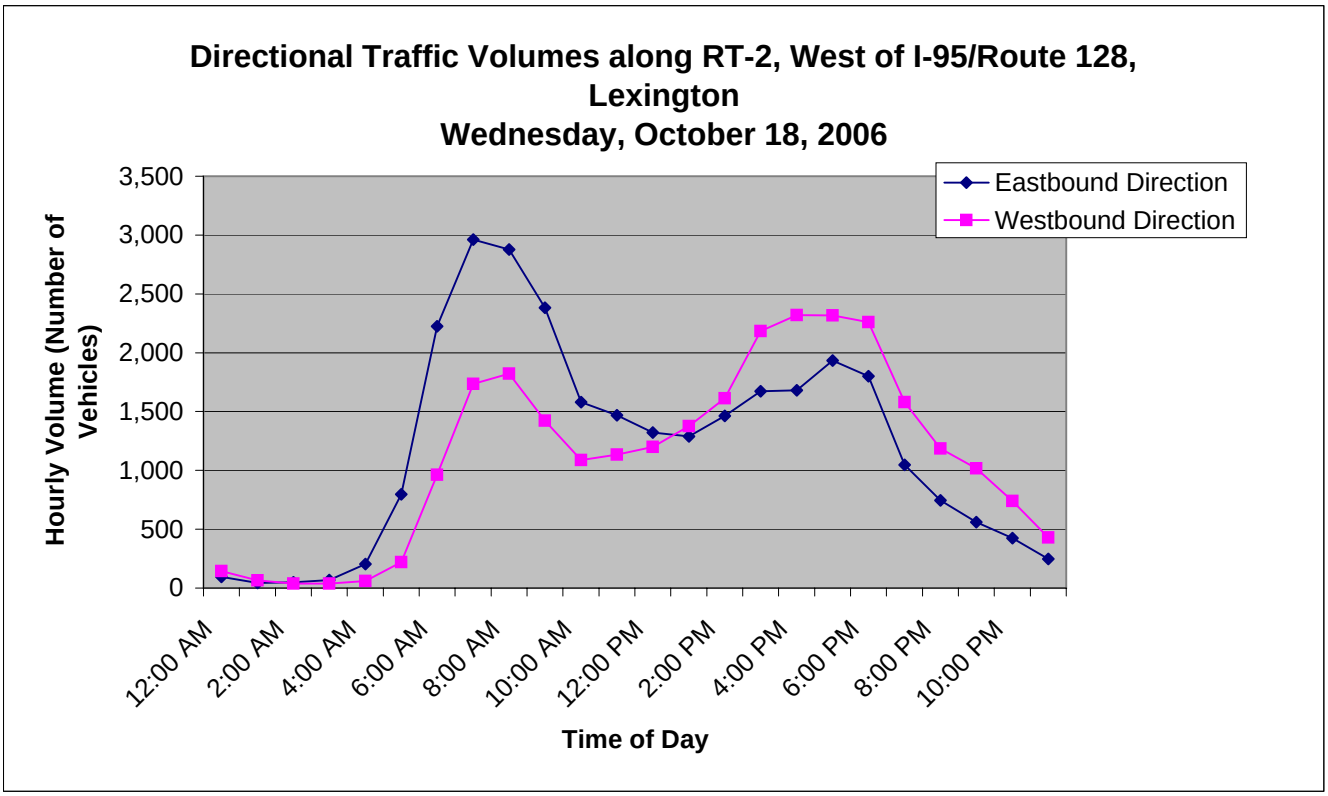
DRIVER CONTRIBUTING CAUSE

TOTAL NO.	DISTRACTED	NO IMPROPER DRIVING	EXCEEDED SPEED LIMIT	FOLLOWED TOO CLOSELY	OVER-CORRECTING/ OVER STEERING	FAILURE TO KEEP IN PROPER LANE	DRIVING TOO FAST FOR CONDITIONS	DISREGARDED TRAFFIC SIGNS, SIGNALS, ROAD MARKINGS	SWERVING OR AVOIDING DUE TO WEATHER CONDITIONS, ROAD SURFACE CONDITIONS, OR OTHER TRAFFIC	UNKNOWN	NOT REPORTED
45	1	5	1	1	2	8	4	3	1	1	18
100%	2%	11%	2%	2%	4%	18%	9%	7%	2%	2%	40%

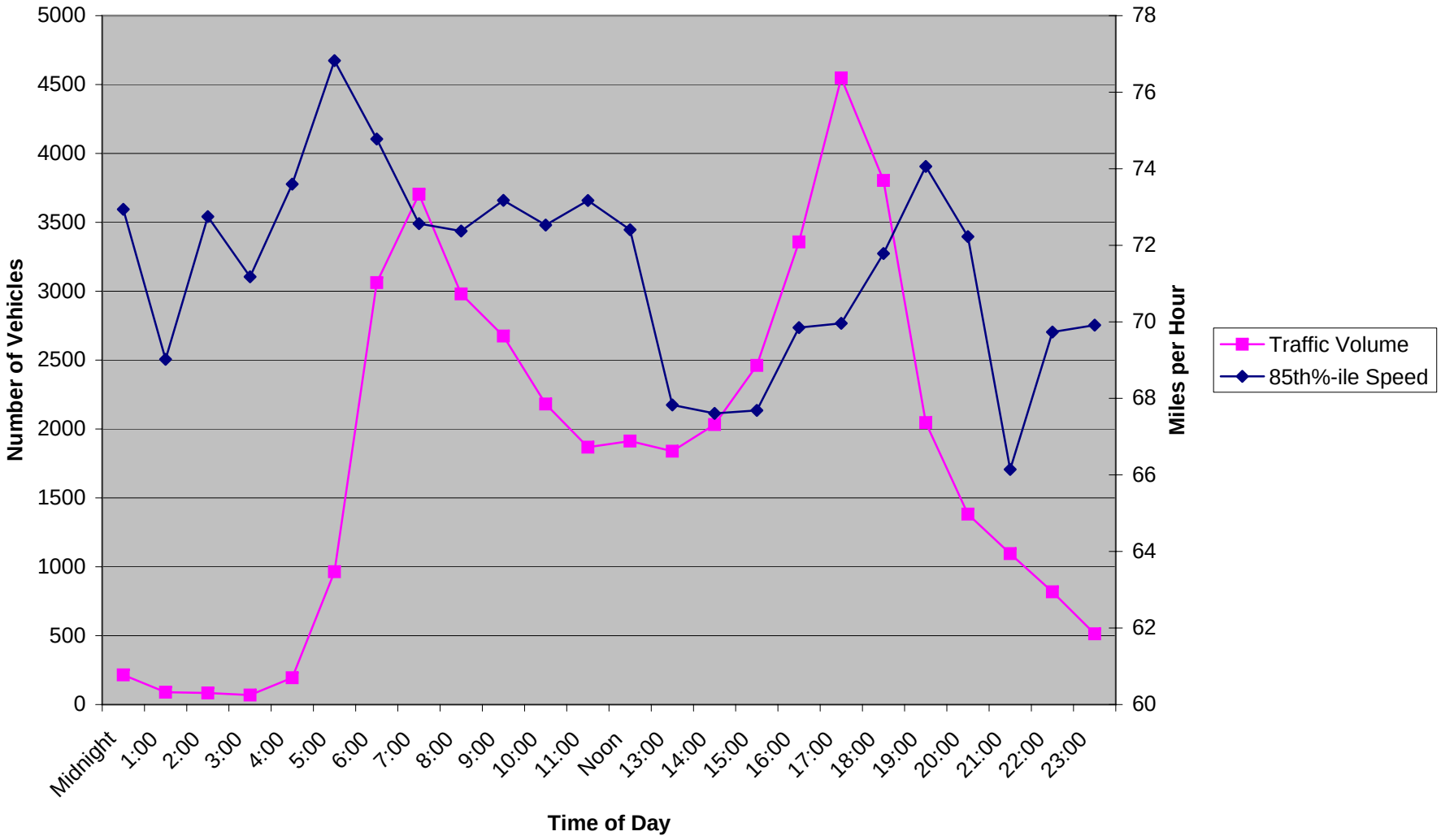
2007 CRASH INFORMATION IS NOT COMPLETE
CRASH SUMMARY IS BASED ON CRASH REPORTS WITH STATE POLICE NARRATIVES

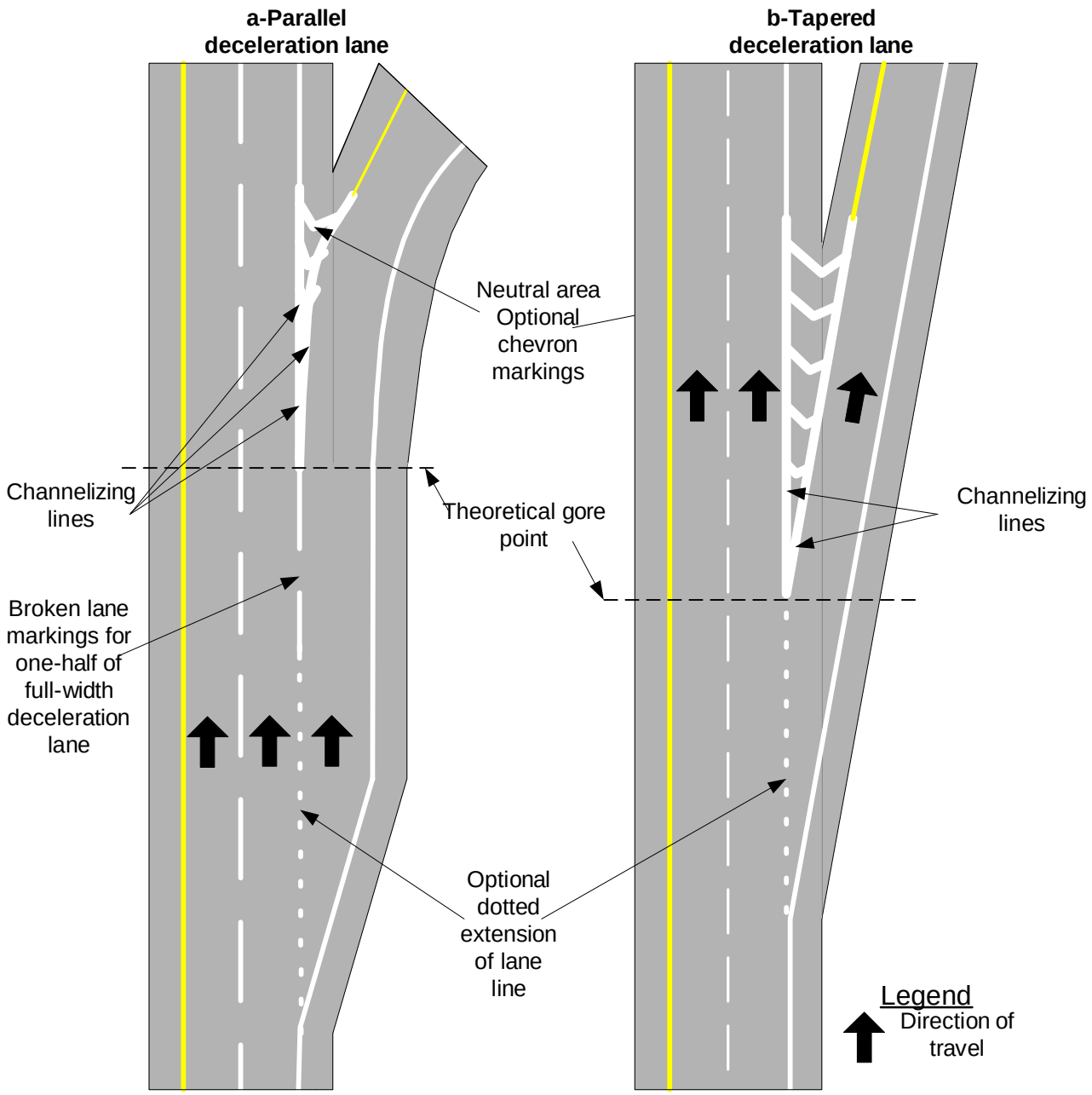
RT-2 West of I-95/RT-128, 10/18/2006

Start time	Eastbound Direction	Westbound Direction	TOTAL
12:00 AM	96	143	239
1:00 AM	44	66	110
2:00 AM	48	38	86
3:00 AM	67	38	105
4:00 AM	204	60	264
5:00 AM	797	220	1,017
6:00 AM	2,224	964	3,188
7:00 AM	2,961	1,735	4,696
8:00 AM	2,878	1,822	4,700
9:00 AM	2,381	1,421	3,802
10:00 AM	1,579	1,089	2,668
11:00 AM	1,468	1,133	2,601
12:00 PM	1,323	1,198	2,521
1:00 PM	1,289	1,375	2,664
2:00 PM	1,464	1,612	3,076
3:00 PM	1,672	2,183	3,855
4:00 PM	1,681	2,319	4,000
5:00 PM	1,933	2,318	4,251
6:00 PM	1,800	2,260	4,060
7:00 PM	1,047	1,579	2,626
8:00 PM	746	1,187	1,933
9:00 PM	559	1,016	1,575
10:00 PM	423	739	1,162
11:00 PM	247	429	676
Daily Total	28,931	26,944	55,875



Route 2 EB, Daily Traffic Volume and Speed
(Wednesday, July 18, 2007)



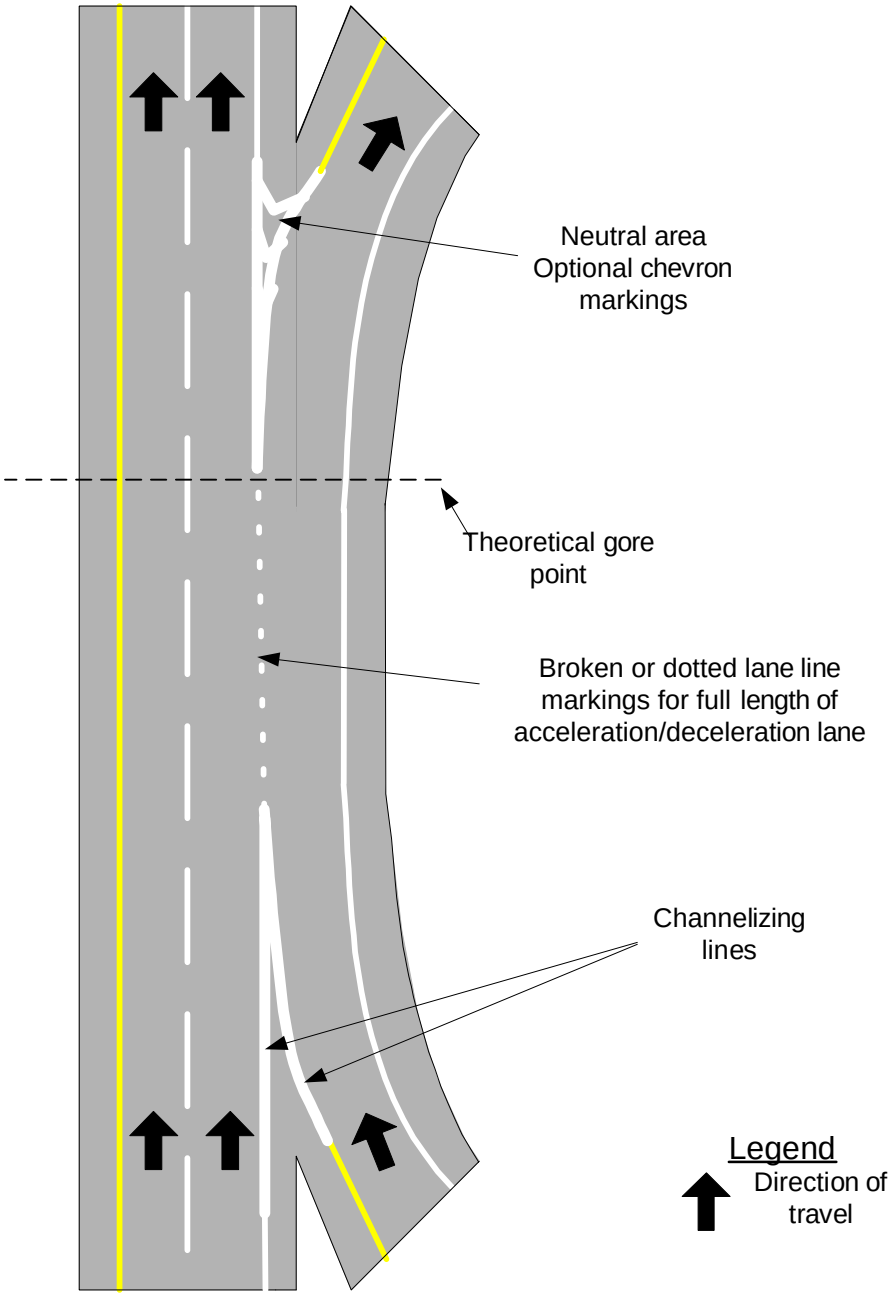


Source: MUTCD

Potential Pavement Markings - Off-Ramp Deceleration Lanes

NOT TO SCALE

MS Transportation Systems, Inc. Framingham, Massachusetts



Source: MUTCD

Example of Channelizing Line Applications for Entrance-Exit (Weave) Ramp Markings

NOT TO SCALE

MS Transportation Systems, Inc. **Framingham, Massachusetts**