MEMORANDUM

TO: Transportation Planning and Programming Committee — October 16, 2008

FROM: Robert Sievert

RE: Safety and Operational Improvements at Selected Intersections (SOISI) Study: Analysis and Recommendations

INTRODUCTION

This memorandum summarizes the analyses, findings, and recommended improvement concepts of the Safety and Operational Improvements at Selected Intersections study. The study was authorized and funded by the Boston Region Metropolitan Planning Organization (MPO).

BACKGROUND

To conduct a study such as this was one of the recommendations of the 2004 Congestion Management System (CMS) report, which identified intersections high in vehicle crashes in each of the Metropolitan Area Planning Council (MAPC) subregions.[1] This study's purpose was to evaluate up to 15 intersections in various parts of the region and to develop recommendations for improvements intended to enhance the safety of drivers, bicyclists, and pedestrians. Some of the selected intersections called for improvements requiring right-of-way acquisitions. Locations were not selected which were currently under study by CTPS or by others or were under design.

Initially, 30 intersections were identified by CTPS from a screening of one main source of data: intersections with high numbers of vehicle crashes, especially those involving bicycles or pedestrians, as shown in the Massachusetts Registry of Motor Vehicles (RMV) data from 1999 to 2001. Via telephone discussions with town officials, the 30 candidate intersections were screened to see whether they were still experiencing safety problems in 2007. For those that were not, other suitable candidates were substituted. (Although RMV crash data for 2002–2005 had become available, that database appeared to contain inaccuracies for many communities in the Boston region and therefore was not used in this study.)

From the original group of 30 intersections, CTPS selected 15 to recommend for detailed study, based on relevant criteria gleaned from the CMS and the Transportation Improvement Program (TIP). The criteria, which were consistent with MPO policies, generally fell under the following categories:

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[1] Central Transportation Planning Staff, *Mobility in the Boston Region: Existing Conditions and Next Steps: The 2004 Congestion Management System Report,* December 2004, Appendix B.

- Safety (the number and severity of crashes involving vehicles, bicycles, and pedestrians)
- Community (regional equity)

CTPS submitted the original 30 and the recommended 15 intersections to the MPO's Transportation Planning and Programming Committee for review. The Committee slightly modified the final list and selected the 15 intersections that are analyzed in this study.

OBJECTIVE AND STUDY PROCESS

This study sought to accomplish the following objective: to develop operational strategies for up to 15 intersections in the Boston Region MPO area that enhance vehicle, bicycle, and pedestrian safety, and, to the extent possible, improve overall traffic operations. The intersections selected for analysis in this study were diverse in terms of geographic location in and around the greater Boston region (see Figure 1). They also varied with respect to being signalized or unsignalized, three-legged or four-legged, and urban or suburban. See Table 1 for a summary of the 15 intersections selected and analyzed, including each location's crash data, level of service (LOS) results, and pedestrian and bicycle safety indices.

The study process consisted of the following steps:

Task 1 Define intersections and receive approval by the Planning and Programming Committee
Task 2 Perform field reconnaissance and collect data
Task 3 Evaluate and analyze the selected intersections
Task 4 Receive input from MassHighway District office staff and local officials
Task 5 Recommend Improvements
Task 6 Document all findings and recommendations

RESULTS

The analyses and recommendations for each of the intersections are presented in sections 1 through 15 of this memorandum. A preliminary version of the text on each intersection was sent for review to officials in the municipality where the intersection is located and also to the appropriate MassHighway district office. The responses received are reflected in the texts presented here. The actual written responses are provided in Appendix A.

The section on each intersection concludes with a summary of the course of action that is recommended. It is hoped that the recommendations will lead the communities to take steps to improve safety and operations at the intersections.

The 15 intersections, and the recommendations for each in summary form, are as follows:

1. BEVERLY: Rantoul Street (Route 1A) at Elliott Street (Route 62)
(page 9)

- The City of Beverly and its consultant should consider the seven improvement concepts analyzed in this study as part of its effort to reconstruct all of Rantoul Street (Route 1A).

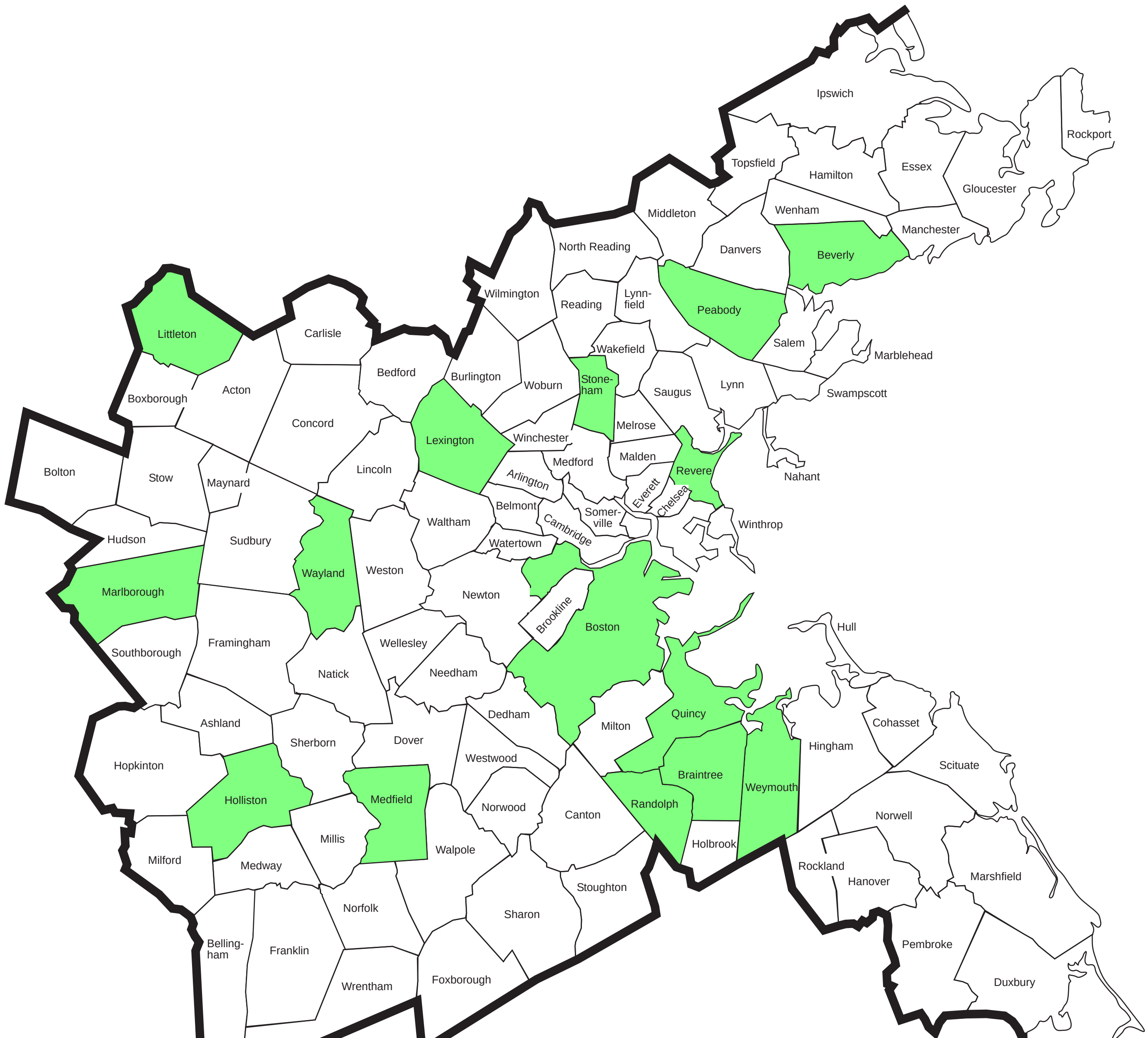

FIGURE 1
Cities and Towns of the Boston Region Metropolitan Planning Organization Area

Communities with intersections selected for study in the Safety and Operational Improvements at Selected Intersections study

2. BOSTON: Hyde Park Avenue at River Street (Cleary Square)
(page 18)

- The City of Boston should consider the three improvement concepts analyzed in this study as part of its effort to optimize traffic signal timing plans along Hyde Park Avenue between Forest Hills and Cleary Square.

3. BRAINTREE: Grove Street at Columbian Street
(page 28)

- Optimize signal timing; extend all-red phase from 1 to 2 seconds.
- Add a second YIELD sign at the Grove Street westbound right-turn lane.
- Relocate one of the Jamie’s Grille and Pub driveways away from the intersection.
- Add sidewalks in the intersection area when reconstruction occurs in the future.

4. HOLLISTON: Washington Street (Routes 16/126) at Hollis Street
(page 36)

- Consider the installation of a new traffic signal.
- Consider the installation of a modern roundabout.
- Construct bulbouts, medians, and/or islands to channelize the intersection area.
- Redesign and move church driveway further west on Hollis Street, away from intersection.
- Consider the addition of a bicycle lane on this portion of Washington Street through Holliston.
- Repaint faded crosswalks, lane markings.

5. LEXINGTON: Massachusetts Avenue (Routes 4/225) at Maple Street (Route 2A)
(page 45)

- Consider the installation of a new traffic signal
- Consider the installation of a modern roundabout.

6. LITTLETON: Great Road (Routes 2A/119) at King Street (Routes 2A/110)
(page 56)

- The Town of Littleton and MassHighway District 3, together with IBM and its consultant, should consider the three improvement concepts analyzed in this study as part of IBM’s traffic mitigation plan for this intersection and the roadways nearby.

7. MARLBOROUGH: Bolton Street (Route 85) at Union Street
(page 64)

- Switch the northbound lead phase to a southbound lead phase.
- Add an exclusive right-turn lane to Union Street westbound.
- Upgrade signs, markings, signal equipment, sidewalks, ADA ramps.

8. MEDFIELD: Main Street (Route 109) at North Meadows Road/ Spring Street (Route 27)
(page 73)

- Optimize the signal splits and cycle lengths.
- Consolidate the driveways in the northeastern quadrant of the intersection.

TABLE 1 (ReS, 080902, SOISI_15_Ints_Summary.xls)

Summary of Safety and Operational Data and Analysis

Crash data are for 1999-2001, from Mass. RMV

Community (MassHighway District No.)	Intersection	Existing Vehicle Crash Rate[1] (based on 2007 PM peak hour)	Average 2005 MassHighway District 3 or 4 Crash Rate[1]	Signalized (S) or Unsignalized (U)	Existing AM / PM Level of Service	Total Number of Crashes	Crash Result (no. of crashes): Property Damg.	Crash Result: Injury	Crash Result: Fatal	Crash Result: Hit & Run	Crash Result: Other	Crash Type (no. of crashes): Angle	Crash Type: Rear End	Crash Type: Head On	Crash Type: Other	Collision With (no. of crashes): Motor Veh. in Traffic	Collision With: Motor Veh. Parked	Collision With: Fixed Object	Collision With: Pedestrian	Collision With: Bicycle	Collision With: School Bus	Collision With: Other	Crosswalk Ped ISI[2]	Through Movement Bike ISI[3]
Beverly (4)	1. Rantoul Street (Route 1A) at Elliott Street (Route 62)	1.93	0.88	S	D / F	**45**	25	15	1	4	0	22	11	3	9	35	4	1	3	0	0	2	**1.9**	**2.6**
Crash data show that some angle crashes may be due to lane changing by vehicles trying to bypass left-turning vehicles, especially on the WB approach. Pedestrians do not use the functioning pedestrian buttons which exist on all 4 corners; rather, they cross the streets concurrently with traffic. Crosswalk markings have begun to fade.																								
Boston (4)	2. Hyde Park Avenue at River Street (Cleary Square)	1.85	0.88	S	F / F	**38**	22	13	0	3	0	20	9	1	8	27	5	1	1	0	0	4	**1.9**	**2.6**
There are conflicts between left-turning vehicles and through vehicles on all approaches. Pedestrians often cross concurrently with traffic, potentially conflicting with turning vehicles, even though an exclusive pedestrian signal phase exists with functioning pedestrian buttons. High proportion of buses and trucks in the vehicle mix.																								
Braintree (4)	3. Grove Street at Columbian Street	1.09	0.88	S	B / C	**39**	24	14	0	0	1	20	10	3	6	34	2	0	0	0	1	2	**2.7**	**3.7**
Pedestrian and bicycle facilities are nonexistent - no crosswalks, no sidewalks, no pedestrian phase/buttons, no bicycle lanes. Some sight distance problems exist. Congestion and delays are generally low.																								
Holliston (3)	4. Washington Street (Routes 16/126) at Hollis Street	1.47	0.79	U	F / C	**37**	22	15	0	0	0	18	10	0	9	30	1	2	0	1	0	3	**3.8**	**2.5**
The intersection is wide and pedestrian-unfriendly. There is no ped. signal, or traffic signal with a ped. phase to protect people wishing to cross by foot. The church driveway on the n. side of Hollis St just w. of the intersection appears to be a cause of rear-end crashes between exiting vehicles and vehicles turning from Washington St.																								
Lexington (4)	5. Massachusetts Ave (Routes 4/225) at Maple St (Route 2A)	2.87	0.63	U	E / F	**61**	43	17	0	0	1	25	31	0	5	54	0	0	0	1	1	5	**3.7**	**3.0**
Intersection has excessive open space. It is pedestrian- and bicyclist-unfriendly. This is one of just two study intersection where rear-end crashes were more numerous than angle crashes - most are on Maple St WB. Also, Maple St left turns conflict with SB through and left-turning vehicles. Sidewalks are uneven and cracked.																								
Littleton (3)	6. Great Road (Rts 2A/119) at King Street (Rts 2A/110)	2.25	0.84	S	D / C	**50**	29	18	0	3	0	35	7	1	7	37	8	1	1	0	0	3	**1.9**	**2.7**
Rear-end, congestion-related crashes were just 14%. The many angle crashes (70%) may be related to poor sight distance to/from Rt 119 EB/WB, and confusion from the lack of a WB left-turn arrow. This may cause conflicts between WB left-turning and EB through vehicles, the highest direction-related types of crashes in the RMV data.																								
Marlborough (3)	7. Bolton Street (Route 85) at Union Street	2.36	0.84	S	E / D	**58**	38	18	0	1	1	32	21	1	4	52	2	0	2	1	1	0	**1.9**	**3.5**
Angle and rear-end crashes were numerous. They were related to the SB direction, which has poor sight distance. SB vehicles were involved in 81% of angle crashes and 48% of rear-end crashes. Signal is only semi-actuated - the NB phase always leads, even if there are no NB left turns. This gives insufficient green time to SB vehicles.																								
Medfield (3)	8. Main Street (Route 109) at N. Meadows Road (Route 27)	1.82	0.84	S	F / F	**55**	35	17	0	3	0	28	13	1	13	44	3	2	0	0	0	6	**1.9**	**2.8**
Angle crashes predominate (51% of all crashes). Rt 109 EB and Rt 27 SB vehicles are involved in the most angle crashes. Rear-end crashes (24% of all crashes) include mostly Rt 109 EB and Rt 27 NB vehicles. Rt 27 NB through vehicles often get stuck behind WB left-turning vehicles, especially in the PM peak.																								
Peabody (4)	9. Central Street at Tremont Street	1.42	0.63	U	C / F	**39**	17	21	0	1	0	18	10	4	7	28	3	4	0	1	0	3	**3.6**	**2.3**
This is the study intersection with the highest percentage of injury-related crashes (54% of all crashes). Many near misses observed between Tremont St WB left-turning vehicles and Central St SB through vehicles. A very pedestrian- and bicyclist-unfriendly intersection.																								
Quincy (4)	10. Hancock Street (Route 3A) at E./W. Squantum Street	2.75	0.88	S	F / F	**86**	63	21	0	2	0	46	21	4	15	75	3	0	2	1	0	5	**2.7**	**2.9**
Congestion and many near-miss angle crashes observed. Good pedestrian facilities exist, but there are problems: excessive open space for pedestrians in the northeast area of the intersection; also, pedestrians cross between queued vehicles on W. Squantum St to reach the Red Line station, potentially conflicting with WB vehicles.																								
Randolph (4)	11. N. Main Street (Route 28) at Reed/Pond/Old Streets	1.12	0.88	S	F / F	**40**	20	20	0	0	0	12	15	3	10	33	0	3	3	0	0	1	**2.8**	**2.9**
Congestion-related crashes and rear-end crashes very much predominate. One of just two study intersections where rear-end crashes were more numerous than angle crashes. 60% of rear-end crashes were in the NB direction. Field work showed left-turning vehicles blocking through vehicles in both the NB and SB directions.																								
Revere (4)	12. Ocean Avenue at Shirley Avenue	4.14	0.88	S	B / C	**55**	32	23	0	0	0	38	6	1	10	40	7	3	2	0	0	3	**2.8**	**3.5**
Not much congestion; instead, crashes involved mostly left-turning and through vehicles. Poor sight distance NB and SB due to the intersection being on a crest. Some signal heads are old and small, not of the LED type. There were above-average numbers of injury-related crashes (compared to the other 14 study intersections).																								
Stoneham (4)	13. Main Street (Route 28) at William Street	1.69	0.88	S	C / C	**55**	38	15	0	2	0	32	11	1	11	49	0	0	3	0	0	3	**2.8**	**2.8**
This intersection has heavy pedestrian use, especially in the AM peak hour (a middle school is nearby). There is interference south of the intersection by left-turning vehicles exiting the Stop & Shop plaza in the PM, turning NB. There is no exclusive pedestrian signal phase. Many angle crash near misses observed (all directions).																								
Wayland (3)	14. Commonwealth Rd (Route 30) at Main St (Route 27)	2.59	0.84	S	F / F	**71**	51	17	0	3	0	32	29	2	8	64	4	1	1	0	0	1	**2.1**	**3.6**
Very congested intersection. Three approaches have just one official general-purpose lane, so left-turning vehicles often block same-direction through vehicles. Some gridlock was observed: WB vehicles blocking SB vehicles. Many near misses observed between left-turning vehicles and opposite-approach through vehicles.																								
Weymouth (4)	15. Pleasant Street at Pine Street/Tall Oaks Drive	0.88	0.63	U	F / F	**25**	17	8	0	0	0	13	6	0	6	20	1	3	0	0	0	1	**3.6**	**2.3**
52% of all crashes occurred 7 PM - 7 AM; i.e., a majority of crashes were darkness-related. Of these, 54% occurred during winter (Nov. - Mar.). Sight distance is somewhat compromised from NB and SB. 68% of crashes occurred at the Tall Oaks Dr intersection, 32% at the slightly offset (about 30 ft to the north) Pine St intersection.																								

[1]Crash rate = the number of crashes per million vehicles entering an intersection; based on 2007 PM peak hour volumes.

[2]Ped ISI = Pedestrian Intersection Safety Index. This safety index is calculated for the crosswalk on the intersection approach with the highest PM peak hour volumes. (Source: U.S. DOT, Federal Highway Administration, Pedestrian and Bicyclist Intersection Safety Indices, April 2007.)

[3]Bike ISI = Bicycle Intersection Safety Index. This safety index is calculated for the bicycle through movement on the main road in the peak direction during the PM peak hour. (Source: U.S. DOT, Federal Highway Administration, Pedestrian and Bicyclist Intersection Safety Indices, April 2007.)

(Note: A higher Ped/Bike ISI would call for a greater priority for an in-depth safety assessment (not done in this study); a lower Ped/Bike ISI, a lower priority for an in-depth safety assessment. For more information on footnotes 2 and 3, go to www.tfhrc.gov/safety/pedbike/pubs/06129/06129.pdf.)

9. PEABODY: Central Street at Tremont Street
(page 85)

- Add a new signal at Central Street at Tremont Street and coordinate it with the flashing beacon at Central Street at Warren Street, located just to the south.
- Enhance street lighting at and near the Central Street at Tremont Street intersection.

10. QUINCY: Hancock Street (Route 3A) at East/West Squantum Street
(page 94)

- Some widening of approach lanes and departure lanes may be required in order to improve overall safety as well as traffic operations.
- Expand the small island in the northeastern part of the intersection and add a pedestrian button in order to improve overall pedestrian safety.
- Make Hollis Avenue right-in, right-out only, during the AM and PM peak periods.
- Prohibit peak period entry/exit to/from the Knights of Columbus parking lot from/to Hollis Avenue in order to prevent cut-through traffic.

11. RANDOLPH: North Main Street (Route 28) at Reed/Pond/Old Streets
(page 108)

- Widen and restripe Pond Street (east of the intersection) to create a three-lane cross section: westbound, an exclusive left-turn lane and a through/right-turn lane; and eastbound, a one-lane departure lane (the current design).
- Consider the same cross section design on Reed Street (west of the intersection).
- Make the signal fully actuated.
- Add signs warning drivers “STATE LAW: STOP for pedestrians in crosswalk” on all approaches.
- Replace older signal heads with new LED types.

12. REVERE: Ocean Avenue at Shirley Avenue
(page 119)

- Improve signage warning drivers of “Medical Area,” “Pedestrian Crossings.”
- Add an LED signal south of intersection warning drivers of “(RED) Signal Ahead.”
- Consider reducing speed limit on Ocean Avenue near the intersection from 35 to 25 miles per hour.
- Only if necessary, implement a split signal phase to eliminate all conflicts between northbound and southbound vehiscles.

13. STONEHAM: Main Street (Route 28) at William Street
(page 126)

- Add a leading eastbound signal phase.
- Consider posting signs prohibiting vehicles from turning left from the two Stop and Shop driveways during the AM and PM peak periods—onto Main street northbound as well as onto William Street westbound.
- Add signs warning drivers “STATE LAW: STOP for pedestrians in crosswalk” on all approaches.
- Restripe all lane markings and crosswalks.

14. WAYLAND: Commonwealth Road (Route 30) at Main Street (Route 27)
(page 134)

- Change the current pretimed signal to a fully actuated signal, and optimize the signal splits and cycle length.
- An exclusive left-turn lane exists on the Route 27 northbound approach. Widen the other three approaches to create similar exclusive left-turn lanes there.
- Replace the old, tilting signal posts with new posts or mast arms.

15. WEYMOUTH: Pleasant Street at Pine Street/Tall Oaks Drive
(page 144)

- The installation of a new signal should be considered at this location.
- Enhance street lighting at and near this intersection.

1. BEVERLY: Rantoul Street (Route 1A) at Elliott Street (Route 62)

Existing Conditions

Geometry/Physical Characteristics

This is a signalized intersection of two state-numbered arterials, and is under local (City of Beverly) jurisdiction. Rantoul Street (Route 1A) has one general-purpose lane southbound, and one exclusive left-turn lane with one through/right-turn lane northbound. On each of the Elliott Street (Route 62) eastbound and westbound approaches there is an exclusive right-turn lane and a through/left-turn lane (see Figure 1-1). The posted speed limit on Rantoul Street is 25 miles per hour, and on Elliott Street it is 30 miles per hour. Field reconnaissance in May and August of 2007 showed that the crosswalks were visible, but the paint had begun to fade.

Traffic Control

This signal is pre-timed, with two phases: northbound/southbound and eastbound/westbound. Right turns on red are allowed on all four approaches. There is an exclusive pedestrian phase that lasts 17 seconds (when manually activated), which is sufficient time to cross each approach. There are functioning pedestrian buttons on all four corners. However, on the days of observation, numerous pedestrians were seen crossing through the intersection and none utilized the pedestrian buttons to activate the pedestrian phase. It is likely that the generally light right-turning traffic from all approaches (except for the eastbound right turns in the PM peak hour) encourages pedestrians to cross concurrently with vehicles during the green phase signal without having to wait for the exclusive pedestrian phase. Right turns on red (RTOR) are permitted on all approaches.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

2007 AM and PM Peak Hour Turning Movements (number of vehicles)

AM Peak Hour (8:00–9:00)											
Rantoul Street (Route 1A)						**Elliott Street (Route 62)**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
200	300	20	30	280	50	80	230	80	10	230	30
520 (total approach)			360 (total approach)			390 (total approach)			270 (total approach)		

- Rantoul Street, NB + SB approaches combined: 880 vehicles
- Elliott Street, EB + WB approaches combined: 660 vehicles
- Pedestrians (all approaches): 35
- Bicycles (all approaches): 8

CTPS

Safety and Operational Improvements at Selected Intersections

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FIGURE 1-1

Beverly: Rantoul Street (Route 1A) at Elliott Street (Route 62)

PM Peak Hour (4:45–5:45)											
Rantoul Street (Route 1A)						**Elliott Street (Route 62)**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
160	320	30	50	380	80	100	310	170	20	260	40
510 (total approach)			510 (total approach)			580 (total approach)			320 (total approach)		

- Rantoul Street, NB + SB approaches combined: 1,020 vehicles
- Elliott Street, EB + WB approaches combined: 900 vehicles
- Pedestrians (all approaches): 53
- Bicycles (all approaches): 5

The approach with the greatest AM peak hour volumes was Rantoul Street northbound, with 520 total vehicles, including 200 left turns. In the PM peak hour, the approach with the greatest volumes was Elliott Street eastbound, with 580 vehicles, including 170 right turns. The Elliott Street westbound approach had the lowest volumes during both the AM and PM peak hours.

Crashes

The vehicle crash rate for this location was 1.93 crashes per million vehicles entering the intersection. This is more than twice the most recent average crash rate of 0.88 for Mass-Highway District 4 area signalized intersections. Specific characteristics of the vehicle crashes include:

- 49% of crashes were angle. Examination of the RMV data revealed no dominant pattern for these crashes. Individual angle collisions involved combinations of vehicles from all approaches.

  Possible causes for angle crashes appeared to be vehicles from all approaches attempting to "beat the yellow light," since the bulk of the crashes involved conflicts between vehicles entering or exiting the intersection perpendicular to each other. Angle crashes also seemingly occurred when through vehicles tried to avoid left-turning vehicles in front of them by changing lanes, thereby side-swiping other vehicles heading in the same direction. This appears to have occurred in the westbound direction in particular, where the exclusive right-turn lane is relatively empty. Some through vehicles may have been tempted to use the right-turn lane as a through lane, thus side-swiping other vehicles as they both tried to enter the one departure lane west of the intersection.

- 24% of crashes were rear-end. This suggests one-fourth of all crashes occurred in congested, stop-and-go traffic. No definitive pattern was seen, since rear-end crashes occurred on all four approaches more or less evenly.

- 7% of crashes were head-on.

- 20% of crashes were other/undetermined.

Additionally:

- 7% of crashes (3 of 45) involved pedestrians. Of these:

    a. One resulted in a fatality; it occurred at 1 AM on a June night under dry road conditions.

    b. One occurred on a September night, also at 1 AM, under foggy and wet road conditions, and resulted in personal injury.

    c. One occurred at 4 PM on a July afternoon under clear and dry road conditions and also resulted in personal injury.

- 0% of crashes involved bicyclists.

- 33% of all crashes resulted in personal injuries.

- 60% of crashes occurred during April–October (spring, summer, fall); 40% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (4 of 45 crashes, or 9%, occurred during rain, snow, or fog).

- 69% of crashes occurred during daytime, 7 AM through 7 PM; 31% occurred during night-time, 7 PM through 7 AM. No predominant darkness-related crash patterns were seen.

Land Use

The surrounding land use is a mix of commercial, small offices, and single- and multiple-family homes. MBTA bus #451 stops at the intersection. The Beverly Shopper's Shuttle, financed by the City of Beverly and the MBTA but operated by CATA (Cape Ann Transportation Authority), also stops at this intersection.

Level of Service (LOS)

Intersection LOS analysis showed that the AM peak hour operated at LOS D, while the PM peak hour operated at LOS F. These measures are broken down further by lane group and total approach, as shown in the following tables.

2007 Intersection LOS Summary (Existing Conditions)

	AM Peak Hour			PM Peak Hour		
Scenario	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing*	D	41	31	F	* (115)	51

* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

2007 LOS by Lane Group, Total Approach (Existing Conditions)

AM Peak Hour (8:00–9:00)											
Rantoul Street (Route 1A)						**Elliott Street (Route 62)**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
F	C			C			D	A		C	A
E (total approach)			C (total approach)			C (total approach)			C (total approach)		
PM Peak Hour (4:45–5:45)											
Rantoul Street (Route 1A)						**Elliott Street (Route 62)**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
F	C			F			F	B		C	A
E (total approach)			F (total approach)			F (total approach)			C (total approach)		

This reveals that during the AM peak hour the northbound left turns experienced delay, operating at LOS F. In the PM peak hour, the northbound left turns, the southbound through vehicles, and the eastbound through vehicles all operated at LOS F. Queues ranged from 5 to 11 vehicles per approach per signal cycle during the AM peak hour, and from 5 to 19 vehicles per approach during the PM peak hour.

Conclusions/Significant Findings

- Pedestrians were not using the push buttons to activate the pedestrian phase. They appeared to feel safe crossing through the intersection concurrently with traffic. This may be due to the relatively low number of right-turning vehicles on some intersection approaches.

- Crosswalk markings were faded. Figure 1-1 above shows that in 2003 all the intersection crosswalks were painted green with white edges. Field observations in 2007 showed that only the crosswalk on the southbound approach is painted green with white edges; the remaining crosswalks consist of just two white lines.

- Some vehicles may be using the eastbound and westbound exclusive right-turn lanes to travel straight through the intersection, bypassing queued vehicles in the through/left-turn lanes. This may have resulted in angle crashes as vehicles from the two lanes on the same approach arrived at the one existing departure lane simultaneously.

- Overall, congestion was more severe in the PM peak hour than in the AM peak hour. However, the northbound left turns in both the AM and PM peak hours experienced delay, operating at LOS F. Southbound and eastbound through traffic also operated at LOS F during the PM peak hour.

Preliminary Conceptual Improvements

The following concepts for improving safety and traffic operations at this intersection were tested:

- Improvement Concept 1: Change the current pre-timed signal to actuated; optimize the signal timing. This was tested to determine whether a re-allocation of green time would reduce queueing and alleviate congestion on some approaches.

- Improvement Concept 2: Replace the exclusive pedestrian phase with a concurrent pedestrian phase. Most of the approaches at this intersection have relatively low left-turn volumes, and even lower right-turn volumes. The highest turning movement volumes were the northbound left turns during the AM and PM peak hours, 200 and 160 vehicles, respectively, and the eastbound right turns in the PM peak hour, 170 vehicles. "Crash data consistently show that crashes with pedestrians occur far more often with turning vehicles than with straight-through traffic. Left-turning vehicles are more often involved in pedestrian collisions than right-turning vehicles, partly because drivers are not clearly able to see pedestrians on the left."[2]

  With this in mind, the existing exclusive pedestrian phase stops traffic on all approaches while pedestrians are allowed to cross in any direction. Replacing the exclusive phase with a concurrent one would allow pedestrians to cross parallel with vehicles that have a green signal. Since field observations showed that the vast majority of pedestrians already cross the intersection concurrently, this improvement concept would give more green time to all vehicles moving through the intersection without unduly compromising pedestrian safety. In addition, as Table 1 above showed, this intersection yielded a Pedestrian Intersection Safety Index (Ped ISI) of 1.9—among the lowest of all the 15 study intersections. As Table 1 and the source below (footnote #3) describe, the higher the Ped ISI, the greater the "priority for an indepth safety assessment." With a relatively low Ped ISI of 1.9, this location appears to be one of the study intersections where further "indepth safety assessment" may not be quite as paramount as at some of the other intersections.[3]

  The following variations of Improvement Concept 2 were tested:

  a. Replace the exclusive pedestrian phase with a concurrent pedestrian phase.

  b. Replace the exclusive pedestrian phase with a concurrent pedestrian phase; however, implement a Leading Pedestrian Interval (LPI) on each signal phase by extending the all-red signal phase to 4 seconds. For the approach about to receive a green signal, the LPI "illuminates the pedestrian WALK signal, while the motor vehicle signal remains red for the first few seconds of the cycle. The LPI gives pedestrians an opportunity to start walking and establish a presence in the crosswalk before drivers can begin their turn."[4]

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[2] From U.S. Department of Transportation, Federal Highway Administration, *Intersection Safety Issue Briefs, No. 9, Pedestrian Safety at Intersections*, p. 2, April 2004.

[3] U.S. Department of Transportation, Federal Highway Administration, *Pedestrian and Bicyclist Intersection Safety Indices*, Publication No. FHWA–HRT–06–129, p. 1, April 2007; see www.tfhrc.gov/safety/pedbike/pubs/06129/06129.pdf

[4] See www.saferoutesinfo.org/guide/engineering/traffic_signals.cfm , *Reduce the Number of Motor Vehicle Movements that Conflict with Pedestrians*. For a case study, go to: www.walkinginfo.org/pedsafe/casestudy.cfm?CS_NUM=66

- Improvement Concept 3: Signal lead-lag combinations. The exclusive pedestrian phase would remain.

  The following variations of Improvement Concept 3 were tested:

  a. Lead with northbound green in phase one, then follow with northbound and southbound in phase two. Phase three gives green time to eastbound and westbound. The intent is to provide the relatively large number of northbound left turns with more green time. This variation may be more applicable to the AM peak period than the PM peak period.

  b. Lead with eastbound green in phase one, then follow with eastbound and westbound in phase two. Phase three gives green time to northbound and southbound. The intent is to provide the large number of eastbound volumes with more green time. This variation may be more applicable to the PM peak period than the AM peak period.

  c. Improvement Concepts 3a + 3b.

- Improvement Concept 4: Switch the two westbound approach lanes to one general-purpose lane. This would eliminate the potential for westbound angle crashes due to lane-shifting. The relatively low-volume westbound approach would be redesigned with a bulbout on the north side of Elliott Street. This would make the east side Elliott Street crosswalk shorter, and pedestrians would be less exposed to vehicular traffic. This could also create a few on-street parking spaces along the north side of Elliott Street, east of the intersection. The exclusive pedestrian phase would remain.

- Improvement Concept 5: Create two general-purpose lanes on the southbound approach. This would help southbound congestion directly, as well as congestion on the other approaches by re-allocating green times. Four southbound on-street parking spaces north of the intersection would need to be removed; however, there is sufficient off-street parking at this location (CVS plaza). There appears to be sufficient room for two departure lanes south of the intersection, at least for the first 200 feet, approximately, where on-street parking is prohibited. The exclusive pedestrian phase would remain.

- Improvement Concept 6: Create two general-purpose lanes on the eastbound approach. This would help eastbound congestion directly, as well as congestion on the other approaches by re-allocating green times. Four eastbound on-street parking spaces, east of the intersection, would need to be removed; however, there is sufficient off-street parking at this location (Walgreens plaza). The exclusive pedestrian phase would remain.

- Improvement Concept 7: Improvement Concepts 1 + 4 + 5 + 6. This concept evaluates the total effects of lane re-allocation. The exclusive pedestrian phase would remain.

The intersection level of service for each of the concepts described above is shown in the table on the next page.

Intersection LOS Summary: Existing Conditions and Improvement Concepts 1–7 Tested (2007 Traffic Volumes)

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing* (87 secs. cy. le.)	D	41	31	F	* (115)	51
Imp. Concept 1 *Optimize timings, change from pre-timed to actuated* (AM: 90 secs. PM: 120 secs.)	C	29	52	D	52	106
Imp. Concept 2a *Concurrent pedestrian phase* (70 secs. cy. le.)	B	18	25	C	23	43
Imp. Concept 2b *Concurrent ped. phase + LPI* (AM: 70 secs. PM: 75 secs.)	C	22	32	D	35	52
Imp. Concept 3a *NB lead phase* (AM: 85 secs. PM: 120 secs.)	C	32	48	E	56	98
Imp. Concept 3b *EB lead phase* (AM: 90 secs. PM: 120 secs.)	C	29	54	D	54	101
Imp. Concept 3c *NB and EB lead phases* (AM: 90 secs. PM: 120 secs.)	C	33	51	E	61	102
Imp. Concept 4 *WB lane changes* (AM: 90 secs. PM: 120 secs.)	C	30	48	D	48	91
Imp. Concept 5 *SB lane changes* (AM: 90 secs. PM: 100 secs.)	C	27	50	C	33	72
Imp. Concept 6 *EB lane changes* (90 secs. cy. le.)	C	22	23	C	33	60
Imp. Concept 7 *WB+SB+EB lane changes* (90 secs. cy. le.)	C	24	34	C	27	50

cy. le. = cycle length
* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

Discussion and Recommendations

Staff sought input from Beverly officials and MassHighway District 4 staff with respect to the conceptual improvements analyzed. The comments received are shown in Appendix A-1.

In implementing improvements at Rantoul Street at Elliott Street the City will have to weigh in on tradeoffs between operational efficiency at the intersection (delays and queues), on-street parking, and safety, especially for pedestrians. The paragraphs below discuss some of these tradeoffs.

Improvement Concept 1 impacts parking and pedestrian safety the least by simply replacing the existing traffic signal with a vehicle-actuated one, optimizing the existing signal timing, and maintaining the existing exclusive pedestrian phase. This improvement alone is expected to bring the intersection level of service to acceptable levels and reduce delays by 30% in the AM peak hour; likely even more in the PM peak hour. The remaining concepts improve operational efficiency and general safety over existing conditions by various degrees, depending on the strategy applied: re-allocation of travel lanes to traffic, replacing the exclusive pedestrian phase with a concurrent one, or reducing on-street parking spaces to accommodate extra lanes.

Improvement Concept 2a yields the best level of service of all concepts by optimizing the signal phases and by allowing pedestrians to move concurrently with traffic. Improvement Concept 2b also allows pedestrians to move concurrently with traffic, but provides additional pedestrian protection through an increased all-red phase. At present, pedestrians crossing at this location do not seem to use the pedestrian button to activate the exclusive pedestrian phase. This indicates a level of confidence and comfort among pedestrians crossing the road concurrently with traffic.

Improvement Concepts 3a, 3b, and 3c explore the potential of reducing angle collisions by implementing various combinations of lead-lag signal phases. In most cases, the resulting level of service is improved over existing conditions, and is within an acceptable range.

Improvement Concepts 4, 5, 6, and 7 explore lane re-allocations and introduce additional lanes by removing parking, all of these concepts yielding delay reductions on the order of at least 50%.

In closing, Improvement Concept 1 would be the least costly to implement in terms of compromising parking or pedestrian safety. If implemented, it would be about as effective during the AM peak hour as would some of the other options; it would be somewhat less effective during the PM peak hour. To implement features from the remaining improvement concepts, public opinion in Beverly would have to weigh in. In fact, this is what the City is about to embark on. City officials have hired a consultant to design the reconstruction of Rantoul Street (Route 1A) through Beverly (reconstruction/resignalization project #600220), including the intersection under analysis here. The consultant and the City will consider the results of the present analysis to reach a recommended design for this location.

2. BOSTON: Hyde Park Avenue at River Street (Cleary Square)

Existing Conditions

Geometry/Physical Characteristics

This is a signalized intersection, and is under local (City of Boston) jurisdiction. Hyde Park Avenue has one general-purpose lane and one exclusive left-turn lane both northbound and southbound. River Street is marked as one general-purpose lane eastbound and westbound. However, River Street eastbound operates as one narrow exclusive left-turn lane and one through/right-turn lane since on-street parking is prohibited in the eastbound direction (see Figure 2-1). The posted speed limit on the Hyde Park Avenue northbound approach is 20 miles per hour. There were no visible speed limit signs near the intersection southbound or on River Street. Field reconnaissance in May, September, and November of 2007 showed that the crosswalks and lane markings were visible and clearly marked.

Traffic Control

This signal is fully actuated, and has five distinct phases: (1) leading northbound, (2) northbound/ southbound, (3) leading eastbound, (4) eastbound/westbound, and (5) an exclusive pedestrian phase that lasts 22 seconds (when manually activated), which is sufficient time to cross through the intersection. There are functioning pedestrian buttons on all four corners. However, on the days of observation, numerous pedestrians were seen crossing through the intersection and only about half utilized the buttons to activate the pedestrian phase. Right turns on red (RTOR) are allowed on all four approaches. The current cycle length is 110 seconds for both the AM and PM peak hours.

In addition, this signal is coordinated with the Gordon Avenue/River Street signal just 350 feet to the west (see Figure 2-2). There has been no analysis of that signal, or of the coordination between the two, in this study due to limited resources. Any eventual changes to the signal timing at Hyde Park Avenue at Gordon Avenue would therefore need to include that of Gordon Avenue at River Street as well.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

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FIGURE 2-1

Boston: Hyde Park Avenue at River Street (Cleary Square)

CTPS

Safety and Operational Improvements at Selected Intersections

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FIGURE 2-2

Cleary Square Neighborhood

2007 AM and PM Peak Hour Turning Movements (number of vehicles)

AM Peak Hour (7:15–8:15)											
Hyde Park Avenue						River Street					
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
140	280	60	20	220	130	270	270	130	30	290	50
480 (total approach)			370 (total approach)			670 (total approach)			370 (total approach)		

- Hyde Park Avenue, NB + SB approaches combined: 850 vehicles
- River Street, EB + WB approaches combined: 1,040 vehicles
- Pedestrians (all approaches): 124
- Bicycles (all approaches): 3

PM Peak Hour (5:00–6:00)											
Hyde Park Avenue						River Street					
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
100	210	50	40	230	130	180	390	130	20	170	40
360 (total approach)			400 (total approach)			700 (total approach)			230 (total approach)		

- Hyde Park Avenue, NB + SB approaches combined: 760 vehicles
- River Street, EB + WB approaches combined: 930 vehicles
- Pedestrians (all approaches): 223
- Bicycles (all approaches): 19

The approach with the greatest AM peak hour volumes was River Street eastbound, 670 total vehicles, including 270 left turns. In the PM peak hour, the approach with the greatest volumes was again River Street eastbound, 700 vehicles, including 180 left turns. The River Street westbound approach had the lowest volumes during both the AM and PM peak hours, 370 and 230 vehicles, respectively.

Crashes

The vehicle crash rate for this location was 1.85 crashes per million vehicles entering the intersection. This is more than twice the most recent average crash rate of 0.88 for Mass-Highway District 4 area signalized intersections. Specific characteristics of the vehicle crashes include:

- 53% of crashes were angle. Examination of the RMV data revealed one dominant pattern: 59% of all crashes identified as angle involved southbound vehicles. These typically were crashes between southbound vehicles and vehicles traveling eastbound or westbound on River Street, as well as crashes with other vehicles traveling southbound—possibly when changing lanes.

- 24% of crashes were rear-end. This suggests that one-fourth of all crashes occurred in congested, stop-and-go traffic. No definitive pattern was seen, since rear-end crashes occurred on all four approaches more or less evenly.

- 3% of crashes were head-on.

- 21% of crashes were other/undetermined.

Additionally:

- 3% of crashes (1 of 38) involved pedestrians. This one crash occurred at 6 PM on a September evening under clear and dry road conditions and resulted in personal injury.

- 0% of crashes involved bicyclists.

- 34% of all crashes resulted in personal injuries.

- 53% of crashes occurred during April–October (spring, summer, fall); 47% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (4 of 38 crashes, or 11%, occurred during rain, snow, or fog).

- 71% of crashes occurred during daytime, 7 AM through 7 PM; 29% occurred during night-time, 7 PM through 7 AM. No predominant darkness-related crash patterns were seen.

Land Use

The surrounding land use is a mix of commercial, small offices, food establishments, governmental (police, post office), and some homes. The Hyde Park commuter rail station is located 250 feet west of the southwest corner, and MBTA buses #32, #33, and #50 stop at the intersection. Therefore, many pedestrians cross through the intersection during both the AM and PM peak periods, and throughout the day (see Figure 2-2).

Level of Service (LOS)

Intersection LOS analysis showed that both the AM and PM peak hours operated at LOS F. These measures are broken down further by lane group and total approach, as shown in the following tables.

2007 Intersection LOS Summary (Existing Conditions)

	AM Peak Hour			PM Peak Hour		
Existing Conditions	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing*	F	* (195)	70	F	* (186)	61

* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

2007 LOS by Lane Group, Total Approach (Existing Conditions)

AM Peak Hour (7:15–8:15)											
Hyde Park Avenue						**River Street**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
F	D		C	F		F	D			F	
F (total approach)			F (total approach)			F (total approach)			F (total approach)		
PM Peak Hour (5:00–6:00)											
Hyde Park Avenue						**River Street**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
F	C		C	E		D	F			F	
F (total approach)			E (total approach)			E (total approach)			F (total approach)		

This reveals that nearly all approaches operated at LOS F during both the AM and PM peak hours. The only exceptions were Hyde Park Avenue southbound and River Street eastbound in the PM peak hour, which both operated at LOS E.

Conclusions/Significant Findings

- Congestion was significant during both the AM and PM peak hours. Vehicle conflicts were observed between turning and through vehicles in all directions and on all approaches.

  The Hyde Park Avenue northbound and River Street eastbound and westbound approaches were particularly congested during the AM and PM peak periods. The three approaches each experienced around 20 queued vehicles per lane during each signal cycle in the AM peak hour, and 10 to 20 queued vehicles per lane during each PM peak hour signal cycle. Traffic operations were also impacted by the large number of MBTA buses stopping at or near the intersection—22 during the AM peak hour and 20 during the PM peak hour.

  A high proportion of heavy vehicles passed through the intersection. This is explained not only by the many MBTA buses but also by the high number of school buses as well as trucks destined for automotive, food distribution, and industrial locations in the surrounding neighborhood and beyond.

- Pedestrians used the push buttons to activate the exclusive pedestrian phase only about 50% of the time. They apparently feel safe crossing through the intersection concurrently with traffic. This may be due to the relatively low number of concurrent right-turn vehicle volumes on some intersection approaches, or impatience on the part of some pedestrians not wishing to wait for the exclusive pedestrian phase.

Preliminary Conceptual Improvements

The following concepts for improving safety and traffic operations at this intersection were tested. LOS results are described in the table and discussion following the conceptual improvement descriptions.

- Improvement Concept 1: Optimize the current signal timing. This was tested to determine whether a re-allocation of green time would reduce queueing and alleviate congestion on some approaches.

  Improvement Concept 1 yielded a cycle length of 150 seconds for the AM peak hour, and 140 seconds for the PM peak hour, when optimizing the signal timings and cycle lengths. These are relatively long cycle lengths and would likely result in longer vehicle queues than under the current 110 second cycle length. In order to reduce the anticipated queue lengths, therefore, the current cycle length of 110 seconds was used when optimizing the signal timings for the AM and PM peak hours. The different cycle lengths analyzed were summarized as Improvement Concepts 1a (optimized at 150 seconds, AM; 140 seconds, PM) and 1b (using the current cycle length for both the AM and PM, 110 seconds).

- Improvement Concept 2: Replace the exclusive pedestrian phase with a concurrent pedestrian phase. The existing exclusive pedestrian phase, 22 seconds long, stops traffic on all approaches while pedestrians are allowed to cross in any direction. Replacing the exclusive phase with a concurrent one would allow pedestrians to cross parallel with vehicles that have a green signal. Since field observations showed that about half of the pedestrians already cross the intersection concurrently, this concept would give more green time to all vehicles moving through the intersection without unduly compromising pedestrian safety.

  The following variations of Improvement Concept 2 were tested:

  a. Replace the exclusive pedestrian phase with a concurrent pedestrian phase (Improvement Concept 2a). This improvement was optimized to a 110 second cycle length for the AM peak hour, and an 80 second cycle length for the PM peak hour.

  b. Replace the exclusive pedestrian phase with a concurrent pedestrian phase; however, implement a Leading Pedestrian Interval (LPI) by extending the all-red signal phase to four or more seconds (Improvement Concept 2b). For the approach about to receive a green signal, the LPI "illuminates the pedestrian WALK signal, while the motor vehicle signal remains red for the first few seconds of the cycle. The LPI gives pedestrians an opportunity to start walking and establish a presence in the crosswalk before drivers can begin their turn."[5] This improvement concept was analyzed with an LPI of 4 seconds for the all-red phase, and was optimized to a 110 second cycle length for the AM peak hour, and a 90 second cycle length for the PM peak hour.

- Improvement Concept 3: Prohibit some on-street parking during the peak periods. In order to process more vehicles through the intersection during congested AM and PM peak periods, one potential improvement could involve prohibiting on-street parking near the intersection. The prohibition could be applicable, for example, 6:30–9:30 AM and 4:00–6:30 PM, weekdays only, but would require consistent enforcement to be effective. A total of about 20 parking spaces would be unusable during these times. The affected spaces would be:

  Northbound: 5 spaces, north of the intersection
  Southbound: 5 spaces, north of the intersection
  Westbound: 6 spaces, east of the intersection
  Westbound: 5 spaces, west of the intersection

  The elimination of these parking spaces in this concept would yield the following increases in travel lanes during the AM and PM peak periods:

Approach	Current lane allocation	Improvement Concept 3 lane allocation
Northbound	1 excl. left-turn lane 1 through/right-turn lane	1 exclusive left-turn lane 1 through lane 1 through/right-turn lane
Southbound	1 excl. left-turn lane 1 through/right-turn lane	1 exclusive left-turn lane 1 through lane 1 through/right-turn lane
Eastbound	1 exclusive left-turn lane 1 through/right-turn lane *(not striped)*	1 exclusive left-turn lane *(striped)* 1 through/right-turn lane *(striped)*
Westbound	1 general-purpose lane	1 through/right-turn lane 1 through/left-turn lane

  Two variations of this concept were analyzed. Improvement Concept 3a was analyzed with the existing exclusive pedestrian phase of 22 seconds in place. It was optimized to a 120 second cycle length for the AM peak hour, and a 110 second cycle length for the PM peak hour. Improvement Concept 3b was analyzed with a concurrent pedestrian phase replacing the exclusive phase, and included an LPI of 4 seconds for the all-red signal phase. It was optimized to a 90 second cycle length for both the AM and PM peak hours.

  The intersection level of service for each of Improvement Concepts 1, 2, and 3 is shown below.

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[5] See www.saferoutesinfo.org/guide/engineering/traffic_signals.cfm, *Reduce the Number of Motor Vehicle Movements that Conflict with Pedestrians*. For a case study, go to: www.walkinginfo.org/pedsafe/casestudy.cfm?CS_NUM=66.

Intersection LOS Summary: Existing Conditions and Improvement Concepts 1, 2, and 3 (2007 Traffic Volumes)

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing* (110 secs. cy. le.)	F	* (195)	70	F	* (186)	61
Imp. Concept 1a *Optimize timings* (AM: 150 secs; PM: 140 secs)	F	* (117)	89	E	75	67
Imp. Concept 1b *Optimize timings* (110 secs. cy. le.)	F	* (180)	70	F	* (114)	57
Imp. Concept 2a *Concurrent pedestrian phase* (AM: 110 secs; PM: 80 secs)	E	63	53	D	46	32
Imp. Concept 2b *Concurrent ped. phase + LPI* (AM: 110 secs; PM: 90 secs)	E	71	55	D	46	38
Imp. Concept 3a *Prohibit on-street pkng; keep excl. ped. phase* (AM: 120 secs; PM: 110 secs)	E	76	45	D	55	36
Imp. Concept 3b *Prohibit on-street pkng; implement concurrent ped. phase + LPI* (90 secs. cy. le.)	D	45	27	D	35	26

cy. le. = cycle length
* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

It was found that merely optimizing the signal timings and cycle lengths did not significantly improve traffic operations, as they yielded LOS F for the AM peak hour, and LOS E for the PM peak hour, while still showing long queues (Improvement Concept 1a). Replacing the exclusive pedestrian phase with a concurrent phase improved operations to LOS E (AM) and D (PM) and yielded shorter queues; however, pedestrian safety would be potentially reduced (Improvement Concepts 2a and 2b). When on-street parking spaces were removed near the intersection and converted into additional travel lanes, operations were improved to LOS E (AM) or D (PM), *and* the exclusive pedestrian phase was retained (Improvement Concept 3a). When the exclusive pedestrian phase was replaced by a concurrent phase, and an LPI of 4 seconds all-red was implemented, operations improved further to LOS D for both the AM and PM peak hours, and the shortest queues were obtained (Improvement Concept 3b).

Discussion and Recommendations

Staff sought feedback from Boston officials and MassHighway District 4 staff regarding the safety and operational analysis at this location. Appendix A-2 at the end of this document contains copies of communications from MassHighway and the City.

Whichever improvement concept is pursued by the City of Boston at Hyde Park Avenue at River Street, there will likely be tradeoffs between reducing vehicle delays and queues, eliminating on-street parking, re-allocating one or more travel lanes in the intersection, and enhancing vehicle and pedestrian safety. While Improvement Concept 1 optimizes the existing signal timing, Improvement Concepts 2 and 3 reduce congestion and improve LOS by means of either replacing the exclusive pedestrian phase with a concurrent one, reducing on-street parking spaces, or re-allocating travel lanes.

From the analysis, the most effective traffic operations strategies are included in Improvement Concepts 3a and 3b: restriping turning lanes at some approaches by removing on-street parking spaces. This improvement could help to reduce angle-type collisions at the intersection. In the event that the City pursues this option, the business community would have to be consulted, including considering parking restrictions in the AM peak hour only, when many of the businesses are closed.

Changing the traffic signal design by replacing the exclusive pedestrian phase with a concurrent pedestrian phase is a less effective strategy, and, more importantly, it raises concerns for pedestrian safety. The numbers of pedestrians and vehicle turning movements at this intersection are high during both peak hours. Concurrent phases would likely promote vehicle and pedestrian conflicts. According to comments received from the City of Boston Transportation Department (BTD), implementing concurrent pedestrian phases when the pedestrian volume is higher than 250 pedestrians does not meet BTD standards.

Included in the City's comments was a request for staff to perform additional analysis and examine various potential new improvements. However, this would absorb additional resources not anticipated by the budget of the present study for Cleary Square. In addition, BTD indicated that the City "is currently studying/developing optimized traffic signal timing plans along Hyde Park Avenue between Forest Hills and Cleary Square." At this time, for efficiency purposes, staff will refrain from recommending a specific improvement from those examined within the context of this study; instead, it recommends that the technical advisors to the City incorporate the data, observations, and analysis from this study with those of the City in order to design the improvements that are of immediate interest to BTD.

3. BRAINTREE: Grove Street at Columbian Street

Existing Conditions

Geometry/Physical Characteristics

This is a signalized intersection. Grove Street is under local (Town of Braintree) jurisdiction, while Columbian Street is under MassHighway jurisdiction. Grove Street southbound has two general-purpose lanes, as does Columbian Street northbound. These two approaches constitute the primary (north-south) roadway. Grove Street westbound has two channelized travel lanes: an exclusive left-turn lane with storage for 3 to 4 vehicles, and a long, exclusive right-turn lane with a large turning radius and storage for 7 to 8 vehicles. The intersection is wide open with good sight lines in the north-south direction. In the eastbound direction there are obscured views for right-turning vehicles from Columbian Street when approaching the Jamie's Grille and Pub driveway. A few hundred feet to the east, Grove Street crosses the Old Colony commuter rail line (see Figure 3-1).

The posted speed limit on Grove Street/Columbian Street southbound is 40 miles per hour. On Columbian Street/Grove Street northbound the speed limit is 35 miles per hour, and on Grove Street eastbound/westbound it is 30 miles per hour. Field reconnaissance in May, September, and December of 2007 showed that the lane markings were visible, but had begun to fade. There are no sidewalks near the intersection, nor any pedestrian crosswalks on any of the approaches.

Traffic Control

This is a semi-actuated signal; it has three distinct phases during both the AM and PM peak hours: (1) leading southbound, (2) northbound/southbound, and (3) westbound. There is no exclusive or concurrent pedestrian phase, no crosswalks or pedestrian buttons. The maximum observed signal cycle length was 120 seconds. It should be noted that the leading southbound phase was rarely actuated during the AM peak hour; however, it was actuated in almost every cycle during the PM peak hour, mostly due to the higher number of left turns during the PM peak hour than in the AM.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

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FIGURE 3-1

Braintree: Grove Street at Columbian Street

2007 AM and PM Peak Hour Turning Movements
(number of vehicles)

AM Peak Hour (7:15–8:15)											
Columbian Street						Grove Street					
Northbound			Southbound			Southbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
N.A.	870	320	N.A.	N.A.	N.A.	240	320	N.A.	210	N.A.	390
1,190 (total approach)			N.A.			560 (total approach)			600 (total approach)		

- Columbian Street, NB + Grove Street, SB approaches combined: 1,750 vehicles
- Grove Street, WB approach: 600 vehicles
- Pedestrians (all approaches): 0
- Bicycles (all approaches): 1

PM Peak Hour (4:15–5:15)											
Columbian Street						Grove Street					
Northbound			Southbound			Southbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
N.A.	490	280	N.A.	N.A.	N.A.	480	920	N.A.	390	N.A.	380
770 (total approach)			N.A.			1,400 (total approach)			770 (total approach)		

- Columbian Street, NB + Grove Street, SB approaches combined: 2,170 vehicles
- Grove Street, WB approach: 770 vehicles
- Pedestrians (all approaches): 3
- Bicycles (all approaches): 3

The approach with the greatest AM peak hour volumes was Columbian Street northbound, 1,190 total vehicles, including 320 right turns onto Grove Street eastbound. The highest individual AM peak hour turning movement was Grove Street westbound right turns, 390 vehicles. In the PM peak hour, the approach with the greatest volumes was Grove Street southbound, 1,400 vehicles, including the highest individual turning movement, 480 left turns onto Grove Street eastbound.

Crashes

The vehicle crash rate for this location was 1.09 crashes per million vehicles entering the intersection. This exceeds the most recent average crash rate of 0.88 for MassHighway District 4 area signalized intersections. Specific characteristics of the vehicle crashes include:

- 51% of crashes were angle. Examination of the RMV data revealed that Columbian Street northbound vehicles were involved in 12 of the 20 angle crashes recorded (60%). These involved northbound vehicles colliding with turning vehicles from the Grove Street southbound (left turns) and westbound (left or right turns) approaches.

The most likely cause for the angle crashes appeared to be southbound vehicles attempting to turn left onto Grove Street after the leading southbound phase had ended and northbound vehicles had begun moving. Contributing to this situation may be the relatively high speeds observed in the northbound and southbound directions (though not necessarily above the speed limit). Likewise, some westbound left-turning vehicles may have proceeded after the westbound green phase had ended. Westbound right-turning vehicles may have collided with northbound through vehicles due to not stopping (at the YIELD sign) to wait for a gap in the northbound traffic stream.

- 26% of crashes were rear-end. This normally would suggest that one-fourth of all crashes occurred in congested, stop-and-go traffic. However, extreme congestion was neither observed in the field, nor indicated by the level of service analysis. Therefore, it is more likely that the rear-end crashes were due to high speeds and sudden stops. Virtually all of the rear-end crashes occurred on the Columbian Street northbound and Grove Street southbound approaches—about half of the crashes on each approach.

- 8% of crashes were head-on.

- 15% of crashes were other/undetermined.

Additionally:

- 0% of crashes involved pedestrians.

- 0% of crashes involved bicyclists.

- 36% of all crashes resulted in personal injuries.

- 72% of crashes occurred during April–October (spring, summer, fall); 28% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (3 of 39 crashes, or 8%, occurred during rain, snow, or fog).

- 82% of crashes occurred during daytime, 7 AM through 7 PM; 18% occurred during night-time, 7 PM through 7 AM. No predominant darkness-related crash patterns were seen.

Land Use

The surrounding land use is relatively undeveloped. Jamie's Grille and Pub is located on the southeast corner. Single-family homes are located a few hundred feet to the north on Grove Street, while some commercial development is found a similar distance to the south on Columbian Street. There is no public transportation bus service in this area, and the closest commuter rail and/or Red Line stations are located about 2 miles to the north (Braintree Station) and south (South Weymouth Station).

Level of Service (LOS)

LOS results for this signalized intersection by total approach and by lane group are shown below.

2007 Intersection LOS Summary (Existing Conditions)

	AM Peak Hour			PM Peak Hour		
Existing Conditions	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing*	B	12	10	C	31	29

Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

2007 LOS by Lane Group, Total Approach (Existing Conditions)

AM Peak Hour (7:15–8:15)							
Columbian Street				**Grove Street**			
Northbound		**Southbound**		**Southbound**		**Westbound**	
Through	Right	Left	Through	Left	Through	Left	Right
B	A	N.A.	N.A.		B	B	B
A (total approach)		N.A.		B (total approach)		B (total approach)	
PM Peak Hour (4:15–5:15)							
Columbian Street				**Grove Street**			
Northbound		**Southbound**		**Southbound**		**Westbound**	
Through	Right	Left	Through	Left	Through	Left	Right
A	A	N.A.	N.A.		B	F	B
A (total approach)		N.A.		B (total approach)		E (total approach)	

This reveals that congestion and delays are not major problems at this intersection. All approaches operated at LOS A or B during both the AM and PM peak hours, except for the Grove Street westbound approach in the PM peak hour. During that time, westbound left turns operated at LOS F while the entire approach operated at LOS E.

Conclusions/Significant Findings

- Overall, there was not much congestion, nor were there long delays, at this intersection. Queue lengths were just 3 to 4 vehicles per approach per cycle during the AM peak hour, while they reached 13 to 14 vehicles per cycle during the PM peak hour.

- Half of all the crashes were angle. This suggests that conflicts occurred between vehicles turning and/or changing lanes. It is possible that vehicle speeds are relatively high, and therefore there is not sufficient yellow + red time (currently, 3 + 1 = 4 seconds) for vehicles to clear the intersection prior to the next signal phase beginning, thus leading to angle crashes.

- There are poor sight lines along Grove Street eastbound. The Jamie’s Grille and Pub driveway on Grove Street is too close to the intersection, and is obscured by landscaped vegetation. Vehicles turning right from Columbian Street northbound may suddenly encounter vehicles entering or exiting the driveway, potentially leading to angle crashes, or to rear-end crashes if a turning vehicle must stop short to let driveway vehicles in or out.

- This intersection does not accommodate pedestrians whatsoever. Although some pedestrians and bicyclists were observed crossing the approaches, there are no sidewalks, crosswalks, pedestrian signal phases/buttons, or bicycle lanes.

Preliminary Conceptual Improvements

At the outset, it is suggested that a complete intersection collision diagram be created. This should be based on local police accident reports, and would provide an insight into exact crash patterns at and near this intersection.

The following concepts for improving safety and traffic operations at this intersection were tested:

- Improvement Concept 1: Optimize the signal timing, and extend the all-red signal phase from 1 to 2 full seconds. This improvement would allow vehicles clearing the intersection to have more time to do so, thereby reducing the potential for conflicts with vehicles proceeding in the subsequent signal phase.The cycle lengths, when optimized, changed from 120 seconds to 60 seconds for the AM peak hour, and from 120 to 90 seconds for the PM peak hour.

- Improvement Concept 2: Redesign the intersection to bring Columbian Street northbound right turns, as well as Grove Street westbound right turns, under signal control. This improvement—although likely to cause an increase in delays from existing conditions—would enhance overall safety and potentially reduce crashes by promoting lower vehicle speeds. Two variations of this concept were tested:

    a. The Columbian Street northbound approach would be redesigned from two through lanes and one channelized right-turn lane, to one through lane and one through/right-turn lane.

    b. The Columbian Street northbound approach would be redesigned from two through lanes and one channelized right-turn lane, to two through lanes and one non-channelized right-turn lane.

    Both Improvement Concepts 2a and 2b would include a widened Grove Street westbound approach, with one exclusive left-turn lane, one shared left/right-turn lane, and one exclusive right-turn lane. All left and right turns would be made from a straightened westbound approach, perpendicular to Grove Street southbound/Columbian Street northbound. This widening would be designed to reduce the incidence of westbound left-turning vehicles blocking right-turning vehicles due to the short storage area. Right turns on red (RTOR) would not be permitted.

- Improvement Concept 3: Reconstruct the intersection into a modern roundabout. The turning movements at this location are significant: at least half of the total traffic through the intersection turns left or right at the approaches. This type of traffic pattern is often conducive to a roundabout treatment. It is not clear what the exact design would be; however, the diameter of the center island would likely be 60–80 feet. The roundabout would be designed with one or, possibly two, circulating lane(s), and with the appropriate deflection for each of the three approaches for entering traffic.

The LOS results for existing conditions and for Improvement Concepts 1, 2, and 3 are shown in the following table.

Intersection LOS Summary: Existing Conditions and Improvement Concepts 1, 2, and 3 (2007 Traffic Volumes)

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing* (120 secs cy.le.)	B	12	10	C	31	29
Imp. Concept 1 (AM: 60 secs. PM: 90 secs.) *Optimized splits, cycle length*	B	14	10	C	31	27
Imp. Concept 2a (AM: 60 secs. PM: 100 secs.) *NB and WB lane reallocation*	B	14	11	D	43	38
Imp. Concept 2b (AM: 60 secs. PM: 80 secs.) *WB lane reallocation*	B	15	14	C	27	27
Imp. Concept 3 *Reconstruct intersection into a roundabout*	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

cy. le. = cycle length
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

The improvement concepts analyzed above were designed primarily to increase safety levels for vehicles traveling through the intersection. Delays and queue lengths were negligible overall, with all approaches and turning movements operating at LOS D or better during both the AM and PM peak hours. The one exception was the Grove Street westbound approach, which operated at LOS E in the PM peak hour; the westbound left turns operated at LOS F. This approach did improve to LOS D in Improvement Concept 2b, with the left and right turns operating at LOS D and E, respectively. Since the optimized cycle lengths were relatively short (AM, 60 seconds; PM, 80 seconds), queue lengths would not exceed 11–12 vehicles per cycle for any approach under this improvement concept.

- Improvement Concept 4: Move the Jamie's Grille and Pub driveway on Grove Street further to the east. In order to reduce the potential for angle and rear-end crashes, this driveway could be moved 50–75 feet to the east, near the corner of the parking lot. There is already a second driveway on Columbian Street, and this improvement would provide for improved sight lines for vehicles turning right from Columbian Street northbound and for vehicles entering or exiting the Grove Street driveway.

- Improvement Concept 5: When reconstruction/resurfacing is planned for Columbian Street and Grove Street in the future, consideration should be given to installing sidewalks at and near the intersection. If sidewalks were installed on the east side of Columbian Street (southward) and Grove Street (northward), this would improve pedestrian access between the residential area to the north and the commercial area to the south of the intersection.

Discussion and Recommendations

Staff sought feedback from Braintree officials and MassHighway District 4 staff on the analysis and recommendations regarding this intersection. The comments received are available in Appendix A-3. The recommendations below reflect the comments of MassHighway District 4 and those of the Braintree Department of Public Works, Engineering Division.

MassHighway and Braintree comments are in agreement that implementing Improvement Concept 1 would be the preferred improvement option, including associated increases to the all-red interval for safer operations. MassHighway will implement the retiming and will also examine the yellow time interval and adjust it, as appropriate. The Grove Street westbound right-turn lane will be treated with an additional YIELD sign, to the left of the yield line.

MassHighway's comments reflect a preference for the existing geometrics at this intersection, which include the Columbian Road northbound and Grove Street westbound turning lanes. Braintree shares this concern, as there would be some loss of capacity when directing the currently free right turns through the traffic signal. Braintree agrees that this option would make the intersection safer.

MassHighway will keep in mind the recommendation to move one of the driveways from the property of Jamie's Grille and Pub (Improvement Concept 4), when the property is redeveloped. Braintree would welcome the relocation of the driveway at Jamie's restaurant, with some concerns that the relocation could invite cut-through traffic.

Finally, the Town welcomes the installation of sidewalks, as indicated in Improvement Concept 4, and they commit to maintaining them, if MassHighway constructs them. Further, the Town hopes that this construction could take place in the context of reconstructing the existing roadway pavement, as anticipated in resurfacing project #086901.

4. HOLLISTON: Washington Street (Routes 16/126) at Hollis Street/Charles Street

Existing Conditions

Geometry/Physical Characteristics

This is an unsignalized intersection, and is under local (Town of Holliston) jurisdiction. Washington Street (Routes 16/126) has one exclusive left-turn lane and one through/right-turn lane on each of the northbound and southbound approaches, respectively. Hollis Street, one of the side streets, is stop-controlled and has two travel lanes in the eastbound direction: an exclusive right-turn lane, and a through/left-turn lane. On the east side of the intersection is Charles Street, a one-lane roadway which is one-way eastbound, away from the intersection (see Figure 4-1).

The posted speed limit on Hollis Street is 25 miles per hour. On Washington Street, the speed limits are 30 miles per hour approaching downtown—including this intersection—both northbound and southbound, and 35 miles per hour leaving the downtown area. Field reconnaissance in May and September of 2007 showed that the blue crosswalks with white edges were visible, but had begun to fade. There were crosswalks on all approaches except for on Washington Street southbound.

Traffic Control

The only traffic control at this intersection is a stop sign for Hollis Street eastbound traffic. Charles Street is one-way eastbound, away from the intersection.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

2007 AM and PM Peak Hour Turning Movements
(number of vehicles)

AM Peak Hour (7:15–8:15)											
Washington Street (Routes 16/126)						Hollis Street			Charles Street		
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
180	850	4	5	470	140	140	3	80	N.A.	N.A.	N.A.
1,034 (total approach)			615 (total approach)			223 (total approach)			N.A. (one-way eastbound)		

- Washington Street, NB + SB approaches combined: 1,649 vehicles
- Hollis Street, EB approach: 223 vehicles
- Pedestrians (all approaches): 0
- Bicycles (all approaches): 3

CTPS

Safety and Operational Improvements at Selected Intersections

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FIGURE 4-1

Holliston: Washington Street (Routes 16/126) at Hollis Street

PM Peak Hour (5:00–6:00)											
Washington Street (Routes 16/126)						**Hollis Street**			**Charles Street**		
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
120	520	20	3	930	170	70	2	240	N.A.	N.A.	N.A.
660 (total approach)			1,103 (total approach)			312 (total approach)			N.A. (one-way eastbound)		

- Washington Street, NB + SB approaches combined: 1,763 vehicles
- Hollis Street, EB approach: 312 vehicles
- Pedestrians (all approaches): 2
- Bicycles (all approaches): 7

The approach with the greatest AM peak hour volumes was Washington Street northbound, 1,034 total vehicles, including 180 left turns onto Hollis Street. In the PM peak hour, the approach with the greatest volumes was Washington Street southbound, 1,103 vehicles, including 170 right turns onto Hollis Street. The greatest single turning movement count was on the Hollis Street eastbound approach, where right-turning vehicles totaled 240 during the PM peak hour.

Crashes

The vehicle crash rate for this location was 1.47 crashes per million vehicles entering the intersection. This exceeds the most recent average crash rate of 0.79 for MassHighway District 3 area unsignalized intersections. Specific characteristics of the vehicle crashes include:

- 49% of crashes were angle. Examination of the RMV data revealed that Hollis Street eastbound vehicles were involved in 13 of the 18 angle crashes recorded (72%). These crashes involved eastbound vehicles either colliding with vehicles from the northbound or southbound approaches in the intersection, or eastbound vehicles side-swiping other eastbound vehicles, most likely due to changing lanes near the intersection.

  The most likely cause for the angle crashes appeared to be eastbound vehicles attempting to turn right or left onto Washington Street. Since gaps in the northbound and southbound vehicle streams were often short and infrequent during the AM and PM peak hours, conflicts occurred between vehicles entering or exiting the intersection perpendicular to each other.

- 27% of crashes were rear-end. This suggests that one-fourth of all crashes occurred in congested, stop-and-go traffic. The only distinct pattern seen involved vehicles traveling westbound. Since Charles Street is one-way eastbound from the intersection, these crashes presumably occurred at or near the church driveway on the north side of Hollis Street, immediately west of the intersection. Vehicles turning from Washington Street onto Hollis Street westbound may have suddenly encountered vehicles exiting the church driveway onto Hollis Street, thereby rear-ending stopped vehicles in front, or being similarly rear-ended by following vehicles.

The church houses the Holliston Community Children's Center, an active day-care facility during AM and PM peak periods. A closer look at the westbound rear-end crashes showed that they all occurred either during the most common child drop-off time (7:00–9:00 AM), or pick-up time (3:00–7:00 PM), respectively.

- 0% of crashes were head-on.
- 24% of crashes were other/undetermined.

Additionally:

- 0% of crashes involved pedestrians.
- 3% of crashes (1 of 37) involved bicyclists. The one bicycle-related crash occurred at 11 PM on a June evening under clear and dry road conditions, and resulted in personal injury.
- 41% of all crashes resulted in personal injuries. The average number of crashes with personal injuries for the 15 intersections included in this study was 35%. This intersection therefore had a slightly above average rate of injury-related crashes. This may possibly be due to the unsignalized nature of the intersection, where Hollis Street vehicles might have been apt to proceed out into insufficient gaps if the Washington Street vehicle stream was too long and congested, and thereby generate more serious, and injury-related, crashes with Washington Street vehicles.
- 57% of crashes occurred during April–October (spring, summer, fall); 43% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (5 of 37 crashes, or 14%, occurred during rain, snow, or fog).
- 78% of crashes occurred during daytime, 7 AM through 7 PM; 22% occurred during night-time, 7 PM through 7 AM. No predominant darkness-related crash patterns were seen.

Land Use

The surrounding land use is a mix of commercial, small offices, banks, churches, and some homes. There is no public transportation serving this area; however, a large number of school buses were observed passing through the intersection during the AM peak period. The Holliston High School, Middle School, and at least one elementary school are all located within a few blocks of this intersection.

Level of Service (LOS)

LOS analysis for this unsignalized intersection showed that the AM peak hour operated at LOS F, while the PM peak hour operated at LOS C. These measures are broken down further by lane group and total approach, as shown below.

2007 Intersection LOS Summary (Existing Conditions)

Existing Conditions	AM Peak Hour: LOS / Delay		PM Peak Hour: LOS / Delay	
	Hollis St. EB appr.	Charles St. WB appr.	Hollis St. EB appr.	Charles St. WB appr.
2007 *Existing*	F / * (206)	No traffic; 1-way EB	C / 20	No traffic; 1-way EB

* = 50 or more seconds total delay per vehicle. When unsignalized intersection approach delay is 50 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.

2007 LOS by Lane Group, Total Approach (Existing Conditions)

AM Peak Hour (7:15–8:15)								
Washington Street (Routes 16/126)				**Hollis Street**		**Charles Street**		
Northbound		**Southbound**		**Eastbound**		**Westbound**		
Left	Through/Right	Left	Through/Right	Left/Through	Right	Left	Through	Right
B		A		F		N.A.	N.A.	N.A.
						(one-way eastbound)		
PM Peak Hour (5:00–6:00)								
Washington Street (Routes 16/126)				**Hollis Street**		**Charles Street**		
Northbound		**Southbound**		**Eastbound**		**Westbound**		
Left	Through/Right	Left	Through/Right	Left/Through	Right	Left	Through	Right
B		A		C		N.A.	N.A.	N.A.
						(one-way eastbound)		

This reveals that the Hollis Street eastbound left turns/throughs operated at LOS F during the AM peak hour, and at LOS C during the PM peak hour. The Washington Street southbound and northbound left turns operated at LOS A and B, respectively, during both the AM and PM peak hours.

Conclusions/Significant Findings

- Crashes at this intersection led to an above-average rate of injuries, compared to the 14 other MPO intersections included in this study (see Table 1 above). Based on an analysis of the crash data, this appeared to stem from sudden intrusions of Hollis Street traffic into the Washington Street traffic stream, thereby not giving the Washington Street vehicles enough time to slow down before collisions occurred.

- This downtown Holliston intersection is very wide, has no raised medians or islands, and is perceived as pedestrian-unfriendly. Since the intersection is unsignalized, there is no pedestrian signal or protected phase when pedestrians can safely cross through the intersection. This impression of “pedestrian-unfriendliness” is confirmed by the very few pedestrians observed: none in the AM peak hour and two in the PM peak hour, respectively.

- Crosswalk markings and other lane stripings had begun to fade.

- The church driveway on the north side of Hollis Street, just west of the intersection, may be a source of conflicts between vehicles exiting the driveway and vehicles turning onto Hollis Street westbound from Washington Street.

Preliminary Conceptual Improvements

The following concepts for improving safety and traffic operations at this intersection were tested:

- Improvement Concept 1: A warrant analysis for installing a traffic signal was performed. From this analysis, the following warrants were met:

Warrant	Met?
1. Eight-hour vehicular volume	Probably (more count data needed)
2. Four-hour vehicular volume	Yes
3. Peak hour	Yes
4. Pedestrian volume	No
5. School crossing	N.A.
6. Coordinated signal system	N.A.
7. Crash experience	Probably (more field trials needed)
8. Roadway network	Yes

If it is determined that a new traffic signal is appropriate, it would provide increased safety for vehicles, pedestrians, and bicyclists wishing to turn from Hollis Street onto or across Washington Street. Table 1 showed that this location had the highest Crosswalk Pedestrian Intersection Safety Index (Ped ISI) of all the 15 study intersections, an index of 3.8. As Table 1 and the source below describe, the higher the Ped ISI, the greater the "priority for an in-depth safety assessment."[6] Although no pedestrian-related crashes, and one bicycle-related crash, were seen in the data, the intersection has a high PED ISI due to the number of Washington Street travel lanes pedestrians must cross (with no raised medians or islands), the high traffic volumes, the posted speed limits, the surrounding predominant commercial land use, and the absence of a traffic signal.

An LOS analysis was performed for a hypothetical new traffic signal, assuming the current intersection geometry, lane allocation, and peak hour volumes. Four variations of this improvement concept were examined (1a, 1b, 1c, and 1d).

In Improvement Concept 1a, optimized to a 150 second cycle length, the signal phasing scheme included a four-phase sequence: (1) a leading northbound (Washington Street) all-traffic phase to accommodate the numerous left turns onto Hollis Street; (2) a northbound/ southbound (Washington Street) phase; (3) an eastbound (Hollis Street) phase; and (4) an exclusive pedestrian phase of 15 seconds, sufficient time to cross all intersection approaches.

[6] U.S. Department of Transportation, Federal Highway Administration, *Pedestrian and Bicyclist Intersection Safety Indices*, Publication No. FHWA–HRT–06–129, p. 1, April 2007; see www.tfhrc.gov/safety/pedbike/pubs/06129/06129.pdf

Improvement Concept 1a yielded a natural cycle length of 150 seconds for both the AM and PM peak hours. This is a relatively long cycle length and would likely result in long vehicle queues. In order to reduce the anticipated queue lengths, therefore, Improvement Concept 1b used a 120 second cycle length to analyze both the AM and PM peak hours. In Improvement Concept 1c, the exclusive pedestrian phase was replaced by a concurrent pedestrian phase and analyzed with a 120 second cycle length.

Improvement Concept 1d also replaced an exclusive pedestrian phase with a concurrent pedestrian phase. However, in this improvement concept a Leading Pedestrian Interval (LPI) was implemented on each signal phase by extending the all-red signal phase to 4 seconds. For the approach about to receive a green signal, the LPI "illuminates the pedestrian WALK signal, while the motor vehicle signal remains red for the first few seconds of the cycle. The LPI gives pedestrians an opportunity to start walking and establish a presence in the crosswalk before drivers can begin their turn."[7] This improvement concept also used a cycle length of 120 seconds.

The results of variations 1a through 1d are shown in the following table.

Intersection LOS Summary: Hypothetical Traffic Signal (2007 Traffic Volumes)

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
Imp. Concept 1a *New signal, four phases* (150 secs. cy.le.)	E	75	64	E	76	54
Imp. Concept 1b *New signal, four phases* (120 secs. cy.le.)	F	* (91)	50	F	* (96)	42
Imp. Concept 1c *New signal, concurrent pedestrian phase* (120 secs. cy.le.)	E	65	57	E	76	54
Imp. Concept 1d *New signal,concurrent pedestrian phase + LPI* (120 secs. cy.le.)	F	* (82)	65	F	* (97)	60

cy. le. = cycle length
* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

[7] See www.saferoutesinfo.org/guide/engineering/traffic_signals.cfm , *Reduce the Number of Motor Vehicle Movements that Conflict with Pedestrians*. For a case study, go to: www.walkinginfo.org/pedsafe/casestudy.cfm?CS_NUM=66

The analysis showed that, in Improvement Concept 1a (a 150 second cycle length with an exclusive pedestrian phase), both the AM and PM peak hours would operate at LOS E, and with relatively long queues.

In Improvement Concept 1b (a 120 second cycle length, also with an exclusive pedestrian phase), both peak hours would operate at LOS F, although queues would decrease somewhat due to the reduced cycle length.

Improvement Concept 1c, also with a cycle length of 120 seconds, replaced the exclusive pedestrian phase with a concurrent pedestrian phase, thereby allocating more green time to moving vehicles through the intersection. Here, the LOS would be E for both the AM and PM peak hours.

In Improvement Concept 1d, the exclusive pedestrian phase was replaced with an LPI. The LOS, based on a 120 second cycle length, would deteriorate to F in both the AM and PM peak hours.

- Improvement Concept 2: Construct bulbouts on the corners, as well as raised medians and islands within the intersection in order to channelize traffic. These geometric improvements would "tighten up" the intersection. It would also enhance pedestrian safety by reducing the open space which pedestrians would be required to traverse when crossing the intersection approaches. Suggested locations would be an island on the west side of the intersection channelizing Hollis Street eastbound traffic from westbound traffic, and a raised median south of the intersection between northbound and southbound traffic.

- Improvement Concept 3: Redesign and move the church driveway about 100 feet further west on Hollis Street. This redesign, still on church property, would enhance safety by making the driveway exit perpendicular to Hollis Street, while improving sight distance in all directions. It would also reduce the potential for conflict between vehicles exiting the driveway and those turning from Washington Street onto Hollis Street westbound.

- Improvement Concept 4: Increase awareness of, and safety for, bicyclists on Washington Street (Routes 16/126) by adding a bicycle lane on the northbound and southbound sides of the roadway. It appears that there would be sufficient space to create a striped bicycle lane five feet in width on both sides of Washington Street.[8] Further study would be required to determine how far to the north and south such bicycle lanes could be implemented on Routes 16/126 throughout Holliston and beyond.

- Improvement Concept 5: Re-paint faded crosswalks and lane markings. Make sure all crosswalks are identical; i.e., paint the Charles Street crosswalk the same color as the crosswalks on the other approaches, not just two white lines. This would add uniformity to the overall appearance, enhancing pedestrian safety at the intersection.

[8] The recommended "minimum width of bike lane when adjacent to parking," from "On-street Facilities/Bike Lanes," at www.bicyclinginfo.org/de/onstreet.htm

Discussion and Recommendations

Staff sought feedback from the Town of Holliston and MassHighway District 3 with respect to the improvement concepts analyzed. The comments received, available in Appendix A-4, are reflected below.

District 3 staff feel that additional work may be needed before the installation of a traffic signal is considered at this location. They are also concerned about considering further the option that contains the Leading Pedestrian Interval (LPI) concept, as this treatment is not common in District 3 and may lead pedestrians to a false sense of security. Finally, they believe that this location would benefit if reconstructed as a modern roundabout. Indeed, this location may be conducive to this type of treatment. One of the criteria for reconstructing an intersection as a roundabout is whether there are turning movements of sufficient magnitude. This criterion is largely met at this location. Also, the present intersection is wide enough to accommodate a circular island within the existing right-of-way. Finally, a roundabout could help in reducing speeds. This concept was not analyzed in this memorandum, but an analysis could be performed easily if this option is considered further.

In closing, the signalization and roundabout options should be considered further when improvements for this location move to the design stage. In addition, Improvement Concepts 2, 3, 4, and 5 are all recommended, at present or with signalization; Improvement Concepts 3 and 4 would still be valid if a roundabout were to be constructed.

5. LEXINGTON: Massachusetts Avenue (Routes 4/225) at Maple Street (Route 2A)

Existing Conditions

Geometry/Physical Characteristics

This is an unsignalized intersection, and is under local (Town of Lexington) jurisdiction. Massachusetts Avenue has one general-purpose lane on each of the northbound and southbound approaches. Maple Street has one general-purpose lane, and approaches the intersection from the east. This approach widens near Massachusetts Avenue, with sufficient, unstriped space for left-turning and right-turning vehicles to proceed side-by-side, about 5–6 cars deep. A small, round, raised island is located so all left-turning traffic must travel around it between the two roadways. Massachusetts Avenue southbound, although marked as one lane, is just wide enough to accommodate left-turning vehicles to Maple Street to line up separately (about 12–15 cars deep) from through vehicles (see Figure 5-1).

The posted speed limit on Massachusetts Avenue is 30–35 miles per hour, while on Maple Street it is 25 miles per hour. Field reconnaissance in May and September of 2007, and in March 2008, showed that the crosswalks and lane markings had begun to fade. There is a crosswalk just south of the intersection on the Massachusetts Avenue northbound approach, north of Plainfield Street.

Traffic Control

The Maple Street westbound approach is assumed to be stop-controlled for left turns (southbound), and yield-controlled for right turns (northbound); however, although these controls are assumed, the stop and yield signs are missing.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

2007 AM and PM Peak Hour Turning Movements (number of vehicles)

AM Peak Hour (7:30–8:30)											
Massachusetts Avenue (Routes 4/225)						Maple Street (Route 2A)					
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
N.A.	310	100	150	850	N.A.	N.A.	N.A.	N.A.	180	N.A.	410
410 (total approach)			1,000 (total approach)			N.A.			590 (total approach)		

- Massachusetts Avenue, NB + SB approaches combined: 1,410 vehicles
- Maple Street, WB approach: 590 vehicles
- Pedestrians (all approaches): 12
- Bicycles (all approaches): 9

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Safety and Operational Improvements at Selected Intersections

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FIGURE 5-1

Lexington: Massachusetts Avenue (Routes 4/225) at Maple Street (Route 2A)

PM Peak Hour (5:00–6:00)											
Massachusetts Avenue (Routes 4/225)						**Maple Street (Route 2A)**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
N.A.	300	110	510	560	N.A.	N.A.	N.A.	N.A.	80	N.A.	190
410 (total approach)			1,070 (total approach)			N.A.			270 (total approach)		

- Massachusetts Avenue, NB + SB approaches combined: 1,480 vehicles
- Maple Street, WB approach: 270 vehicles
- Pedestrians (all approaches): 1
- Bicycles (all approaches): 13

The approach with the greatest AM peak hour volumes was Massachusetts Avenue southbound, 1,000 total vehicles. The highest single AM peak hour turning movement occurred on Maple Street westbound, with 410 vehicles turning right. In the PM peak hour, the approach with the greatest volumes was again Massachusetts Avenue southbound, 1,070 vehicles, including 510 left turns onto Maple Street. This was the greatest single turning movement count during the PM peak hour.

Crashes

The vehicle crash rate for this location was 2.87 crashes per million vehicles entering the intersection. This exceeds the most recent average crash rate of 0.63 for MassHighway District 4 area unsignalized intersections. Specific characteristics of the vehicle crashes include:

- 41% of crashes were angle, below the 15-intersection study average of 51%. Examination of the RMV data revealed that Maple Street westbound vehicles were involved in 15 of the 25 angle crashes recorded (60%). These crashes involved westbound left- and right-turning vehicles colliding with vehicles from the northbound or southbound approaches.

  The most likely cause for the angle crashes appeared to be westbound vehicles attempting to turn right or left onto Massachusetts Avenue. Since gaps in the northbound and southbound vehicle streams were often short and infrequent during the AM and PM peak hours, conflicts occurred between vehicles entering or exiting the intersection perpendicular to each other. One particular near-collision situation observed was Maple Street westbound left-turning vehicles nearly getting hit by Massachusetts Avenue southbound through vehicles, as Maple Street vehicles squeezed through the southbound left-turning queue, only to nearly collide with the through vehicles.

- 51% of crashes were rear-end, significantly above the study average of 27%. This suggests that one-half of all crashes occurred in congested, stop-and-go traffic. The only somewhat distinct pattern observed involved vehicles traveling on Maple Street westbound—14 of the 31 rear-end crashes were on the westbound approach (45%).

- 0% of crashes were head-on.

- 8% of crashes were other/undetermined.

Additionally:

- 0% of crashes involved pedestrians.

- 2% of crashes (1 of 61) involved bicyclists. This one crash occurred at 11 AM on a July morning under dry and clear road conditions, and resulted in personal injury.

- 26% of all crashes resulted in personal injuries. The average number of crashes with personal injuries for the 15 intersections included in this study was 35%. This intersection therefore had a below average rate of injury-related crashes.

- 62% of crashes occurred during April–October (spring, summer, fall); 38% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (3 of 61 crashes, or 5%, occurred during rain, snow, or fog).

- 97% of crashes occurred during daytime, 7 AM through 7 PM; 3% occurred during night-time, 7 PM through 7 AM. Of the 15 study intersections, this had the lowest incidence of darkness-related crashes (3%). No predominant darkness-related crash patterns were seen.

Land Use

Located in the southeastern part of Lexington, the intersection's surrounding land use is mostly single-home residential. The National Heritage Museum is located a few hundred yards to the north on Massachusetts Avenue, while the Lexington business district is located about one mile further to the north. MBTA buses #s 62 and 76 run on Massachusetts Avenue and serve this area of Lexington.

Level of Service (LOS)

LOS analysis for this unsignalized intersection, by approach, is shown below.

2007 LOS Summary, by Approach (Existing Conditions)

	AM Peak Hour: LOS / Delay			PM Peak Hour: LOS / Delay		
Existing Conditions	Maple Street		Mass. Ave.	Maple Street		Mass. Ave.
	WB lefts	WB rights	SB lefts	WB lefts	WB rights	SB lefts
2007 *Existing*	E / 38	B / 11	A / 4	F / * (100)	A / 9	B / 11

* = 50 or more seconds total delay per vehicle. When unsignalized intersection approach delay is 50 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.

This reveals that the Maple Street westbound left turns operated at LOS E during the AM peak hour, and LOS F during the PM peak hour. The westbound right turns operated at LOS B and A, and the Massachusetts Avenue southbound left turns operated at LOS A and B, during the AM and PM peak hours, respectively.

Conclusions/Significant Findings

- Overall, traffic often operated at a virtual "free-for-all" during the AM and PM peak hours. This was in part due to the very large amount of open, unchannelized space in the intersection footprint. Many near-collisions were observed between vehicles turning left from Maple Street and almost colliding with Massachusetts Avenue southbound left-turning vehicles as well as with through vehicles. In the PM peak hour, in particular, it was observed how Maple Street left-turning vehicles slowly proceeded, negotiating between northbound through and southbound left-turning vehicles, only to nearly collide with southbound through vehicles that bypassed the left-turning queue, sometimes at dangerously high speeds.

- Maple Street westbound peak hour queues were observed to be 15–20 vehicles, sometimes more than what could be seen beyond the roadway curvature.

- Massachusetts Avenue northbound vehicles occasionally backed up close to this intersection, extending southward from the downstream Marrett Road (Route 2A) intersection by the National Heritage Museum, a few hundred yards to the north.

- The corner radii for right-turning vehicles are much too large for safe traffic operations. As a result, vehicles turning right from Massachusetts Avenue northbound and from Maple Street westbound proceed at high speeds, potentially endangering pedestrians and bicyclists, as well as contributing to the incidence of angle and rear-end crashes.

- The intersection is very bicycle- and pedestrian-unfriendly. Since the intersection is unsignalized, there is no pedestrian signal or protected phase when pedestrians can safely cross the through the intersection. This impression was confirmed by the relatively few pedestrians observed during the manual turning movement counts: 12 in the AM peak hour and one in the PM peak hour, respectively.

- The sidewalks near the intersection are cracked, uneven, and constructed from different materials (asphalt, concrete), giving a non-uniform appearance.

- Crosswalk markings and other lane stripings have begun to fade.

Preliminary Conceptual Improvements

The following concepts for improving safety and traffic operations at this intersection were tested:

- Improvement Concept 1: <u>A warrant analysis for installing a traffic signal was performed.</u> From this analysis, the following warrants were met:

Warrant	Met?
1. Eight-hour vehicular volume	Very likely *(more count data needed)*
2. Four-hour vehicular volume	Yes
3. Peak hour	Yes
4. Pedestrian volume	No
5. School crossing	Not tested
6. Coordinated signal system	Not tested
7. Crash experience	Probably *(more field trials needed)*
8. Roadway network	Yes

If it is determined that a new traffic signal is appropriate, it would provide increased safety for all pedestrians, bicyclists, and vehicles, especially those vehicles wishing to turn from Maple Street onto Massachusetts Avenue. Also, Table 1 above showed that this location has the second highest Crosswalk Pedestrian Intersection Safety Index (Ped ISI) of all 15 study intersections, an index of 3.7. As Table 1 and the source below describe, the higher the Ped ISI, the greater the "priority for an indepth safety assessment."[9] Although no pedestrian-related crashes, and one bicycle-related crash, were seen in the data, the intersection has a high PED ISI due to the high traffic volumes on both Massachusetts Avenue and Maple Street, the posted speed limits, and the absence of a traffic signal.

An LOS analysis was performed for a hypothetical new traffic signal. This improvement concept assumed the current (2007) peak hour volumes; however, the intersection would be restriped to include an exclusive left-turn lane on Massachusetts Avenue southbound, to accommodate the numerous left turns onto Maple Street. Three variations of this improvement concept were examined (1a, 1b, and 1c).

In Improvement Concept 1a, optimized to a cycle length of 80 seconds for the AM peak hour and 90 seconds for the PM peak hour, the signal phasing scheme included a three-phase sequence: (1) a northbound/southbound (Massachusetts Avenue) phase; (2) a westbound (Maple Street) phase; and, (3) an exclusive pedestrian phase of 15 seconds, sufficient time to cross any of the intersection approaches. Right turns on red (RTOR) would be permitted.

In Improvement Concept 1b, the exclusive pedestrian phase was replaced by a concurrent pedestrian phase and analyzed with an 80 second cycle length for both the AM and PM peak hours. RTOR would not be permitted.

Improvement Concept 1c also replaced the exclusive pedestrian phase with a concurrent pedestrian phase. However, in this improvement concept a Leading Pedestrian Interval (LPI) was implemented on each of the two signal phases by extending the all-red signal phase to 4 seconds. For the approach about to receive a green signal, the LPI "illuminates the pedestrian WALK signal, while the motor vehicle signal remains red for the first few seconds of the cycle. The LPI gives pedestrians an opportunity to start walking and to

[9] U.S. Department of Transportation, Federal Highway Administration, *Pedestrian and Bicyclist Intersection Safety Indices*, Publication No. FHWA–HRT–06–129, p. 1, April 2007; see www.tfhrc.gov/safety/pedbike/pubs/06129/06129.pdf

establish a presence in the crosswalk before drivers can begin their turn."[10] This improvement concept used cycle lengths of 100 and 80 seconds for the AM and PM peak hours, respectively. RTOR would not be permitted.

The LOS results for the existing conditions as well as for Improvement Concepts 1a, 1b, and 1c are shown in the following tables:

Intersection LOS Summary: Existing Conditions and Improvement Concepts 1a, 1b and 1c (2007 Traffic Volumes)

Unsignalized

	AM Peak Hour: LOS / Delay			PM Peak Hour: LOS / Delay		
Existing Conditions	Maple Street		Mass. Ave.	Maple Street		Mass. Ave.
	WB l. turns	WB r. turns	SB l. turns	WB l. turns	WB r. turns	SB l. turns
2007 *Existing*	E / 38	B / 11	A / 4	F / * (100)	A / 9	B / 11

* = 50 or more seconds total delay per vehicle. When unsignalized intersection approach delay is 50 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.

Signalized

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
Imp. Concept 1a *New signal w. excl. ped. phase* (AM: 80 secs. PM: 90 secs.)	B	15	15	B	18	12
Imp. Concept 1b *New signal w. conc. ped. phase* (80 secs. cy. le.)	C	31	35	C	21	21
Imp. Concept 1c *New signal w. LPI ped. phase* (AM: 100 secs. PM: 80 secs.)	D	37	46	C	26	23

cy. le. = cycle length
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

The analysis showed that in Improvement Concept 1a—the installation of a new traffic signal, optimized to a cycle length of 80 seconds for the AM peak hour and 90 seconds for the PM peak hour, and including an exclusive left-turn lane southbound and a 15-second exclusive pedestrian phase—the AM and PM peak hours would both operate at LOS B. Queues would range from 1–9 vehicles per approach per signal cycle. Right turns on red (RTOR) would be permitted.

[10] See www.saferoutesinfo.org/guide/engineering/traffic_signals.cfm , *Reduce the Number of Motor Vehicle Movements that Conflict with Pedestrians*. For a case study, go to: www.walkinginfo.org/pedsafe/casestudy.cfm?CS_NUM=66

Improvement Concept 1b assumed the same changes as in Improvement Concept 1a, although the exclusive pedestrian phase would be replaced by a concurrent pedestrian phase. When the optimized cycle length was reduced to 80 seconds for both the AM and PM peak hours, the analysis yielded LOS C for both peak hours. However, the queue lengths increased somewhat, to 3–17 vehicles per approach per signal cycle. RTOR would not be permitted.

In Improvement Concept 1c, in addition to the same improvements as for concepts 1a and 1b, the exclusive pedestrian phase was replaced with an LPI. Traffic operations, based on 100 and 80 second cycle lengths for the AM and PM peak hours, respectively, would deteriorate slightly (from Improvement Concept 1b) to LOS D and C, respectively, and with somewhat longer queues in both peak hours, 4–23 vehicles per approach per signal cycle. RTOR would not be permitted.

- Improvement Concept 2: The potential installation of a roundabout was analyzed. The intersection footprint appears to be large enough to construct a modern roundabout, rather than to install a new traffic signal. A modern roundabout features "yield control for all entering traffic, channelized approaches and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically less than 30 miles per hour."[11]

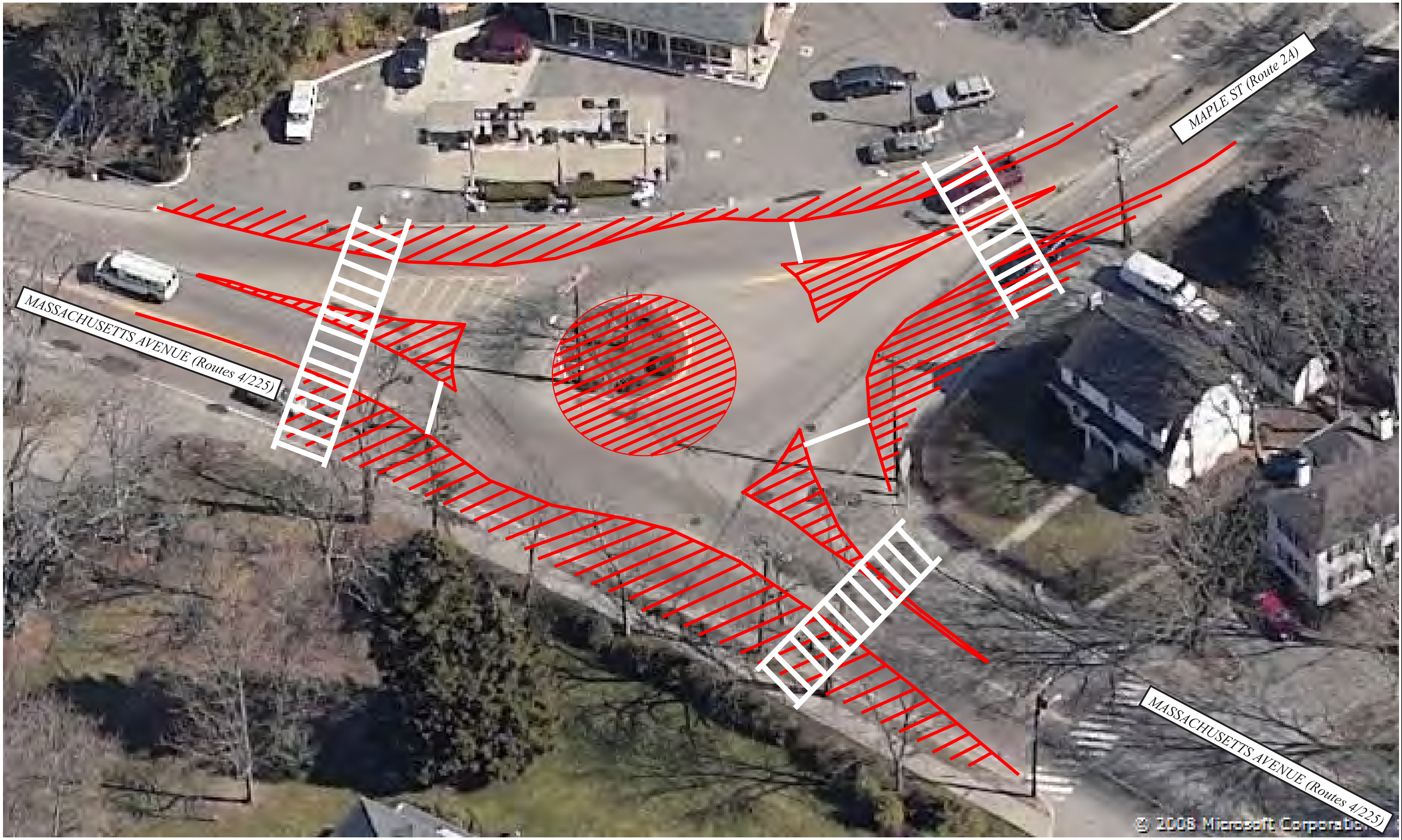
  The safety rationale for installing a roundabout rather than a new signal involves the reduction of potential conflict points between vehicles turning (especially to the left) or passing through the intersection. Typically, the number of crashes are reduced when a roundabout is constructed. In addition, the severity of crashes are usually lessened due to the slower speeds associated with roundabouts.[12]

  Finally, although installation of a roundabout is not a panacea with respect to improving the movement of pedestrians and bicyclists, or for solving congestion and delays at intersections generally, "a roundabout that operates within its capacity will generally produce lower delays than a signalized intersection operating with the same traffic volumes and right-of-way limitations."[13]

  A roundabout that may be applicable at Massachusetts Avenue at Maple Street would have one circulating lane on which vehicles have the right-of-way, i.e., no traffic control; three one-lane, yield-controlled, approaches; and, crosswalks on all three approaches, slightly set back from the circulating lane (see Figure 5-2 for a draft design).

  Capacity analysis for a hypothetical roundabout, described as above, yielded LOS A for both the AM and PM peak hours. See the table below for LOS details for both peak hours, by approach.

[11] U.S. Department of Transportation, Federal Highway Administration, and Institute of Transportation Engineers, *Intersection Safety Issue Briefs, #14 Roundabouts*, p. 1, www.ite.org/library/IntersectionSafety/BriefingSheets.pdf.
[12] Ibid, p. 3.
[13] U.S. Department of Transportation, Federal Highway Administration, *Roundabouts: An Informational Guide* (brochure), p. 2, www.tfhrc.gov/safety/00068.pdf.



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Safety and Operational Improvements at Selected Intersections

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FIGURE 5-2

Improvement Concept 2: Modern Roundabout (DRAFT design)

= **area of geometric changes**

Hypothetical Roundabout

	AM Peak Hour		PM Peak Hour	
Improvement Concept 2 *Roundabout, with a 1-lane circulating lane, and three 1-lane approaches*	LOS	Average Delay (sec.)	LOS	Average Delay (sec.)
Massachusetts Avenue, northbound	A	4	A	10
Maple Street, westbound	A	9	A	8
Massachusetts Avenue, southbound	A	6	A	7
ALL VEHICLES:	A	7	A	8

This analysis shows that Improvement Concept 2, the installation of a roundabout at Massachusetts Avenue at Maple Street, would yield LOS A for all three approaches during both the AM and PM peak hours.

- Improvement Concept 3: Reconstruct all the sidewalks in the vicinity of this intersection, creating uniform and even surfaces for pedestrians to walk on safely.

- Improvement Concept 4: Restripe all lane and shoulder markings.

Discussion and Recommendations

Staff sought input from the Town of Lexington and MassHighway District 4 staff regarding analysis and recommendations at this location. All comments received are included in Appendix A-5.

The amount of traffic through this intersection appears to justify the installation of a traffic signal with an exclusive pedestrian phase. In addition, the heavy turns and the right-of-way available make this location a prime candidate for the construction of a roundabout. In the event that a roundabout is designed for construction, care must be taken to make it safe for pedestrians and bicyclists. Also, the design must include the right deflection angle at the point where each of the approaches meets the circulating lane so that reduced speeds are achieved.

CTPS staff favors the design and construction of a roundabout, but Town officials and the general public need to weigh in for the selection of one of the examined options. Specifically, the Town’s input included the following comments:

- At design time, the intersection needs to be studied along with the intersection of Massachusetts Avenue at Marrett Road, a few hundred yards to the north.

- The Town has a study under contract for a section of Massachusetts Avenue that includes this intersection.

- Alternatives to a roundabout design must be considered, as constructing a roundabout could have property impacts.

- Consider the proximity of the Minuteman Bike Trail in the redesign of the intersection.

- The intersection is within a zoned historic district; therefore, appropriate certificates and approvals are required.

Finally, according to MassHighway District 4 comments, regardless of which option is selected, design must consider the impacts to the driveways of the gas station at the northwest corner of the intersection and any historic issues related to the historic nature of Massachusetts Avenue.

In closing, staff recommends that the Town of Lexington proceed with design for this very important intersection to resolve traffic circulation and safety concerns at this location and vicinity.

6. LITTLETON: King Street (Route 110/2A) at Great Road (Route 119/2A)

Existing Conditions

Geometry/Physical Characteristics

This is a signalized intersection of two state-numbered arterials. Both roadways, including this intersection, are under state (MassHighway) jurisdiction. King Street (Route 110) has two general-purpose lanes both northbound and southbound. On each of the Great Road (Route 119) eastbound and westbound approaches there is an exclusive left-turn lane and one through/right-turn lane (see Figure 6-1). The posted speed limit is 25 miles per hour approaching the intersection from all directions. Leaving the intersection, the posted speed limit ranges from 35 to 45 miles per hour. Field reconnaissance in May, September, and December of 2007 showed that the crosswalks and lane markings were visible, but had begun to fade. In addition, the roadway surface appeared to be uneven and in need of repaving.

Traffic Control

This signal is fully-actuated, with four distinct signal phases during both the AM and PM peak periods: (1) leading westbound, (2) eastbound/westbound, (3) northbound/southbound, and (4) a manually activated, exclusive pedestrian phase which lasts 18 seconds, sufficient time for most pedestrians to cross any of the approaches. There are functioning pedestrian buttons on all four corners. However, the pedestrian signal faces are not uniform; some are red “hands,” some show “DON’T WALK.” At least one had become so misaligned that seeing the signal face from across the street was virtually impossible. Right turns on red (RTOR) are allowed on all four approaches. The current maximum peak period cycle length is 123 seconds in both peak hours.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

2007 AM and PM Peak Hour Turning Movements (vehicles)

AM Peak Hour (7:15–8:15)											
King Street (Route 110/2A)						Great Road (Route 119/2A)					
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
110	220	2	30	120	100	180	460	90	40	80	2
332 (total approach)			250 (total approach)			730 (total approach)			122 (total approach)		

- King Street, NB + SB approaches combined: 582 vehicles
- Great Road, EB + WB approaches combined: 852 vehicles
- Pedestrians (all approaches): N.A.
- Bicycles (all approaches): N.A.

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Safety and Operational Improvements at Selected Intersections

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FIGURE 6-1

Littleton: Great Road (Routes 2A/119) at King Street (Routes 2A/110)

PM Peak Hour (4:45–5:45)											
King Street (Route 110/2A)						**Great Road (Route 119/2A)**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
90	140	0	50	250	280	90	200	80	190	450	4
230 (total approach)			580 (total approach)			370 (total approach)			644 (total approach)		

- King Street, NB + SB approaches combined: 810 vehicles
- Great Road, EB + WB approaches combined: 1,014 vehicles
- Pedestrians (all approaches): N.A.
- Bicycles (all approaches): N.A.

The approach with the greatest AM peak hour volumes was Great Road eastbound, 730 total vehicles, including 180 left turns. In the PM peak hour, the approach with the greatest volumes was Great Road westbound, 644 vehicles, including 190 left turns. The highest individual turning movement was King Street southbound with 280 right turns during the PM peak hour.

It should be noted that two one-way streets exist near the intersection which effectively have removed all the right turns from two of the approaches (see Figure 6-1). Stevens Street connects King Street northbound and Great Road eastbound. The AM peak hour volume on this street was 340 vehicles while the PM peak hour volume was 270. Similarly, Meetinghouse Road connects Great Road westbound with King Street northbound. The AM peak hour volume on this street was 40 vehicles; the PM peak hour volume was 120 vehicles. As seen below in the Level Of Service section, the effect of these two streets is that the intersection experiences less delay and congestion than would otherwise have been the case.

Crashes

The vehicle crash rate for this location was 2.25 crashes per million vehicles entering the intersection. This significantly exceeds the most recent average crash rate of 0.84 for Mass-Highway District 3 area intersections. Specific characteristics of the vehicle crashes include:

- 70% of crashes were angle, higher than the 15-intersection study average of 51%. Examination of the RMV data revealed a distinct pattern for these crashes. By far, individual collisions involved combinations of vehicles from the eastbound and/or westbound approaches. Of the 31 recorded angle crashes, 20 (65%) involved one or more eastbound or westbound vehicles.

  Because of this pattern, the most likely causes for angle crashes appeared to be eastbound or westbound vehicles turning left and colliding with an opposite direction through vehicle. Some angle crashes also were due to vehicles in the same direction colliding, presumably when changing lanes near the intersection.

- 14% of crashes were rear-end, below the study average of 27% for rear-end crashes. This suggests that about one-eighth of all crashes occurred during congested, stop-and-go traffic conditions. Although few in number, five of the six recorded rear-end crashes were either on the eastbound or westbound approaches.

It should be noted that there is limited sight distance in the eastbound/westbound directions, since the eastbound approach is on an upgrade. This lack of full view of the intersection and of oncoming vehicles could therefore be a contributing factor in the high number of eastbound/westbound vehicle conflicts.

- 2% of crashes were head-on.
- 14% of crashes were other/undetermined.

Additionally:

- 2% of crashes (1 of 50) involved pedestrians. This one crash ocurred at 2 PM on a June afternoon under clear and dry road conditions and resulted in personal injury.
- 0% of crashes involved bicyclists.
- 36% of all crashes resulted in personal injuries.
- 66% of crashes occurred during April–October (spring, summer, fall); 34% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (9 of 50 crashes, or 18%, occurred during rain, snow, or fog).
- 78% of crashes occurred during daytime, 7 AM through 7 PM; 22% occurred during night-time, 7 PM through 7 AM. No predominant darkness-related crash patterns were seen.

Land Use

The surrounding land use is a mix of commercial, residential, town common green space, and, a bit further away, office complexes. Great Road links the intersection to I-495 (Exit 31), located about 1,000 feet to the west. There are no public transportation bus routes which service this location.

Level of Service (LOS)

Intersection LOS analysis showed that during the AM and PM peak hours the intersection operated at LOS C. This is very likely a lower level of service than would have been the case if Stevens Street and Meetinghouse Road did not divert large numbers of right turns from the intersection during the peak hours (see Figure 6-1). These LOS measures are broken down further by lane group and total approach, as shown in the following tables.

2007 Intersection LOS Summary (Existing Conditions)

	AM Peak Hour			PM Peak Hour		
Existing Conditions	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing*	C	32	22	C	29	26

Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

2007 LOS by Lane Group, Total Approach (Existing Conditions)

AM Peak Hour (7:15–8:15)											
King Street (Route 110/2A)						**Great Road (Route 119/2A)**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
	C			B		C	D		D	B	
C (total approach)			B (total approach)			D (total approach)			C (total approach)		
PM Peak Hour (4:45–5:45)											
King Street (Route 110/2A)						**Great Road (Route 119/2A)**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
	C			B		D	D		D	C	
C (total approach)			B (total approach)			D (total approach)			C (total approach)		

This reveals that during the AM and PM peak hours the Great Road eastbound approach experienced some delays and congestion, operating at LOS D. Queues were about 15–20 vehicles per cycle on this approach. The three remaining approaches operated at LOS B or C during both peak hours.

Conclusions/Significant Findings

- During field visits in May, September, and December of 2007, it was observed that very few pedestrians crossed through the intersection.

- Overall congestion levels and delays are light to moderate at this intersection. Traffic operated at LOS C during both the AM and PM peak hours. Queues were typically 20 or fewer vehicles per approach per signal cycle. Only the Great Road eastbound approach experienced some moderate delays, operating at LOS D during both peak hours. The westbound left turns also operated at LOS D during the peak hours.

- 70% of all crashes were angle, most of these by far involving vehicles traveling in the eastbound or westbound directions. Limited sight distance could be a contributing factor since the eastbound approach is on a significant upgrade. Another factor could be the absence of a left-turn arrow during the leading westbound phase. As a result, westbound drivers may believe they still have a protected left once the phase shifts to a permitted eastbound/westbound phase.

- Pedestrian signal heads are older and of various types. At least one was quite misaligned and difficult to see from across the street.

- The intersection and approaching roadway surfaces were uneven and in need of repaving.

Preliminary Conceptual Improvements

The following concepts for improving safety and traffic operations at this location were tested:

- Improvement Concept 1: Add an exclusive left-turn phase for left-turning vehicles on the eastbound/westbound approaches. This improvement was designed to give ample—and protected—time for vehicles turning left, and thereby reduce potential conflicts between turning and through vehicles. Left-turning vehicles would not be permitted to proceed once the eastbound/westbound phase for through vehicles has begun. The 18 seconds exclusive pedestrian phase would remain. This improvement concept optimized the cycle lengths to 80 seconds for the AM peak hour, and to 75 seconds for the PM peak hour.

- Improvement Concept 2: Implement a split phasing scheme between eastbound and westbound traffic; optimize the signal splits and cycle lengths. This improvement concept was intended to completely separate the eastbound and westbound traffic flows, turning as well as through vehicles, and thereby reduce the high number of crashes involving vehicles from these two directions. The exclusive pedestrian phase of 18 seconds would remain.

  The LOS results of existing conditions, and of Improvement Concepts 1 and 2, are shown in the following table.

Intersection LOS Summary: Existing Conditions, Improvement Concepts 1 and 2 (2007 Traffic Volumes)

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing* (123 secs. cy. le.)	C	32	22	C	29	26
Imp. Concept 1 *Add excl. l .turn phase EB/WB, optimize splits, cycle length* (AM: 80 secs PM: 75 secs)	C	24	14	C	26	15
Imp. Concept 2 *Add split phases EB/WB, optimize splits, cy. length* (90 secs. cy. le.)	C	29	16	D	36	22

cy. le. = cycle length
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

The LOS analyses showed that when Improvement Concept 1 was tested—the addition of an exclusive left turn phase for eastbound/westbound turning vehicles—traffic operations remained at LOS C, and yielded slightly shorter queues than during existing conditions. When Improvement Concept 2 was analyzed—the implementation of a split phase for eastbound and westbound traffic—the intersection would operate at LOS C in the AM peak hour, and LOS D in the PM peak hour. Overall queues in the intersection would also be shorter than current levels.

- Improvement Concept 3: Replace signal heads that may be of an older variety, particularly the pedestrian signal faces. Make sure all signal faces are LED and uniform in appearance, function, and alignment.

Discussion and Recommendations

Staff has received comments from MassHighway District 3, the Town of Littleton, and MAPC. The reader is referred to Appendix A-6 for the full text of the comments.

The focus of the analysis by staff was to separate and protect through traffic from turning traffic in the east-west (Great Road) direction, where the highest traffic volumes are. Concepts 1 and 2 are both effective in achieving a better level of service than existing conditions.

MassHighway District 3 staff commented that additional benefit could result from the change in lane use and subsequent protection of left turns at both King Street approaches in the following manner: "The northbound approach of King Street could be converted into an exclusive left-turn lane and a shared through/right lane. The southbound approach could then be modified into three lanes (by incorporating one of the two departing lanes of the northbound approach) with an exclusive left-turn lane, a through lane, and an exclusive right-turn lane. Both approaches would have only one departure (through) lane. As part of this improvement, the traffic signal timings and phasing at the intersection would have to be modified as well." The intersection could be reanalyzed with District's comments alone or in combination with Concepts 1 or 2. In either case, the traffic signal phase and timings would likely be different than those in Concepts 1 and 2.

The Town of Littleton is concerned that the traffic volumes used in the analysis do not reflect the likely traffic volumes, when the IBM plant opens nearby. Also, from historical information traffic volumes between 1987 and 1999 had been 25 to 40 percent higher than what was counted in 2007 for this study. In addition, the Town has a strong interest in maintaining this intersection pedestrian-friendly.

MAPC's comments reflect general agreement with the emphasis of the concepts which separate turning traffic from through traffic in order to minimize opportunities for conflicts. Extending the yellow and all-red intervals are another way to further reduce potential conflicts by drivers who "jump" the yellow or red interval. MAPC staff also recognizes the need for analyzing the intersection under 2009 conditions, when the IBM plant opens.

In light of all above comments, staff recommends that IBM and its consultants analyze the intersection again as part of the company's traffic mitigation plan. IBM will occupy fully (approximately 2,300 employees) the 550 King Street office park at the northwestern quadrangle of the intersection by mid-year 2009. According to the Town's comments, another 1,100 IBM employees will be located along Route 110 in Westford, just northeast of the intersection.

IBM and its consultants should consider the results of this study and the comments received by the Town, MassHighway, and MAPC, including: replacing the older traffic signal equipment; altering lane-use at the approaches to include exclusive left-turn lanes and protected traffic signal phases; extending yellow and all-red intervals; enhancing pedestrian crosswalks; and, establishing pedestrian signal phases of adequate length.

7. MARLBOROUGH: Bolton Street (Route 85) at Union Street

Existing Conditions

Geometry/Physical Characteristics

This is a signalized intersection, and is under local (City of Marlborough) jurisdiction. Bolton Street (Route 85) has one exclusive left-turn lane and a through/right-turn lane both northbound and southbound. On each of the Union Street eastbound and westbound approaches there is one general-purpose lane (see Figure 7-1). The posted speed limit on Bolton Street is 35 miles per hour, and on Union Street it is 25 miles per hour. Field reconnaissance in May, September, and December of 2007 showed that the crosswalks and lane marking were clear and visible.

Traffic Control

This signal is semi-actuated, with four distinct signal phases during both the AM and PM peak periods: (1) leading northbound, (2) northbound/southbound, (3) eastbound/westbound, and (4) a manually activated, exclusive pedestrian phase which lasts 19 seconds, sufficient time for most pedestrians to cross any of the approaches. It should be noted that there are crosswalks on all except the northbound approach. There are functioning pedestrian buttons on three of the four corners—none on the southeast corner. The pedestrian signal faces are clear and visible. Right turns on red (RTOR) are not allowed on any of the four approaches. The current maximum peak period cycle length is 94 seconds in the AM peak hour and 96 seconds in the PM peak hour.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

2007 AM and PM Peak Hour Turning Movements (vehicles)

AM Peak Hour (7:00–8:00)											
Bolton Street (Route 85)						Union Street					
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
60	430	20	120	570	50	70	160	30	30	150	130
510 (total approach)			740 (total approach)			260 (total approach)			310 (total approach)		

- Bolton Street, NB + SB approaches combined: 1,250 vehicles
- Union Street, EB + WB approaches combined: 570 vehicles
- Pedestrians (all approaches): 32
- Bicycles (all approaches): 1

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FIGURE 7-1

Marlborough: Bolton Street (Route 85) at Union Street

SOISI/Marlborough/Figure 7-1

PM Peak Hour (4:00–5:00)											
Bolton Street (Route 85)						Union Street					
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
20	610	20	120	520	70	80	180	50	20	110	200
650 (total approach)			710 (total approach)			310 (total approach)			330 (total approach)		

- Bolton Street, NB + SB approaches combined: 1,360 vehicles
- Union Street, EB + WB approaches combined: 640 vehicles
- Pedestrians (all approaches): 12
- Bicycles (all approaches): 1

The approach with the greatest AM peak hour volumes was Bolton Street southbound, 740 total vehicles. The single highest AM peak hour turning movement was Union Street westbound right turns, 130 vehicles; Bolton Street southbound had 120 left turns. In the PM peak hour, the approach with the greatest volumes was again Bolton Street southbound, 710 vehicles. The single highest PM peak hour turning movement was once more Union Street westbound, 200 right turns, while Bolton Street southbound left turns totaled 120 vehicles.

Crashes

The vehicle crash rate for this location was 2.36 crashes per million vehicles entering the intersection. This significantly exceeds the most recent average crash rate of 0.84 for Mass-Highway District 3 area intersections. Specific characteristics of the vehicle crashes include:

- 55% of crashes were angle. Examination of the RMV data revealed a distinct pattern for these crashes. Although individual collisions involved combinations of vehicles from all approaches, the southbound approach had by far the most angle crashes. 26 of the 32 angle crashes (81%) involved one or more vehicles from the southbound approach.

  The data showed that the highest combination of angle crashes occurred between southbound and northbound vehicles. This likely involved a southbound (or northbound) left-turning vehicle being struck by an opposing through vehicle. Of the identified angle crashes, 30% involved a southbound/northbound vehicle combination.

  One possible cause for the high number of southbound vehicles being involved in angle crashes is that the intersection is located on a crest, and sight distance is compromised for vehicles traveling in the southbound direction. Drivers in southbound vehicles may not see northbound vehicles turning left onto Union Street in time before arriving at the intersection, thereby colliding with the turning vehicle.

- 36% of crashes were rear-end, slightly above the 15-intersection study average of 27%. This suggests that more than one-third of all crashes occurred during congested, stop-and-go traffic conditions. Again, southbound vehicles dominated with ten of the 21 rear-end crashes (48%) occurring on the southbound approach. As with the angle crashes, drivers approaching from the north may arrive at the intersection rather suddenly due to compromised sight distance, and thus not be able to stop in time before colliding with a queued vehicle in front.

- 2% of crashes were head-on.
- 7% of crashes were other/undetermined.

Additionally:

- 3% of crashes (2 of 58) involved pedestrians. Of these, one ocurred at 7 AM on a March morning under clear and dry road conditions and resulted in personal injury. The second occurred at 2 PM on an April afternoon under clear and dry road conditions, and also resulted in personal injury.
- 2% of crashes (1 of 58) involved bicyclists. The one crash occurred at 8 AM on a rainy September morning and resulted in personal injury.
- 31% of all crashes resulted in personal injuries.
- 66% of crashes occurred during April–October (spring, summer, fall); 34% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (3 of 58 crashes, or 5%, occurred during rain, snow, or fog).
- 79% of crashes occurred during daytime, 7 AM through 7 PM, and 21% during night-time, 7 PM through 7 AM. No predominant darkness-related crash patterns were seen.

Land Use

The surrounding land use is a mix of single- and multiple-family homes. There is a middle school on the northeast corner and a gas station on the southeast corner. Marlborough Hospital is located about 0.25 miles to the west on Union Street. There are no public transportation bus routes which service this location.

Level of Service (LOS)

Intersection LOS analysis showed that the AM peak hour operated at LOS E, while the PM peak hour operated at LOS D. These measures are broken down further by lane group and total approach, as shown in the following tables.

2007 Intersection LOS Summary (Existing Conditions)

	AM Peak Hour			PM Peak Hour		
Existing Conditions	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing*	E	64	55	D	38	32

Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

2007 LOS by Lane Group, Total Approach (Existing Conditions)

AM Peak Hour (7:00–8:00)											
Bolton Street (Route 85)						**Union Street**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
D	C		D	D			F			D	
C (total approach)			D (total approach)			F (total approach)			D (total approach)		
PM Peak Hour (4:00–5:00)											
Bolton Street (Route 85)						**Union Street**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
D	C		D	C			F			D	
C (total approach)			C (total approach)			F (total approach)			D (total approach)		

This reveals that the eastbound approach operated at LOS F during both the AM and PM peak hours. The other three approaches operated at LOS C or D during both peak hours.

Conclusions/Significant Findings

- There are sight distance concerns at this intersection. Southbound vehicles arrive at the intersection from over a slight crest. Depending on the vehicle speed, conflicts can occur between southbound through vehicles, and, in particular, northbound left-turning vehicles.

- Union Street eastbound experienced the heaviest delays of all four approaches (LOS F in both the AM and PM peak hours), although vehicle queues were only moderate (6–22 vehicles per approach per cycle). The eastbound delays may be attributed to relatively high numbers of left turns and through vehicles as compared to the westbound direction traffic mix. The eastbound roadway downgrade may also be a factor in reducing traffic flow.

- It was observed that the leading northbound phase, designed to accommodate northbound left turns, was activated every cycle, even if there were no vehicles in the exclusive left-turn lane.

Preliminary Conceptual Improvements

At the outset, it is suggested that a complete intersection collision diagram be performed. This should be based on local police accident reports, and would provide an insight into exact crash patterns at and near this intersection.

The following concepts for improving safety and traffic operations at this intersection were tested:

- Improvement Concept 1: <u>Change the current semi-actuated signal timing to fully actuated; optimize the splits and cycle lengths.</u> This was to determine whether a re-allocation of green time and change in cycle length would reduce delays and queueing on some approaches. In addition, this change would cause the signal to activate the leading northbound phase only when there are vehicles actually queued in the northbound left-turn lane.

Three variations of this concept were tested:

a. Improvement Concept 1a optimized the signal timing splits, but used the current cycle lengths of 94 seconds for the AM peak hour and 96 seconds for the PM peak hour.

b. Improvement Concept 1b was identical to Improvement Concept 1a; however, RTOR were permitted on all approaches in order to improve overall traffic flow.

c. Improvement Concept 1c optimized both the signal splits and cycle lengths. RTOR were permitted, and a cycle length of 120 seconds was yielded for both the AM and PM peak hours.

- Improvement Concept 2: <u>Widen the Union Street westbound approach in order to add an exclusive right-turn lane.</u> The westbound right turns are the highest single turning movements in both the AM (130 turns) and PM (200 turns) peak hours. The northeast corner of the intersection is also the one location where there is some room to widen the roadway, depending on the available right-of-way. The other three corners are fully developed with either private driveways or lawns, or a gas station (see Figure 7-2). This improvement concern was optimized with a cycle length of 120 seconds for both the AM and PM peak hours.

  The LOS results of existing conditions and of Improvement Concepts 1 and 2 are shown in the following table.

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FIGURE 7-2

Improvement Concept 2

= **area of geometric changes**

Intersection LOS Summary: Existing Conditions and Improvement Concepts 1 and 2 (2007 Traffic Volumes)

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing* (AM: 94 secs PM: 96 secs)	E	64	55	D	38	32
Imp. Concept 1a *Optimize splits* (AM: 94 secs PM: 96 secs)	E	66	58	E	58	33
Imp. Concept 1b *Optimize splits, allow RTOR* (AM: 94 secs PM: 96 secs)	E	62	57	E	60	33
Imp. Concept 1c *Optimize splits, cycle length, allow RTOR* (120 secs. cy.le.)	D	52	58	D	42	44
Imp. Concept 2 *Add a westbound right turn lane* (120 secs. cy.le.)	D	44	63	C	32	41

cy. le. = cycle length
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

The LOS analyses showed that when the different variations of Improvement Concept 1 were analyzed, the intersection would still operate at LOS D or E. Only Improvement Concept 2, the widening of the westbound approach to create an exclusive right-turn lane, improved traffic operations to LOS C or D.

- Improvement Concept 3: <u>Add an LED sign on the southbound approach a few hundred feet north of the intersection warning drivers of an upcoming signal.</u> This improvement would be to counteract the diminished sight distance on the southbound approach due to the slight crest before the intersection. An additional remedy for this concern would be to lower the posted speed limit from 35 miles per hour to 25 miles per hour for vehicles approaching the intersection from the north.

- Improvement Concept 4: <u>Add a fourth pedestrian button—on the southeast corner where there is no button. Add a fourth crosswalk—on the northbound approach where one is lacking. Add curbing where possible on the southeast corner—the entire gas station road frontage is one large curb cut.</u>

Discussion and Recommendations

Staff sought feedback from Marlborough officials and MassHighway District 3 staff. The full text of their comments is available in Appendix A-7 for review.

MassHighway District 3 staff agreed with Improvement Concepts 1 through 5 above. In addition, they offered that, given the type of crashes occurring at this location (especially the high percentage of conflicts involving southbound vehicles), southbound traffic—not northbound traffic—should be assigned a lead phase. This recommendation is in agreement with a 1999 study performed by Vanasse Hangen Brustlin (VHB) for the City of Marlborough, which also recommended upgrading the signal equipment, pavement markings, American with Disabilities Act (ADA) ramps, sidewalks and other pedestrian amenities; widening of the westbound Union Street approach to provide for an exclusive right-turn lane and a through/left-turn lane; and, upgrading markings and signs to provide drivers with positive guidance to turning lanes.

The VHB recommendations are still valid since a comparison of the 1999 traffic volumes to those collected for this study in 2007 showed that traffic volumes have not increased since 1999. As a matter of fact, it appears that they have declined for many of the movements within the intersection.

Based on the input received, the following is recommended:

- Switch the northbound lead phase to the southbound direction and optimize the signal timing (Improvement Concept 1).

- Widen the westbound Union Street approach to provide an exclusive right-turn lane and a through/left-turn lane (Improvement Concept 2).

- Upgrade signs and markings to direct traffic to the appropriate lanes (Improvement Concept 3).

- Upgrade traffic signal equipment, including the controller, signal heads, and mast arm(s) (Improvement Concept 4).

- Allow westbound right-turning traffic to proceed during the southbound lead phase.

- Retain the existing exclusive pedestrian phase of 19 seconds

- Provide improved sidewalks, crosswalks, and ADA ramps.

8. MEDFIELD: North Meadows Road/Spring Street (Route 27) at Main Street (Route 109)

Existing Conditions

Geometry/Physical Characteristics

This is a signalized intersection, and is under local (Town of Medfield) jurisdiction. Route 27, which is North Meadows Road north of the intersection and Spring Street south of the intersection, has a general-purpose lane and an exclusive left-turn lane on both the northbound and southbound approaches. The left-turn lanes have storage for 9 vehicles northbound and 17 vehicles southbound, respectively. There are also short, channelized, exclusive right-turn lanes on both approaches, which have room for 3 vehicles northbound and 2 vehicles southbound. Main Street (Route 109) eastbound and westbound each has an exclusive left-turn lane and a through/right-turn lane. The left-turn lanes have storage for 8 and 5 vehicles, eastbound and westbound, respectively (see Figure 8-1).

The posted speed limit is 25 miles per hour approaching the intersection from all four directions. Leaving the intersection, the speed limit is 40, 35, and 25 miles per hour on North Meadows Road northbound/Spring Street southbound, Main Street westbound, and Main Street eastbound, respectively. Field reconnaissance in May and September of 2007 showed that the crosswalks and roadway lane markings on all four approaches were faded.

Traffic Control

This is a fully-actuated signal that has five distinct signal phases during both the AM and PM peak periods: (1) leading northbound/southbound left turns, (2) northbound/southbound throughs/right turns only, (3) leading eastbound/westbound left turns, (4) eastbound/westbound throughs/right turns only, and (5) a manually activated, exclusive pedestrian phase which lasts 15 seconds, sufficient time for most pedestrians to cross any of the approaches. There are functioning pedestrian buttons on all corners. The current maximum peak period cycle length is 120 seconds. Right turns on red (RTOR) are permitted.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

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FIGURE 8-1

Medfield: Main Street (Route 109) at North Meadows Road/Spring Street (Route 27)

2007 AM and PM Peak Hour Turning Movements
(vehicles)

AM Peak Hour (7:30–8:30)											
North Meadows Road/Spring Street (Route 27)						Main Street (Route 109)					
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
100	350	200	130	300	10	30	560	90	80	260	70
650 (total approach)			440 (total approach)			680 (total approach)			410 (total approach)		

- North Meadows Road/Spring Street, NB + SB approaches combined: 1,090 vehicles
- Main Street, EB + WB approaches combined: 1,090 vehicles
- Pedestrians (all approaches): 4
- Bicycles (all approaches): 1

PM Peak Hour (5:00–6:00)											
North Meadows Road/Spring Street (Route 27)						Main Street (Route 109)					
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
190	330	110	150	340	30	50	330	120	200	550	80
630 (total approach)			520 (total approach)			500 (total approach)			830 (total approach)		

- North Meadows Road/Spring Street, NB + SB approaches combined: 1,150 vehicles
- Main Street, EB + WB approaches combined: 1,330 vehicles
- Pedestrians (all approaches): 6
- Bicycles (all approaches): 1

The approaches with the greatest AM peak hour volumes were Main Street eastbound, 680 total vehicles, and Spring Street northbound, 650 vehicles. The single highest AM peak hour turning movement was Spring Street northbound right turns, 200 vehicles. The approach with the greatest PM peak hour volumes was Main Street westbound, 830 vehicles. The highest PM peak hour turning movements were Main Street westbound left turns, 200 vehicles, and Spring Street northbound left turns, 190 vehicles.

Crashes

The vehicle crash rate for this location was 1.82 crashes per million vehicles entering the intersection. This significantly exceeds the most recent average crash rate of 0.84 for Mass-Highway District 3 area intersections. Specific characteristics of the vehicle crashes include:

- 51% of crashes were angle. Examination of the RMV data revealed no distinct crash patterns for these crashes. Individual collisions involved combinations of vehicles from all approaches. This “non-pattern” of angle crashes was confirmed somewhat during field reconnaissance. When observing turning movements during both the AM and PM peak hours, numerous near-collisions were seen involving turning and through vehicles from all directions. Based on field observations, the likely cause(s) for the angle crashes that actually do occur appeared to be vehicles from all approaches attempting to "beat the yellow light," as well as vehicles attempting to turn left during very short gaps in the opposing through traffic stream.

- 24% of crashes were rear-end. This suggests that one-fourth of all crashes occurred during congested, stop-and-go traffic conditions. The distinct pattern seen in the data involved vehicles traveling on Spring Street northbound and Main Street eastbound. Of the 13 rear-end crashes recorded, five (38%) occurred when a northbound vehicle rear-ended another northbound vehicle, and five occurred when an eastbound vehicle rear-ended another eastbound vehicle.

- 2% of crashes were head-on.

- 24% of crashes were other/undetermined.

Additionally:

- 0% of crashes involved pedestrians.

- 0% of crashes involved bicyclists.

- 31% of all crashes resulted in personal injuries.

- 60% of crashes occurred during April–October (spring, summer, fall); 40% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (7 of 55 crashes, or 13%, occurred during rain, snow, or fog).

- 78% of crashes occurred during daytime, 7 AM through 7 PM; 22% occurred during night-time, 7 PM through 7 AM. No predominant darkness-related crash patterns were seen.

Land Use

This is a very busy, suburban intersection in the central part of Medfield. North Meadows Road/ Spring Street (Route 27) is a north-south arterial connecting numerous town centers in a circular pattern about 20–30 miles from Boston. Main Street (Route 109) runs east-west between town centers, and links Boston (West Roxbury) with I-95 (Route 128), I-495, and beyond, in a southwesterly direction.

The immediate surrounding land use consists of a Friendly's Restaurant on the northwest corner; a gas station on the southwest corner; a CVS, liquor store, and professional building on the northeast corner; and, a small town park on the southeast corner. The remainder of the town business district continues eastward along Main Street. There are no public transportation bus routes or commuter rail lines that service this location.

Level of Service (LOS)

Intersection LOS analysis showed that both the AM and PM peak hours operated at LOS F. These measures are broken down further by lane group and total approach, as the tables below show.

2007 Intersection LOS Summary (Existing Conditions)

	AM Peak Hour			PM Peak Hour		
Existing Conditions	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing*	F	* (102)	68	F	* (123)	80

* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

2007 LOS by Lane Group, Total Approach (Existing Conditions)

AM Peak Hour (7:30–8:30)											
North Meadows Road/Spring Street (Route 27)						**Main Street (Route 109)**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
E	F	D	E	F	C	E	F		F	D	
F (total approach)			F (total approach)			F (total approach)			D (total approach)		
PM Peak Hour (5:00–6:00)											
North Meadows Road/Spring Street (Route 27)						**Main Street (Route 109)**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
F	F	C	E	F	C	E	D		F	F	
F (total approach)			F (total approach)			D (total approach)			F (total approach)		

Three approaches operated at LOS F during the AM and PM peak hours. Only Main Street westbound operated at LOS D during the AM peak hour, while Main Street eastbound operated at LOS D during the PM peak hour. AM peak hour queues ranged from 12 to 22 vehicles per approach per signal cycle; the PM peak hour queues ranged from 13 to 33 vehicles per approach per signal cycle.

Conclusions/Significant Findings

- Peak period delays are significant. There is not enough peak hour intersection capacity, and there are long queues on all approaches. Cycle failures were observed where queued vehicles needed more than one cycle to pass through the intersection.
- Numerous near-collisions were observed on all four approaches at this intersection. Turning vehicles nearly crashed with through vehicles as well as with other turning vehicles.

- Some vehicle conflicts were observed at the CVS driveways 50–75 feet to the north of the intersection on North Meadows Road. Vehicles exiting the driveways and turning left interrupted the northbound traffic flow, causing vehicles to back up into the intersection.

Preliminary Conceptual Improvements

The following concepts for improving safety and traffic operations at this intersection were tested:

- Improvement Concept 1: Optimize the AM and PM peak hour signal timing splits and cycle lengths. This was tested to determine whether a re-allocation of green time and change in cycle length would reduce queueing and alleviate congestion on some approaches. This improvement concept, when optimized, yielded the same as the existing cycle length, 120 seconds, for both the AM and PM peak hours.

- Improvement Concept 2: Replace the exclusive pedestrian phase with a concurrent pedestrian phase. Two variations of this concept were performed:

  a. Most of the approaches at this intersection have low, to moderate, numbers of left- and right-turn volumes. “Crash data consistently show that crashes with pedestrians occur far more often with turning vehicles than with straight-through traffic. Left-turning vehicles are more often involved in pedestrian collisions than right-turning vehicles, partly because drivers are not clearly able to see pedestrians on the left.”[14]

     It should also be noted that based on field visits during the AM and PM peak periods, few pedestrians or bicyclists were observed crossing through the intersection. The manual turning movement counts, performed in June, 2007, recorded four and six pedestrians, and one bicyclist each, in the AM and PM peak hours, respectively.

     With this in mind, the existing exclusive pedestrian phase stops traffic on all approaches while pedestrians are allowed to cross in any direction. Replacing the exclusive phase with a concurrent one would allow pedestrians to cross parallel with vehicles that have a green signal. Although it is acknowledged that this is not a safety-oriented improvement for pedestrians and bicyclists, it is more of a theoretical exercise designed to reduce vehicle delay by providing more time for vehicles to travel through the intersection. However, in order to eliminate conflicts between pedestrians and left-turning vehicles, the concurrent pedestrian signal would not display “WALK” during the green exclusive left-turn phases. Rather, it would only display “WALK” during the green throughs/right-turn signal phases. In addition, RTOR would not be permitted. This improvement concept was optimized to a 120 second cycle length for both the AM and PM peak hours (Improvement Concept 2a).

[14] From U.S. Department of Transportation, Federal Highway Administration, *Intersection Safety Issue Briefs, No. 9, Pedestrian Safety at Intersections*, p. 2, April 2004.

b. Replace the exclusive pedestrian phase with a concurrent pedestrian phase. However, to "return" a measure of safety to pedestrians and bicycles, while at the same time reducing vehicle delays, implement a Leading Pedestrian Interval (LPI) by extending the all-red signal phase to four or more seconds. For the approach about to receive a green signal, the LPI "illuminates the pedestrian WALK signal, while the motor vehicle signal remains red for the first few seconds of the cycle. The LPI gives pedestrians an opportunity to start walking and establish a presence in the crosswalk before drivers can begin their turn."[15] This improvement concept was analyzed with an LPI of 4 seconds for the all-red phase, and was optimized to a 120 second cycle length for both the AM and PM peak hours. Again, RTOR would not be permitted (Improvement Concept 2b).

- Improvement Concept 3: Add 12-foot wide exclusive right-turn lanes to the Main Street (Route 109) eastbound and westbound approaches. (This improvement concept may be difficult to implement due to limited available right-of-way; however, for illustrative purposes, it is included in order to show the capacity improvements required to reduce congestion and delays, and to improve intersection level of service.) Depending on available right-of-way, a four-lane cross section on both Main Street approaches (eastbound and westbound) would be created. This could be accomplished by taking strips of land from the southwest (by the gas station) and northeast (near the liquor store) corners, approximately 150–200 feet in length along Main Street. The westbound approach would also lose one or two on-street parking spaces (in front of the liquor store). Finally, included in this improvement concept would be the extension of the Spring Street (Route 27) northbound right-turn lane, to accommodate the large number of right turns. This would be done by taking 150–200 feet of land along the town park on the southeast corner (see Figure 8-2). Two variations of this concept were analyzed:

a. The exclusive pedestrian phase of 15 seconds was retained, and the concept was optimized to 120 second cycle lengths for both the AM and PM peak hours. RTOR would be permitted (Improvement Concept 3a).

b. The exclusive pedestrian phase would be replaced by a concurrent pedestrian phase, including an LPI of 4 seconds for the all-red phase. The cycle lengths would be optimized to 100 seconds for both the AM and PM peak hours. RTOR would not be permitted in this variation (Improvement Concept 3b).

The LOS results of existing conditions, and of Improvement Concepts 1, 2, and 3 are shown in the following table.

[15] See www.saferoutesinfo.org/guide/engineering/traffic_signals.cfm, *Reduce the Number of Motor Vehicle Movements that Conflict with Pedestrians*. For a case study, go to: www.walkinginfo.org/pedsafe/casestudy.cfm?CS_NUM=66.

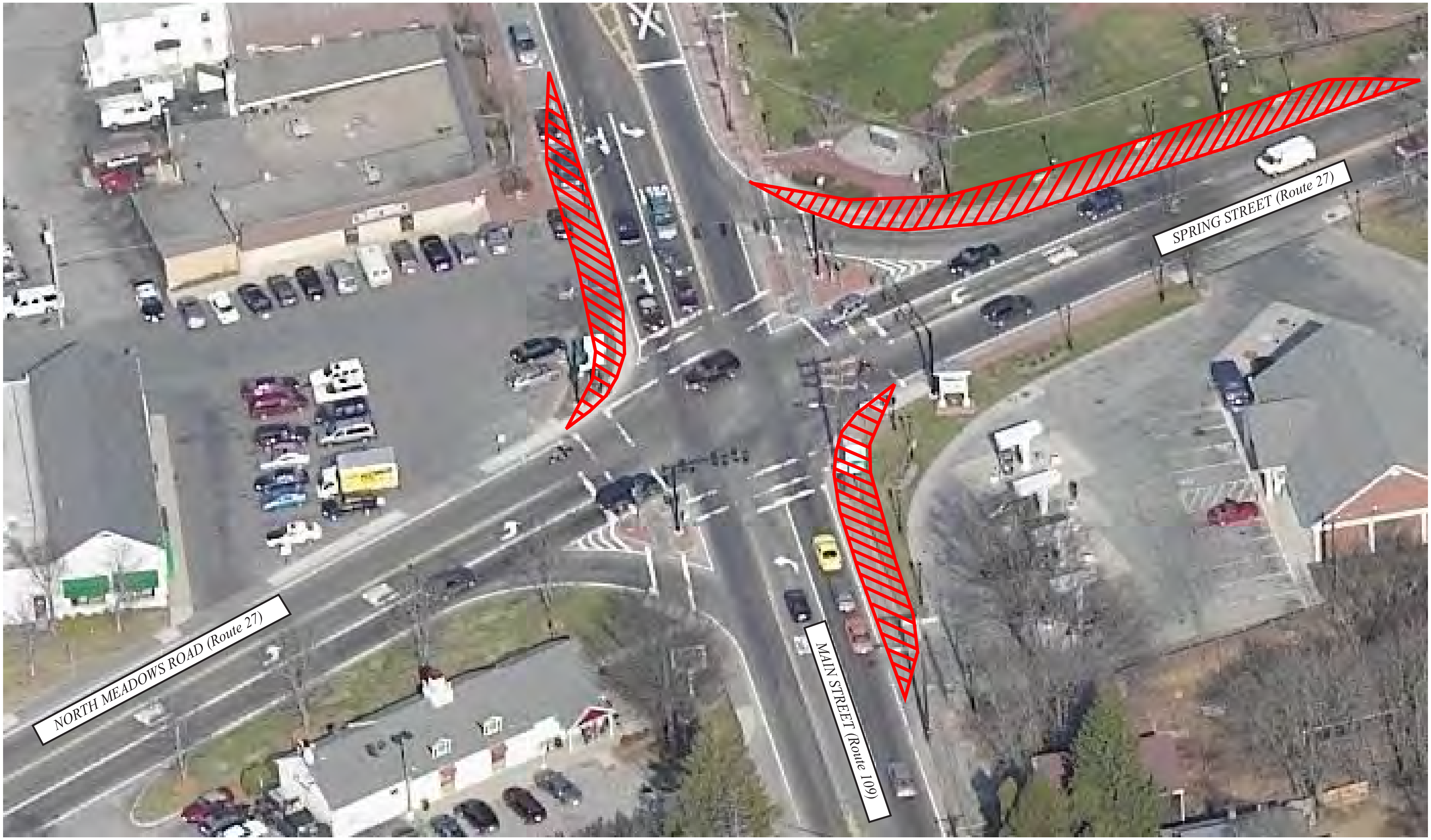

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FIGURE 8-2

Improvement Concept 3

= **area of geometric changes**

Intersection LOS Summary: Existing Conditions and Improvement Concepts 1, 2, and 3 (2007 Traffic Volumes)

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing* (120 secs. cy. le.)	F	* (102)	68	F	* (123)	80
Imp. Concept 1 *Optimized splits, cycle lengths* (120 secs. cy. le.)	F	* (82)	63	F	* (95)	75
Imp. Concept 2a *Concurrent ped. phase* (120 secs. cy. le.)	E	75	74	F	* (85)	87
Imp. Concept 2b *Concurrent ped. phase + LPI* (120 secs. cy.le.)	F	* (84)	77	F	* (95)	90
Imp. Concept 3a *EB/WB excl. right-turn lane, excl. ped phase* (120 secs. cy. le.)	E	59	54	E	66	64
Imp. Concept 3b *EB/WB excl. right-turn lane + LPI ped phase* (100 secs. cy. le.)	E	65	59	E	72	70

cy. le. = cycle length
* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

The LOS analyses showed that when Improvement Concepts 1 or 2 were analyzed, delays were slightly reduced. However, queues generally became somewhat longer and the intersection would still operate at LOS E or F. The queue lengths would range from 12–31 vehicles per approach per signal cycle during the AM and PM peak hours.

Only in Improvement Concept 3, the addition of right-turn lanes on Main Street eastbound and westbound, and the extension of the Spring Street northbound right-turn lane, would traffic operations improve to LOS E in all circumstances. Additionally, in this concept the queue lengths are consistently the lowest, ranging from 10–24 vehicles per approach per signal cycle during both peak hours.

- Improvement Concept 4: <u>Consider moving and/or consolidating the CVS driveways on the east side of North Meadows Road, north of the intersection.</u> In order to reduce “turbulence” near the intersection from vehicles exiting onto North Meadows Road and making left turns, consider consolidating the two CVS driveways into one wide driveway as far from the intersection as possible. Alternatively, it might be possible to utilize the space between CVS and the small professional building just to the north on North

Meadows Road. Perhaps vehicles could enter the premises via the existing driveway closest to the CVS building, and then exit via a new, one-way driveway between CVS and the professional building to the north. In this concept, there would likely be some land takings of the space between the two buildings in order to realize this improvement (see Figure 8-3).

Discussion and Recommendations

CTPS staff sought feedback on the preceding analysis from Medfield town officials and MassHighway District 3 staff. All comments received are shown in Appendix A-8.

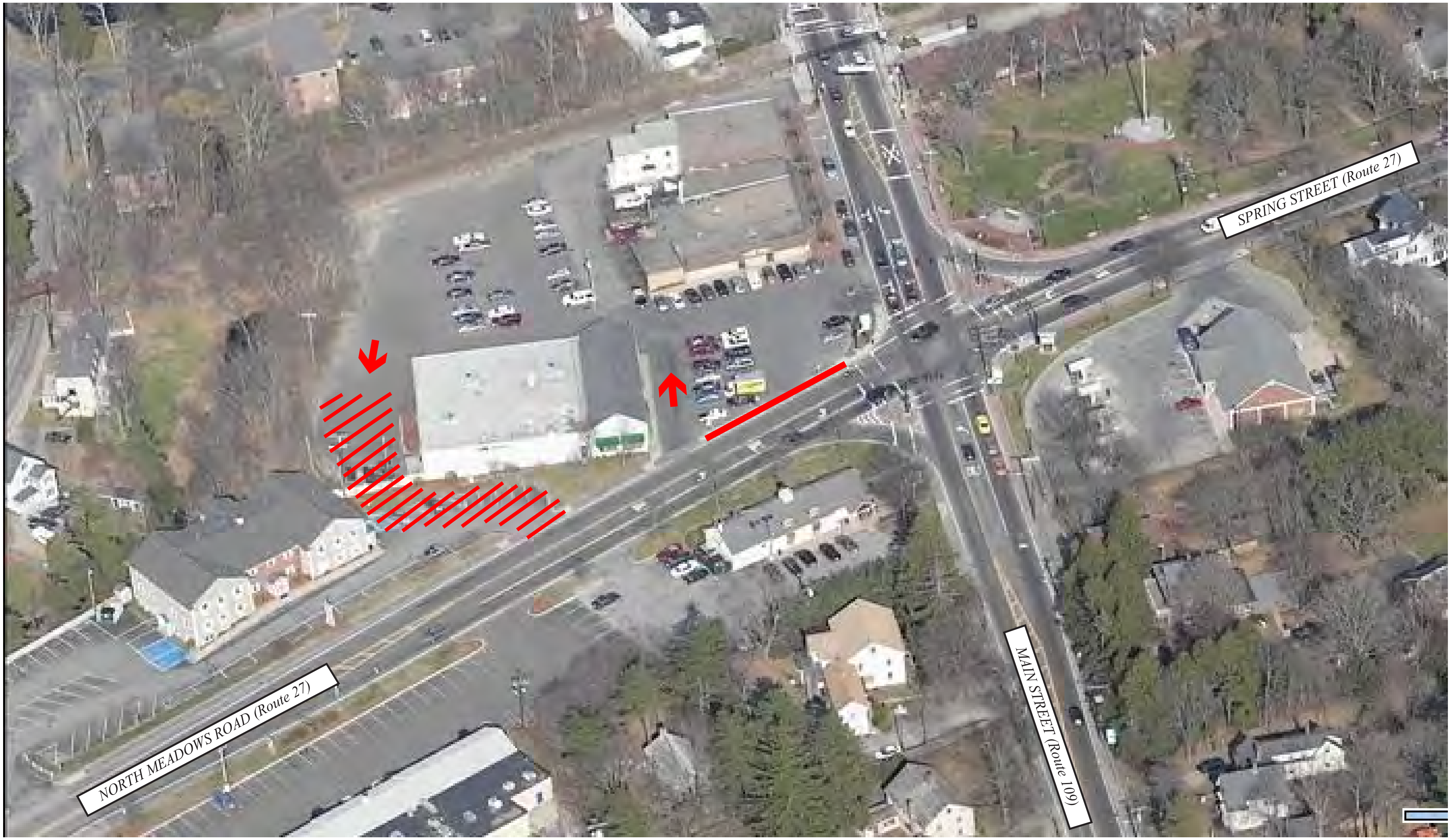
Traffic flows through this intersection are high. A review of a recent MPO study, "Route 109 Corridor Transportation Planning Study", March 2003, showed that traffic had grown significantly between 2002 and 2007, with growth ranging between 10 and 25 percent depending on the location. In addition, traffic volumes contain a high percentage of trucks, approximately 10%, the highest proportion of trucks in traffic of all observed intersections along Route 109.

On the supply side, the intersection's geometric design is appropriate for the level and type of traffic flows through it in yielding the maximum capacity that is allowed within the available right-of-way. The geometric and traffic signal designs are well-coordinated and provide adequate separation between conflicting traffic flows. In spite of the left-turn protection that the signal's design provides at this location, 51 percent of the crashes are of the angle type. There may be several reasons for this: either not all of the left turns are served during the exclusive phases and some motorists force themselves through the intersection during the change intervals; there may be conflicts between right turns (RTOR are allowed) and through traffic; angle crashes occur at driveways accessing properties around the intersection; or, and most likely, for all these reasons combined. The only way to find out precisely where the crashes occurred within the intersection is to construct a collision diagram from detailed police and operators crash reports, not available to staff for this analysis.

Implementing Improvement Concept 1, which optimized signal splits and cycle lengths, would yield, roughly, a 20 percent reduction in the overall intersection delay, while the level of service and queues would remain the same. This concept is recommended and would be inexpensive to implement.

Improvement Concepts 2a and 2b, concurrent pedestrian phase or concurrent pedestrian phase with leading pedestrian interval, respectively, are not recommended. According to the preceding discussion, the intersection carries high volumes, including high volumes of trucks. Pedestrians would be safer if they triggered the exclusive pedestrian phase manually, when needed. In addition, when compared to Improvement Concept 1, the improvement in delay and level of service would be marginal, and could jeopardize pedestrian and bicyclist safety.

Improvement Concepts 3a and 3b, the addition of eastbound/westbound exclusive right-turn lanes, would require right-of-way takings and elimination of a few parking spaces. In addition, construction costs would be significant, as sidewalks and other pedestrian amenities would have to be reconstructed. The resulting benefit would be a reduction in overall delay by 50 percent compared to existing conditions, and by 30 percent compared to Improvement Concept 1. The



CTPS

Safety and Operational Improvements at Selected Intersections

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FIGURE 8-3

Improvement Concept 3

= **area of geometric changes**

level of service would be better than during existing conditions, but would still be unacceptable. The queue lengths would remain roughly the same.

Improvement Concept 4, driveway consolidation, is a good recommendation and would help alleviate secondary crashes and reduce turbulence around the intersection. The Town of Medfield would need to facilitate this effort between the CVS establishment and adjacent property owners.

All in all, Improvement Concepts 1 and 4 are the recommendations of staff to improve traffic conditions somewhat at this intersection.

9. PEABODY: Central Street at Tremont Street

Existing Conditions

Geometry/Physical Characteristics

This is an unsignalized intersection, and is under local (City of Peabody) jurisdiction. Central Street has one general-purpose lane on each of the northbound and southbound approaches. Tremont Street is stop-controlled, has one general-purpose lane, and approaches the intersection in the westbound direction. Central Street southbound, although marked as one lane, is wide enough to accommodate left-turning vehicles onto Tremont Street to line up separately (about six cars deep) from through vehicles. Likewise, where Tremont Street meets Central Street, it is sometimes possible for two vehicles to line up side-by-side (just one car deep) and turn left or right, respectively (see Figure 9-1). The posted speed limit on both streets is 30 miles per hour. Field reconnaissance in May and September of 2007 showed that the crosswalks had begun to fade. There are crosswalks on the southbound and westbound approaches.

Traffic Control

The only traffic control at this intersection is a stop sign for Tremont Street westbound traffic. However, about 100 feet to the south, there is a side street intersecting Central Street from the west, Warren Street. That intersection is also unsignalized; however, there are flashing beacons—yellow for Central Street, red for Warren Street traffic. The flashing beacons also become a pedestrian-activated signal by means of four push buttons on all four corners. The exclusive pedestrian phase lasts 19 seconds.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

2007 AM and PM Peak Hour Turning Movements (number of vehicles)

AM Peak Hour (7:30–8:30)											
Central Street						**Tremont Street**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
N.A.	670	60	360	630	N.A.	N.A.	N.A.	N.A.	40	N.A.	420
730 (total approach)			990 (total approach)			N.A.			460 (total approach)		

- Central Street, NB + SB approaches combined: 1,720 vehicles
- Tremont Street, WB approach: 460 vehicles
- Pedestrians (all approaches): 0
- Bicycles (all approaches): 0

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Safety and Operational Improvements at Selected Intersections

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FIGURE 9-1

Peabody: Central Street at Tremont Street

PM Peak Hour (4:30–5:30)											
Central Street						**Tremont Street**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
N.A.	620	100	360	780	N.A.	N.A.	N.A.	N.A.	70	N.A.	340
720 (total approach)			1,140 (total approach)			N.A.			410 (total approach)		

- Central Street, NB + SB approaches combined: 1,860 vehicles
- Tremont Street, WB approach: 410 vehicles
- Pedestrians (all approaches): 0
- Bicycles (all approaches): 1

The approach with the greatest AM peak hour volumes was Central Street southbound, 990 total vehicles, including 360 left turns onto Tremont Street. In the PM peak hour, the approach with the greatest volumes was again Central Street southbound, 1,140 vehicles, including 360 left turns onto Tremont Street. The greatest single turning movement count was on Tremont Street, where right-turning vehicles totaled 420 during the AM peak hour.

Crashes

The vehicle crash rate for this location was 1.42 crashes per million vehicles entering the intersection. This exceeds the most recent average crash rate of 0.63 for Mass-Highway District 4 area unsignalized intersections. Specific characteristics of the vehicle crashes include:

- 46% of crashes were angle. Examination of the RMV data revealed that Tremont Street westbound vehicles were involved in 10 of the 15 angle crashes recorded (67%). These crashes involved westbound vehicles colliding with vehicles from the northbound or southbound approaches.The distribution was fairly uniform with respect to the number of westbound turning vehicles colliding with northbound or southbound vehicles.

  The most likely cause for the angle crashes appeared to be westbound vehicles attempting to turn right or left onto Central Street. Since gaps in the northbound and southbound vehicle streams were often short and infrequent during the AM and PM peak hours, conflicts occurred between vehicles entering or exiting the intersection perpendicular to each other.

  It is noteworthy that Tremont Street westbound right turns outnumber the left turns 11 to 1 in the AM peak hour, and 5 to 1 in the PM peak hour. However, the crashes involving westbound vehicles with an equal number of northbound and southbound vehicles does make some sense. Although fewer in number, the westbound left turns onto Central Street southbound were far more precarious than the right turns due to having to cross the northbound lane, turning in front of southbound left-turning queued vehicles, and then avoiding colliding with southbound through vehicles that bypassed the left-turning queue. These maneuvers often included obscured views due to the presence of other vehicles.

- 26% of crashes were rear-end. This suggests that one-fourth of all crashes occurred in congested, stop-and-go traffic. The only somewhat distinct pattern involved vehicles traveling southbound—four of the nine rear-end crashes were on the southbound approach (44%).

- 10% of crashes were head-on.

- 18% of crashes were other/undetermined.

Additionally:

- 0% of crashes involved pedestrians.

- 3% of crashes (1 of 39) involved bicyclists. This one crash occurred at 7 PM on a November evening under dry, clear, and dark (but lighted) road conditions, and resulted in personal injury.

- 54% of all crashes resulted in personal injuries. The average number of crashes with personal injuries for the 15 intersections included in this study was 35%. This intersection therefore had a significantly above average rate of injury-related crashes. This may possibly be due to the unsignalized nature of the intersection, where Tremont Street vehicles might have been apt to proceed out into insufficient gaps if the Central Street vehicle stream was too long and congested, and thereby collide with Central Street vehicles.

- 72% of crashes occurred during April–October (spring, summer, fall); 28% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (8 of 39 crashes, or 21%, occurred during rain, snow, or fog).

- 64% of crashes occurred during daytime, 7 AM through 7 PM; 36% occurred during night-time, 7 PM through 7 AM. Although no predominant darkness-related crash patterns were seen, this percentage (36%) of crashes occurring in the evening/night-time was the second highest of all 15 study area intersections. It is conceivable that there is not enough lighting at or near the intersection, thereby contributing to the high number of darkness-related crashes.

Land Use

The surrounding land use is mostly single- and multiple-family homes, with just two or three local neighborhood businesses nearby. There are municipal and office buildings a few blocks to the north, as well as the downtown Peabody commercial district to the south. MBTA buses #s 435 and 465 serve this area and the Central Street corridor.

Level of Service (LOS)

LOS analysis for this unsignalized intersection, by approach, is shown below.

2007 LOS Summary, by Approach (Existing Conditions)

	AM Peak Hour: LOS / Delay			PM Peak Hour: LOS / Delay		
Existing Conditions	Tremont St		Central St	Tremont St		Central St
	WB lefts	WB rights	SB lefts	WB lefts	WB rights	SB lefts
2007 *Existing*	F / * (77)	C / 16	B / 15	F / * (259)	B / 13	C / 15

* = 50 or more seconds total delay per vehicle. When unsignalized intersection approach delay is 50 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.

This reveals that the Tremont Street westbound left turns operated at LOS F during both the AM and PM peak hours. The westbound right turns operated at LOS C and B, and the Central Street southbound left turns operated at LOS B and C, during the AM and PM peak hours, respectively.

Conclusions/Significant Findings

- Crashes at this intersection led to the highest rate of injuries (54% of all crashes), compared to the 14 other MPO area intersections included (overall study average, 35%). Based on an analysis of the crash data, and corroborated from numerous field visits, this appeared to stem from sudden intrusions of side street (Tremont Street) traffic into the short gaps in the main street (Central Street) traffic stream, thereby not giving the main street vehicles enough time to slow down before collisions occurred.

- Overall, traffic operated at a virtual “free-for-all” during the AM and PM peak hours. Many near-collisions were observed between vehicles turning left from Tremont Street and almost colliding with Central Street southbound left turns, as well as with through vehicles.

- Tremont Street westbound peak hour queues were observed to be well over 20 vehicles, more than what could be seen beyond the roadway curvature.

- Central Street northbound vehicles occasionally backed up into this intersection, possibly extending southward from the downstream signalized intersection of Central Street, Endicott Street, and Andover Street (Route 114), 0.3 miles to the north.

- The intersection is very bicycle- and pedestrian-unfriendly. Since the intersection is unsignalized, there is no pedestrian signal or protected phase when pedestrians can safely cross the through the intersection. This impression was confirmed by the very few pedestrians observed during the manual turning movement counts: none in the AM peak hour and one in the PM peak hour, respectively. As mentioned above, however, there is an actuated pedestrian signal at Central Street at Warren Street, about 100 feet to the south.

- Crosswalk markings and other lane stripings had begun to fade.

Preliminary Conceptual Improvements

The following concepts for improving safety and traffic operations at this intersection were tested:

- Improvement Concept 1: A warrant analysis for installing a traffic signal was performed. From this analysis, the following warrants were met:

Warrant	Met?
1. Eight-hour vehicular volume	Probably *(more count data needed)*
2. Four-hour vehicular volume	Yes
3. Peak hour	Yes
4. Pedestrian volume	➔ *(Not tested; there is a pedestrian sig-*
5. School crossing	➔ *nal 100 ft to the south at Warren St.)*
6. Coordinated signal system	N.A.
7. Crash experience	Probably *(more field trials needed)*
8. Roadway network	Yes

If it is determined that a new traffic signal is appropriate, it would provide increased safety for all pedestrians, bicyclists, and vehicles, especially those vehicles wishing to turn from Tremont Street onto Central Street. Also, Table 1 above showed that this location had the third highest Crosswalk Pedestrian Intersection Safety Index (Ped ISI) of all 15 study intersections, an index of 3.6. As Table 1 and the source below describe, the higher the Ped ISI, the greater the "priority for an indepth safety assessment."[16] Although no pedestrian-related crashes, and one bicycle-related crash, were seen in the data, the intersection has a high PED ISI due to the high traffic volumes on both Central Street and Tremont Street, the posted speed limits, and the absence of a traffic signal.

A LOS analysis was performed for a hypothetical new traffic signal, assuming the current intersection geometry, lane allocation, and peak hour volumes. Three variations of this improvement concept were examined (Improvement Concepts 1a, 1b, and 1c).

In Improvement Concept 1a, optimized to a 100 second cycle length for the AM peak hour, and a 120 second cycle length for the PM peak hour, the signal phasing scheme included a four-phase sequence: (1) a leading southbound (Central Street) all-traffic phase to accommodate the numerous left turns onto Tremont Street; (2) a northbound/ southbound (Central Street) phase; (3) a westbound (Tremont Street) phase; and, (4) an exclusive pedestrian phase of 15 seconds, sufficient time to cross any of the intersection approaches.

In Improvement Concept 1b, the exclusive pedestrian phase was replaced by a concurrent pedestrian phase and analyzed with a 90 second cycle length for the AM peak hour, and a 60 second cycle length for the PM peak hour.

Improvement Concept 1c also replaced an exclusive pedestrian phase with a concurrent pedestrian phase. However, in this improvement concept a Leading Pedestrian Interval (LPI) was implemented on each signal phase by extending the all-red signal phase to 4 seconds. For the approach about to receive a green signal, the LPI "illuminates the pedestrian WALK signal, while the motor vehicle signal remains red for the first few

[16] U.S. Department of Transportation, Federal Highway Administration, *Pedestrian and Bicyclist Intersection Safety Indices*, Publication No. FHWA–HRT–06–129, p. 1, April 2007; see www.tfhrc.gov/safety/pedbike/pubs/06129/06129.pdf

seconds of the cycle. The LPI gives pedestrians an opportunity to start walking and establish a presence in the crosswalk before drivers can begin their turn."[17] This improvement concept used cycle lengths of 90 and 70 seconds for the AM and PM peak hours, respectively.

The LOS results for the existing conditions as well as for Improvement Concepts 1a, 1b, and 1c are shown in the following tables.

Intersection LOS Summary: Existing Conditions and Improvement Concepts 1a, 1b and 1c (2007 Traffic Volumes)

Unsignalized

	AM Peak Hour: LOS / Delay			PM Peak Hour: LOS / Delay		
Existing Conditions	Tremont St		Central St	Tremont St		Central St
	WB lefts	WB rights	SB lefts	WB lefts	WB rights	SB lefts
2007 *Existing*	F / * (77)	C / 16	B / 15	F / * (259)	B / 13	C / 15

* = 50 or more seconds total delay per vehicle. When unsignalized intersection approach delay is 50 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.

Signalized

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
Imp. Concept 1a *New signal, excl. pedestrian phase* (AM:100 secs. PM: 120 secs.)	D	50	35	E	68	58
Imp. Concept 1b *New signal, concurrent pedestrian phase* (AM: 90 secs. PM: 60 secs.)	D	41	37	D	46	26
Imp. Concept 1c *New signal, con-current ped. phase + LPI* (AM: 90 secs. PM: 70 secs.)	D	51	41	E	62	37

Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

In Improvement Concept 1a (the installation of a new traffic signal, optimized to a 100 second cycle length for the AM peak hour and a 120 second cycle length for the PM peak

[17] See www.saferoutesinfo.org/guide/engineering/traffic_signals.cfm , *Reduce the Number of Motor Vehicle Movements that Conflict with Pedestrians*. For a case study, go to: www.walkinginfo.org/pedsafe/casestudy.cfm?CS_NUM=66

hour, and including a 15-second exclusive pedestrian phase), the AM peak hour would operate at LOS D, and the PM peak hour would operate at LOS E.

Improvement Concept 1b also included the installation of a new signal, although the exclusive pedestrian phase would be replaced by a concurrent pedestrian phase. When the optimized cycle lengths were reduced to 90 and 60 seconds for the AM and PM peak hours, respectively, LOS remained at D for the AM, and improved to D in the PM peak hour. The queue lengths in the PM peak hour, in particular, were significantly reduced.

In Improvement Concept 1c, the exclusive pedestrian phase was replaced with an LPI. Traffic operations, based on 90 and 70 second cycle lengths for the AM and PM peak hours, would deteriorate slightly (from Improvement Concept 1b) to LOS D and E, respectively, and with somewhat longer queues in both peak hours.

Estimated queue lengths as a result of the new signal under Improvement Concept 1 showed that the longest queues would occur on the Central Street northbound approach. During the AM peak hour, they ranged from 20–22 vehicles per signal cycle; during the PM, 14–26 vehicles. In the southbound direction, the AM peak hour queues ranged from 13–16 vehicles, and from 10–23 vehicles per signal cycle in the PM peak hour. The Tremont Street westbound approach would experience shorter queues during both peak hours, about 2–3 vehicles per signal cycle during the AM, and 2–9 vehicles during the PM.

Based on these results, it is clear that the northbound queues under any improvement concept tested would affect traffic operations at the unsignalized Central Street/Warren Street intersection, located just to the south. Since the queues would extend through that intersection, causing Warren Street left-turning vehicles to be blocked, it may be necessary to evaluate whether a second traffic signal, in coordination with the potential Central Street/Tremont signal, may be required. Turning movement counts were not obtained at that intersection; therefore, it is beyond the scope of this study to determine what, if any, additional improvements may be required at that location.

- Improvement Concept 2: Ensure that lighting is sufficient at and near the intersection. Since this location had the second highest percentage of darkness-related crashes of all 15 study intersections, it is conceivable that there may be insufficient lighting. This could therefore contribute to an increase in crashes, and should be addressed whether or not a new traffic signal is installed.

Discussion and Recommendations

CTPS staff sought and received feedback from Peabody officials and MassHighway District 4 staff. These comments are included in Appendix A-9.

This intersection (project # DM0276), and the intersection of Central Street and Warren Street just south of Tremont Street, qualify for the installation of a traffic signal.[18] Recommendations from a 2001 Functional Design Report (FDR) for both intersections included, under minimal land-takings conditions, the installation of a traffic signal flashing system at the Central Street/Warren Street intersection, and the installation of a fully actuated three-phase (assumes a concurrent pedestrian phase) traffic signal at Central Street and Tremont Street. Further takings would be required to achieve an acceptable level of service. In the event that takings were feasible, the recommendation was to treat the two intersections as one and install a fully actuated five-phase traffic signal with separate left- and right-turn lanes on Tremont Street westbound, and an additional lane at the Central Street northbound approach. The traffic signal flashing system was installed in 2001 at Central Street at Warren Street; however, the traffic signal at Central Street at Tremont Street has not been installed.

CTPS staff analysis is generally in agreement with the analysis and results of the 2001 Functional Design Report about the need for signalization at both intersections. Also, there is agreement in the need to treat the two locations as one intersection with a single controller.

Implementing staff's Improvement Concept 1a, new signal with exclusive pedestrian phase, assumes a four-phase signal and maintains the existing intersection geometry. Improvement Concepts 1b and 1c would convert the exclusive pedestrian phase into a concurrent one, or one with a Leading Pedestrian Interval (LPI). These concepts match the low-end recommendation contained in the Bayside Engineering FDR.

MassHighway District 4 commented that a concurrent pedestrian phase would not be desirable at this location. They also recommended that the two intersections be analyzed together. The latter was outside the scope of the present analysis but it is covered adequately in the Bayside Engineering FDR.

[18] Staff performed the warrant analysis for Central and Tremont Street only. The warrant analysis for Central Street at Warren Street was performed by Bayside Engineering as part of the Functional Design Report, "Traffic and Safety Improvements for the Central Street at Tremont Street and Warren Street Intersection", February 2001. Staff was not aware of the existence of that report when this Peabody intersection was included for analysis in the present study at the recommendation of City officials.

10. QUINCY: Hancock Street (Route 3A) at East/West Squantum Street

Existing Conditions

Geometry/Physical Characteristics

This is a signalized intersection, and is under local (City of Quincy) jurisdiction. Hancock Street (Route 3A) has two general-purpose lanes on both the northbound and southbound approaches. West Squantum Street eastbound has an exclusive left-turn lane and a through/right-turn lane. East Squantum Street westbound has a short exclusive left-turn lane (about 3–4 cars storage length), a through lane, and a very wide, but short, lane for right-turning vehicles (about 2–3 cars storage length). This wide right-turn lane also includes a crosswalk to a small island. The posted speed limit in the area ranges from 20 miles per hour to the north and east (during school hours) near the North Quincy High School, to 25 and 30 miles per hour south and west of the intersection. Field reconnaissance in May, September, and November of 2007 showed that the crosswalks on all four approaches and roadway lane markings were all clearly visible (see Figure 10-1).

Traffic Control

This is a fully actuated signal and has five distinct signal phases during both the AM and PM peak periods: (1) leading eastbound, (2) eastbound/westbound, (3) leading northbound, (4) northbound/southbound, and (5) an exclusive pedestrian phase which lasts 22 seconds, sufficient time for most pedestrians to cross the intersection. There are functioning pedestrian buttons on all corners except the northeast corner. At that location, pedestrians must first walk from the sidewalk unprotected across the wide East Squantum Street westbound right-turn lane to a small island. There, they can push a pedestrian button to safely cross through the rest of the intersection. The current maximum peak period cycle length is 115 seconds. Right turns on red (RTOR) are prohibited on three of the four approaches. East Squantum Street westbound has a channelized right-turn lane; therefore, RTOR are permitted.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

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FIGURE 10-1

Quincy: Hancock Street (Route 3A) at East/West Squantum Street

2007 AM and PM Peak Hour Turning Movements
(vehicles)

AM Peak Hour (7:15–8:15)											
Hancock Street (Route 3A)						W. Squantum Street			E. Squantum Street		
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
180	720	100	30	280	210	250	320	40	80	330	100
1,000 (total approach)			520 (total approach)			610 (total approach)			510 (total approach)		

- Hancock Street, NB + SB approaches combined: 1,520 vehicles
- E./W. Squantum Street, EB + WB approaches combined: 1,120 vehicles
- Pedestrians (all approaches): 188
- Bicycles (all approaches): 7

PM Peak Hour (5:00–6:00)											
Hancock Street (Route 3A)						W. Squantum Street			E. Squantum Street		
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
180	440	100	40	630	230	190	350	70	90	220	30
720 (total approach)			900 (total approach)			610 (total approach)			340 (total approach)		

- Hancock Street, NB + SB approaches combined: 1,620 vehicles
- E./W. Squantum Street, EB + WB approaches combined: 950 vehicles
- Pedestrians (all approaches): 202
- Bicycles (all approaches): 14

The approach with the greatest AM peak hour volumes was Hancock Street northbound, 1,000 total vehicles. The single highest AM peak hour turning movement was West Squantum Street eastbound left turns, 250 vehicles. In the PM peak hour, the approach with the greatest volumes was Hancock Street southbound, 900 vehicles. The single highest PM peak hour turning movement was Hancock Street southbound right turns, 230 vehicles.

Crashes

The vehicle crash rate for this location was 2.75 crashes per million vehicles entering the intersection. This by far exceeds the most recent average crash rate of 0.88 for Mass-Highway District 4 area intersections. Specific characteristics of the vehicle crashes include:

- 53% of crashes were angle. Examination of the RMV data revealed no distinct crash patterns for these crashes. Individual collisions involved combinations of vehicles from all approaches. This “non-pattern” of angle crashes was confirmed somewhat during field reconnaissance. When observing turning movements during both the AM and PM peak hours, numerous near-collisions were seen involving turning and through vehicles from all directions.

Based on field observations, the likely cause(s) for the angle crashes appeared to be vehicles from all approaches attempting to "beat the yellow light," as well as vehicles attempting to turn left during very short gaps in the opposing through traffic stream.

- 24% of crashes were rear-end. This suggests one-fourth of all crashes occurred during congested, stop-and-go traffic conditions. The only distinct pattern seen in the data involved vehicles traveling northbound. Of the 21 rear-end crashes recorded, 12 (57%) occurred when a northbound vehicle rear-ended another northbound vehicle. Nine of the 21 rear-end crashes (43%) occurred during either the AM (7:00–9:00) or PM (4:00–6:00) peak periods.

- 5% of crashes were head-on.

- 15% of crashes were other/undetermined.

Additionally:

- 2% of crashes (2 of 86) involved pedestrians. Of these:

  a. One occurred at 9 PM on a June evening under cloudy and dry road conditions and resulted in personal injury.

  b. The other occurred at 11 AM on a July morning under clear and dry road conditions and also resulted in personal injury.

- 1% of crashes (1 of 86) involved bicyclists. This crash occurred at 7 PM on an August evening under clear and dry road conditions and resulted in personal injury.

- 24% of all crashes resulted in personal injuries. This is somewhat below the 15-intersection study average of 35%.

- 59% of crashes occurred during April–October (spring, summer, fall); 41% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (16 of 86 crashes, or 19%, occurred during rain, snow, or fog).

- 74% of crashes occurred during daytime, 7 AM through 7 PM; 26% occurred during night-time, 7 PM through 7 AM. No predominant darkness-related crash patterns were seen.

Land Use

This is a very busy, urban intersection in North Quincy. Hancock Street (Route 3A) is a north-south arterial used as a commuter route between Quincy and the South Shore suburbs and Boston. Hancock Street is fed by numerous east-west collector roads, such as East and West Squantum Street.

The surrounding land use is very active. On the northwest corner is a gas station. To the west and north of the gas station are the North Quincy Red Line Station, a fire station, and a McDonald's. On the northeast corner is North Quincy High School, including a student drop-off/pick-up area on Hancock Street, about 150 feet north of the intersection. On the southwest corner is a gas station, and on the southeast corner is a currently closed auto dealership.

There are many pedestrians crossing through the intersection to and from the Red Line station and from the high school during the peak periods. Three MBTA bus routes stop at the intersection or at the Red Line station. There is a mix of residential and commercial land use away from the intersection in all directions.

Level of Service (LOS)

Intersection LOS analysis showed that both the AM and PM peak hours operated at LOS F. These measures are broken down further by lane group and total approach, as the tables below show.

2007 Intersection LOS Summary (Existing Conditions)

	AM Peak Hour			PM Peak Hour		
Existing Conditions	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing*	F	* (255)	64	F	* (161)	67

* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

2007 LOS by Lane Group, Total Approach (Existing Conditions)

AM Peak Hour (7:15–8:15)											
Hancock Street (Route 3A)						**W. Squantum Street**			**E. Squantum Street**		
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
	F			C		F	D		E	F	A
F (total approach)			C (total approach)			F (total approach)			E (total approach)		
PM Peak Hour (5:00–6:00)											
Hancock Street (Route 3A)						**W. Squantum Street**			**E. Squantum Street**		
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
	F			F		F	F		F	D	B
F (total approach)			F (total approach)			F (total approach)			F (total approach)		

This reveals that most approaches experienced significant congestion. The northbound and eastbound approaches both operated at LOS F during the AM peak hour, while the southbound and westbound approaches operated at LOS C and E, respectively. During the PM peak hour, all four approaches operated at LOS F. Queues ranged from 5–25 vehicles per approach per signal cycle in the AM peak hour; during the PM peak hour, the queues ranged from 10–25 vehicles per approach per signal cycle.

Conclusions/Significant Findings

- Peak period congestion is significant. Essentially, there is not enough intersection capacity for the amount of traffic attempting to travel through this location during the AM and PM peak periods. There are long queues on all approaches, and occasional cycle failures occur where queued vehicles need more than one cycle to pass through the intersection.

  The Hancock Street northbound and West Squantum Street eastbound approaches are particularly congested during the AM and PM peak periods. Both approaches experience on average about 20 or more queued vehicles per lane during each signal cycle.

  In addition, vehicles on Hancock Street northbound, just prior to the intersection, experience constant interference from vehicles entering and exiting Hollis Avenue. This narrow, two-lane local street, located just 150 feet to the south of East Squantum Street, acts as a feeder route for the neighborhood between Hancock Street and Quincy Shore Drive, which is less than 0.5 mile to the east. Vehicles from Hollis Avenue turning left (south) onto Hancock Street, as well as southbound traffic turning left (east) onto Hollis Avenue, often block northbound traffic, thereby extending the queues even further southward.
  Vehicles to and from Hollis Avenue were also frequently observed using the Knights of Columbus parking lot on the corner south of Hollis Avenue, in order to access Hancock Street. These maneuvers often seemed to be dangerous since vehicles would cut through the parking lot at excessive speeds, potentially putting other vehicles and pedestrians at risk.

- Numerous near-collisions were observed on all four approaches at this congested intersection. Turning vehicles nearly collided with through vehicles as well as with other turning vehicles.

- Many pedestrians were seen not using the west side crosswalk, but instead were crossing midblock between eastbound queued vehicles, from the south side of West Squantum Street to the north side to reach the Red Line Station. This potentially exposed them to being struck by vehicles traveling in both directions on West Squantum Street.

- The crosswalk between the northeast corner and the small island is unprotected, i.e., a pedestrian must first cross the wide East Squantum Street westbound right-turn lane before reaching the pedestrian button on the island.

Preliminary Conceptual Improvements

The following concepts for improving safety and traffic operations at this intersection were tested (RTOR are permitted in all improvement concepts):

- Improvement Concept 1: <u>Optimize the current signal timing splits and cycle length.</u> This was tested to determine whether a re-allocation of green time would reduce queueing and alleviate congestion on some approaches.

Improvement Concept 1 yielded a cycle length of 150 seconds for both the AM and PM peak hours when optimizing the signal timings and cycle length. This is a relatively long cycle length and would likely result in longer vehicle queues than under the current 115 second cycle length. In order to reduce the anticipated queue lengths, therefore, Improvement Concept 1 also used a 115 second cycle length to analyze both the AM and PM peak hours. These two cycle lengths analyzed were summarized as Improvement Concepts 1a (150 seconds) and 1b (115 seconds).

- Improvement Concept 2: Implement a signal phase which protects eastbound and westbound left turns. This improvement concept establishes an exclusive left-turn phase for West Squantum Street eastbound and East Squantum Street westbound left turns. It would attempt to reduce overall congestion by allocating more green time to left-turning vehicles, especially the heavy West Squantum Street eastbound left turns. A 115 second cycle length was used to analyze this improvement concept.

- Improvement Concept 3: Widen East and West Squantum Streets. The widening would be implemented both east and west of the intersection. To the east, a 200 foot long portion of the grassy area between East Squantum Street and the North Quincy High School parking lot would be taken. This strip of land would be of sufficient width, perhaps 15 feet, and would be used to realign the westbound approach, and to accommodate two general-purpose lanes westbound and two departure lanes eastbound. West of the intersection, a small strip of land, also perhaps 15 feet wide, would be taken from the gas station property on the northwest corner, a distance of approximately 150 feet along West Squantum Street. This widening would then match the rest of West Squantum Street to the west, which already has two travel lanes in both directions for about 1,000 feet. West Squantum Street eastbound would be restriped as two general-purpose lanes. This improvement concept was analyzed with a 115 second cycle length.

  As part of this concept, it could also be possible to add a narrow, raised median on West Squantum Street between eastbound and westbound traffic. The median would stretch from Hancock Street to the west one block to the Red Line station bus driveway. In order to prevent pedestrians from crossing West Squantum Street midblock, the median could include a 6-ft high wire fence. This would enhance safety by forcing pedestrians to cross at the marked crosswalks rather than at midblock locations between queued vehicles. See Figure 10-2 for details.

The LOS results of existing conditions, and of Improvement Concepts 1, 2, and 3 are shown in the following table.

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FIGURE 10-2

Improvement Concept 3

= **area of geometric changes**

Intersection LOS Summary: Existing Conditions and Improvement Concepts 1, 2, and 3 (2007 Traffic Volumes)

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing* (115 secs. cy.le.)	F	* (255)	64	F	* (161)	67
Imp. Concept 1a *Optimize signal timing* (150 secs. cy.le.)	F	* (197)	87	F	* (157)	87
Imp. Concept 1b *Optimize signal timing* (115 secs. cy.le.)	F	* (228)	67	F	* (180)	67
Imp. Concept 2 *Leading EB/WB exclusive left-turn signal phase* (115 secs. cy.le.)	F	* (249)	70	F	* (171)	69
Imp. Concept 3 *Widen East and West Squantum Streets* (115 secs. cy.le.)	F	* (288)	53	F	* (206)	53

cy. le. = cycle length
* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

The LOS analyses showed that no matter which improvement concept was analyzed, the intersection would still operate at LOS F. Only Improvement Concept 3, the widening and realignment of East and West Squantum Street—a very costly undertaking—improves queue lengths from existing conditions. However, the improvement is very slight, with only a small reduction in overall vehicle queues.

Improvement Concepts 1, 2, and 3 dealt specifically with enhancing safety by improving intersection traffic operations, and thereby reducing vehicle crashes. Improvement Concepts 4, 5, 6, and 7 are discussed below. These propose to improve safety by redesigning portions of the intersection geometry, or by eliminating vehicle movements near the intersection that impact overall safety and traffic operations.

- Improvement Concept 4: <u>Widen the Hancock Street southbound departure lane(s).</u> Through traffic on Hancock Street southbound is currently not able to proceed to two 12-foot wide departure lanes. Instead, there is one wide lane which slowly receives vehicles from the two through lanes north of the intersection. It appears that a narrow strip of land (about 6 feet wide, 150 feet in length) could be taken on the southwest corner along a gas station in order to accommodate two 12-foot wide departure lanes. See Figure 10-3 for details.

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Safety and Operational Improvements at Selected Intersections

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FIGURE 10-3

Improvement Concept 4

= **area of geometric changes**

SOISI/Quincy/Figure 10-3

- Improvement Concept 5: Redesign the small island in the northeastern area of the intersection. The island could be redesigned by making the wide westbound right-turn lane narrower. This would shorten the distance that pedestrians would walk unprotected into the intersection. Additionally, a new pedestrian button could be added to the sidewalk on the northeastern corner and create one more location where pedestrians could activate the exclusive pedestrian phase. See Figure 10-4 for details.

- Improvement Concept 6: Make Hollis Avenue right-in, right-out only during AM and PM peak periods. During field work it was observed that Hancock Street southbound traffic turning left onto Hollis Avenue occasionally blocked following traffic. The resulting queues reached all the way back to the East/West Squantum Street intersection. In addition, vehicles turning left (southbound) from Hollis Avenue often reached just half-way across Hancock Street, and were then unable to proceed due to heavy southbound through traffic. This resulted in Hancock Street northbound vehicles being blocked and unable to proceed. Signs could therefore be placed at this location—with strict enforcement—stating that Hancock Street southbound left turns as well as Hollis Avenue westbound left turns be prohibited 6:30–9:00 AM and 4:00–7:00 PM. See Figure 10-5 for details.

- Improvement Concept 7: Prohibit peak period entry/exit to the Knights of Columbus driveway from Hollis Avenue. This could be accomplished either through signage—with subsequent enforcement—or through a chain blocking entry to the driveway. During field work it was observed that Hollis Avenue westbound vehicles used the Knights of Columbus driveway and parking lot to bypass queued vehicles. The vehicles cut through the parking lot and entered Hancock Street via the parking lot's southern entrance. This current traffic pattern could potentially have legal ramifications should a vehicle racing through the parking lot hit another vehicle, bicyclist, or pedestrian on the Knights of Columbus property. See Figure 10-5 for details.

Discussion and Recommendations

CTPS staff sought feedback from Quincy officials and MassHighway District 4 staff on the analysis and potential improvements for this intersection. The comments received are available in Appendix A-10.

None of Improvement Concepts 1 through 3 that were examined at Hancock Street at East/West Squantum Street yields sufficient reduction in overall delay and queues to return the operation of the intersection to acceptable levels of service. Modest takings of abutting land in order to re-allocate one or more travel lanes in the intersection—a very expensive proposition—showed very little improvement in traffic operations.

In fact, a hypothetical analysis showed that it would require widening to accommodate as many as three general-purpose lanes northbound and eastbound, respectively, and two general-purpose lanes westbound, in order to improve intersection performance. This analysis yielded intersection LOS D using widened approaches of such magnitude. In this hypothetical analysis, only one approach would still operate at LOS F, West Squantum Street eastbound in the PM peak hour,

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FIGURE 10-4

Improvement Concept 5

= **area of geometric changes**

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FIGURE 10-5

Improvement Concepts 6 and 7

while one would operate at LOS E, East Squantum Street westbound during the PM peak hour. See the table below for a summary of these results.

2007 Intersection LOS Summary (Hypothetical Scenario)

- **3 general-purpose lanes, Hancock Street northbound**
- **2 general-purpose lanes, Hancock Street southbound**
- **3 general-purpose lanes, West Squantum Street eastbound**
- **2 general-purpose lanes, East Squantum Street westbound**
- **115 second cycle length**

	AM Peak Hour			PM Peak Hour		
Improvement Concept	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
Hypothetical	D	40	72	D	50	73

Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

2007 LOS by Lane Group, Total Approach (Hypothetical Scenario)

AM Peak Hour (7:15–8:15)											
Hancock Street (Route 3A)						**W. Squantum Street**			**E. Squantum Street**		
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
	D			C			D			D	
D (total approach)			C (total approach)			D (total approach)			D (total approach)		
PM Peak Hour (5:00–6:00)											
Hancock Street (Route 3A)						**W. Squantum Street**			**E. Squantum Street**		
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
	C			C			F			E	
C (total approach)			C (total approach)			F (total approach)			E (total approach)		

The required right-of-way to achieve LOS D under 2007 traffic conditions (likely even lower level of service under future conditions) would be significant. For this reason, CTPS staff will refrain from making a recommendation to the City of Quincy to implement the necessary takings and reconstruction; City officials and the public must weigh in regarding this decision.

MassHighway District 4 expressed concern about the proposed fence and width of the proposed median between the eastbound and westbound directions of West Squantum Street designed as a pedestrian safety measure.

Improvement Concepts 4, 5, 6, and 7 deal mainly with safety and they could be implemented within the scope of the eventual geometric design afforded by the City.

11. RANDOLPH: North Main Street (Route 28) at Pond Street/Reed Street/Old Street

Existing Conditions

Geometry/Physical Characteristics

This is a signalized intersection. North Main Street (Route 28), which is under state (Mass-Highway) jurisdiction, has two general-purpose lanes on both the northbound and southbound approaches. Reed Street eastbound and Pond Street westbound each have a general-purpose lane. Old Street is a one-way, one lane street for vehicles traveling away from the intersection in the southwest direction. Reed Street, Pond Street, and Old Street are all under local (Town of Randolph) jurisdiction (see Figure 11-1).

The posted speed limit is 30 miles per hour approaching the intersection from all four directions. Field reconnaissance in May, September, and December of 2007 showed that the crosswalks on all four approaches and roadway lane markings were visible but had begun to fade.

Traffic Control

This is a pre-timed signal, and has three distinct signal phases during both the AM and PM peak periods: (1) eastbound/westbound, (2) northbound/southbound, and (3), a manually activated, exclusive pedestrian phase which lasts 24 seconds, sufficient time for most pedestrians to cross any of the approaches. There are functioning pedestrian buttons on all corners, and there are “NO TURN ON RED” signs on all approaches except on Reed Street eastbound. The current AM and PM peak hour cycle length is 94 seconds.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

2007 AM and PM Peak Hour Turning Movements
(vehicles)

AM Peak Hour (7:30–8:30)											
North Main Street (Route 28)						**Reed Street**			**Pond Street**		
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
20	1,430	130	20	460	30	70	180	50	70	130	50
1,580 (total approach)			510 (total approach)			300 (total approach)			250 (total approach)		

- North Main Street, NB + SB approaches combined: 2,090 vehicles
- Reed Street, EB + Pond Street, WB approaches combined: 550 vehicles
- Pedestrians (all approaches): 4
- Bicycles (all approaches): 2

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Safety and Operational Improvements at Selected Intersections

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FIGURE 11-1

Randolph: North Main Street (Route 28) at Reed Street/Pond Street/Old Street

PM Peak Hour (4:30–5:30)											
North Main Street (Route 28)						**Reed Street**			**Pond Street**		
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
30	700	60	40	1,210	30	50	200	80	240	270	50
790 (total approach)			1,280 (total approach)			330 (total approach)			560 (total approach)		

- North Main Street, NB + SB approaches combined: 2,070 vehicles
- Reed Street, EB + Pond Street, WB approaches combined: 890 vehicles
- Pedestrians (all approaches): 20
- Bicycles (all approaches): 3

The approach with the greatest AM peak hour volumes was North Main Street northbound, 1,580 total vehicles. The single highest AM peak hour turning movement was North Main Street northbound right turns, 130 vehicles. In the PM peak hour, the approach with the greatest volumes was North Main Street southbound, 1,280 vehicles. The single highest PM peak hour turning movement was Pond Street westbound left turns, 240 vehicles.

Crashes

The vehicle crash rate for this location was 1.12 crashes per million vehicles entering the intersection. This exceeds the most recent average crash rate of 0.88 for Mass-Highway District 4 area signalized intersections. Specific characteristics of the vehicle crashes include:

- 30% of crashes were angle. This percentage is well below the study's 15-intersection average of 51% for angle crashes. Examination of the RMV data revealed that individual angle collisions involved combinations of vehicles from all approaches except Reed Street eastbound. During field reconnaissance, when observing turning movements during both the AM and PM peak hours, numerous near-collisions were seen involving turning and through vehicles.

  The likely cause(s) for the angle crashes that actually do occur appeared from field observations to be vehicles attempting to "beat the yellow light," as well as attempting to turn left during very short gaps in the opposing through traffic stream.

- 38% of crashes were rear-end, somewhat above the 15-intersection study average of 27%. This suggests that more than one-third of all crashes occurred during congested, stop-and-go traffic conditions. The distinct pattern seen in the data involved vehicles traveling northbound. Of the 14 rear-end crashes recorded, nine (64%) occurred when a northbound vehicle rear-ended another northbound vehicle.

- 8% of crashes were head-on.

- 25% of crashes were other/undetermined.

Additionally:

- 8% of crashes (3 of 40) involved pedestrians. Of these:

  a. One crash ocurred at 5 PM on a January afternoon under rainy, wet, and dark (but lighted) road conditions and resulted in personal injury.

  b. Another occurred at 8 AM on a June morning under clear and dry road conditions and resulted in personal injury.

  c. The third crash occurred at 3 PM on a June afternoon under clear and dry road conditions and resulted in personal injury.

- 0% of crashes involved bicyclists.

- 50% of all crashes resulted in personal injuries. This is substantially above the 15-intersection study average of 35%.

- 55% of crashes occurred during April–October (spring, summer, fall); 45% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (8 of 40 crashes, or 20%, occurred during rain, snow, or fog).

- 70% of crashes occurred during daytime, 7 AM through 7 PM; 30% occurred during night-time, 7 PM through 7 AM. No predominant darkness-related crash patterns were seen.

Land Use

This is a very busy, suburban intersection in the northern section of Randolph. North Main Street (Route 28) is a north-south arterial used as a commuter route to Milton and Boston, as well as a feeder route to I-93 (Route 128) located one mile to the north.

The immediate surrounding land use consists of a dental office and a pub on the northwest corner; a monument company (memorial stones) and a restaurant/pub on the southwest corner; a small food market on the northeast corner; and, an insurance office, a barber shop, and a cleaners on the southeast corner. There are both multiple- and single-family residences away from the intersection in all directions. There are public transportation bus routes that service this location: MBTA bus #240 and a Brockton Area Transit (BAT) bus both stop north and south of the intersection.

Level of Service (LOS)

Intersection LOS analysis indicated that both the AM and PM peak hours operated at LOS F. These measures are broken down further by lane group and total approach, as the tables below show.

2007 Intersection LOS Summary (Existing Conditions)

	AM Peak Hour			PM Peak Hour		
Existing Conditions	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing*	F	* (164)	53	F	* (287)	72

* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

2007 LOS by Lane Group, Total Approach (Existing Conditions)

AM Peak Hour (7:30–8:30)											
North Main Street (Route 28)						**Reed Street**			**Pond Street**		
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
	F			D			F			F	
F (total approach)			D (total approach)			F (total approach)			F (total approach)		
PM Peak Hour (4:30–5:30)											
North Main Street (Route 28)						**Reed Street**			**Pond Street**		
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
	F			F			E			F	
F (total approach)			F (total approach)			E (total approach)			F (total approach)		

This reveals that most approaches experienced significant delay. Three of the four approaches operated at LOS F during both the AM and PM peak hours; only North Main Street southbound operated at LOS D during the AM peak hour, and Reed Street eastbound operated at LOS E during the PM peak hour.

Conclusions/Significant Findings

- Peak period delays are significant. Essentially, there is barely enough intersection capacity for the amount of traffic attempting to travel through this location during the AM and PM peak hours. There are long queues, particularly on North Main Street northbound in the AM peak hour (about 30 queued vehicles per signal cycle), and on North Main Street northbound and southbound, and Pond Street westbound, in the PM peak hour (15–25 queued vehicles per signal cycle).

- On numerous occasions it was observed how left-turning vehicles were seen blocking through vehicles in the northbound and southbound directions. As a result, the blocked vehicles would attempt to switch to the right side through lane, and thereby nearly collide with same-direction through or right-turning vehicles.

- Numerous near-collisions were observed on all four approaches at this congested intersection. Turning vehicles nearly crashed with opposing through vehicles as well as with other turning vehicles.

- There are different signal heads in the intersection; some are LED while others are the old, smaller, and less visible type.

Preliminary Conceptual Improvements

The following concepts for improving safety and traffic operations at this intersection were tested:

- Improvement Concept 1: Change the current pretimed signal timing to fully-actuated, and optimize the signal splits and cycle length. This was tested to determine whether a re-allocation of green time and change in cycle length would reduce queueing and alleviate congestion on some approaches. Two variations of this concept were performed.

  Improvement Concept 1a used the current cycle length of 94 seconds for both the AM and PM peak hours when optimizing only the signal splits. Improvement Concept 1b yielded a cycle length of 120 seconds for both the AM and PM peak hours when optimizing the signal splits and cycle length. Right turns on red (RTOR) were permitted in both variations.

- Improvement Concept 2: Replace the exclusive pedestrian phase with a concurrent pedestrian phase. Two variations of this concept were performed:

  a. Most of the approaches at this intersection have relatively low left- and right-turn volumes, with the exception of Pond Street PM peak hour westbound left turns (240 vehicles) and North Main Street AM peak hour northbound right turns (130 vehicles). "Crash data consistently show that crashes with pedestrians occur far more often with turning vehicles than with straight-through traffic. Left-turning vehicles are more often involved in pedestrian collisions than right-turning vehicles, partly because drivers are not clearly able to see pedestrians on the left."[19]

     With this in mind, the existing exclusive pedestrian phase stops traffic on all approaches while pedestrians are allowed to cross in any direction. Replacing the exclusive phase with a concurrent one would allow pedestrians to cross parallel with vehicles that have a green signal. This would then provide more time for vehicles to travel through the intersection. This improvement concept was optimized to an 80 second cycle length for the AM peak hour, and to a 70 second cycle length for the PM peak hour. RTOR were not permitted in Improvement Concept 2a.

[19] From U.S. Department of Transportation, Federal Highway Administration, *Intersection Safety Issue Briefs, No. 9, Pedestrian Safety at Intersections*, p. 2, April 2004.

b. Replace the exclusive pedestrian phase with a concurrent pedestrian phase; however, implement a Leading Pedestrian Interval (LPI) by extending the all-red signal phase to four or more seconds. For the approach about to receive a green signal, the LPI "illuminates the pedestrian WALK signal, while the motor vehicle signal remains red for the first few seconds of the cycle. The LPI gives pedestrians an opportunity to start walking and establish a presence in the crosswalk before drivers can begin their turn."[20] This improvement concept was analyzed with an LPI of 4 seconds for the all-red phase, and was optimized to a 90 second cycle length for the AM peak hour, and a 110 second cycle length for the PM peak hour. RTOR were not permitted in Improvement Concept 2b.

- Improvement Concept 3: Restripe the Pond Street (east side) approach to accommodate a three-lane cross section: a westbound exclusive left-turn lane and a through/right-turn lane, and one eastbound departure lane. There is approximately 33 feet between the Pond Street north side and south side sidewalks. The north side sidewalk is quite wide, and if necessary, a few feet of this sidewalk could be taken in order to facilitate this widening (see Figure 11-2). The purpose of the widening would be to accommodate the larger number of Pond Street westbound left turns, especially during the PM peak hour, and thereby to re-allocate the overall available green time. Two variations of this improvement concept were performed:

a. With the existing, but optimized, signal splits and cycle lengths, and with the exclusive pedestrian signal phase reduced from 24 to 17 seconds. RTOR were permitted in this variation.

b. With the existing, but optimized, signal splits and cycle lengths, and with the exclusive pedestrian signal phase replaced by a concurrent pedestrian phase, including an LPI of 4 seconds for the all-red signal phase. RTOR were not permitted in this variation.

The LOS results of existing conditions, and of Improvement Concepts 1, 2, and 3 are shown in the following table.

[20] See www.saferoutesinfo.org/guide/engineering/traffic_signals.cfm, *Reduce the Number of Motor Vehicle Movements that Conflict with Pedestrians*. For a case study, go to: www.walkinginfo.org/pedsafe/casestudy.cfm?CS_NUM=66.

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Safety and Operational Improvements at Selected Intersections

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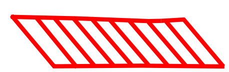
FIGURE 11-2

Improvement Concept 3

 = **area of geometric changes**

SOISI/Randolph/Figure 11-2

Intersection LOS Summary: Existing Conditions and Improvement Concepts 1, 2, and 3 (2007 Traffic Volumes)

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing* (94 secs. cy. le.)	F	* (164)	53	F	* (287)	72
Imp. Concept 1a (94 secs. cy. le.) *Optimized splits*	D	43	26	F	* (164)	43
Imp. Concept 1b (120 secs. cy. le.) *Optimized splits, cycle lengths*	D	37	36	F	* (137)	59
Imp. Concept 2a (AM: 80 secs. PM: 70 secs.) *Concurrent ped. phase*	C	30	30	E	75	39
Imp. Concept 2b (AM: 90 secs. PM: 110 secs.) *Concurrent ped. phase + LPI*	D	38	36	F	* (101)	69
Imp. Concept 3a (AM: 100 secs. PM: 110 secs.) *Restripe Pond St WB approach; reduce ped. phase by 7 secs.*	C	35	30	D	49	44
Imp. Concept 3b (90 secs. cy. le.) *Restripe Pond St WB approach; replace exclusive ped. phase w. concurrent ped. phase + LPI*	C	34	35	D	38	42

cy. le. = cycle length
* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

The LOS analyses showed that when Improvement Concept 1 was tested (optimizing the current signal splits and cycle length), delays decreased and queues became shorter. The AM peak hour would improve to LOS D, but the intersection would still operate at LOS F in the PM peak hour.

Improvement Concept 2, replacing the exclusive pedestrian phase with a concurrent phase (2a), improved traffic operations to LOS C and E for the AM and PM peak hours, respectively. When the LPI option was included (2b), the improvement was slightly smaller, but still improved to LOS D in the AM peak hour, but remained at LOS F in the PM peak hour. Queues were also shorter than under existing conditions.

Improvement Concept 3, restriping (and potentially widening) the Pond Street approach to a three-lane cross section, improved traffic operations significantly from existing conditions for the AM and PM peak hours. LOS improved to C and D, respectively, for Improvement Concepts 3a and 3b, for both peak hours. Queue lengths were also reduced, yielding 4–18 vehicles per approach per signal cycle in the AM peak hour, and 7–14 vehicles in the PM peak hour.

- Improvement Concept 4: Add signs warning drivers: "STATE LAW: STOP for pedestrians in crosswalk." This measure should be implemented for existing conditions, regardless of whether Improvement Concepts 1, 2, or 3 are pursued in the future.

- Improvement Concept 5: Replace any older signal heads with new LED types. This improvement would ensure that all signal heads in the intersection would be uniform in appearance, LED-illuminated, and be clear and visible from a distance.

Discussion and Recommendations

CTPS staff sought input from Randolph officials and MassHighway District 4 staff on the analysis and improvement concepts described. All comments are included in Appendix A-11.

During the AM peak hour, most of the improvement in delay and level-of-service was achieved in the analysis by optimizing the signal splits and cycle length of the traffic signal (Improvement Concept 1). During the PM peak hour, signal retiming yielded some improvement but LOS would not improve to acceptable levels. Based on MassHighway's comments, District 4 recently implemented some signal timing adjustments.

Intersection delay and LOS improved further for both the AM and PM peak hours under Improvement Concept 2, where the exclusive pedestrian phase would be replaced by a concurrent one. There were similar improvements under Improvement Concept 3, where Pond Street westbound would be restriped to two lanes, for left turns only and for through/right turns, respectively. Improvement Concept 3 would include a minor, and appropriate, reduction in the length of the exclusive pedestrian phase.

As Improvement Concept 3a yielded an acceptable level of service with insignificant impacts to pedestrian safety, this concept, and not Improvement Concept 2, is recommended to MassHighway and the Town for implementation. In fact, this is the Town's preferred improvement option. Also, the Town recommends that the two-lane approach treatment for Pond Street also be applied to Reed Street. Staff feels that this may not be necessary, or even feasible; however, it should be tested at the time that a functional design report is prepared.

MassHighway commented as follows regarding the improvements analyzed, and about Improvement Concept 3, in particular: the intersection would benefit from a fully-actuated traffic signal, while the widening of the westbound Pond Street approach would require right-of-way takings, the availability of which is not currently known.

Finally, Improvement Concepts 4 and 5 are appropriate to implement, before or in conjunction with implementation of Improvement Concept 3.

12. REVERE: Ocean Avenue at Shirley Avenue

Existing Conditions

Geometry/Physical Characteristics

This is a signalized intersection. Ocean Avenue, and Shirley Avenue east of the intersection, are under the jurisdiction of the Department of Conservation and Recreation (DCR), while Shirley Avenue west of the intersection is under local (City of Revere) jurisdiction. Ocean Avenue has two general-purpose lanes both northbound and southbound. On each of the Shirley Avenue eastbound and westbound approaches there is a general-purpose lane which accommodates all movements (see Figure 12-1). The posted speed limit on Ocean Avenue is 35 miles per hour. No posted speed limits were seen on Shirley Avenue, but vehicles typically drive 15–20 miles per hour due to the street's narrow alignment and on-street parking (west of the intersection). Field reconnaissance in May and August of 2007 showed that the pedestrian crosswalks and lane stripings were clearly marked and visible.

Traffic Control

This signal is actuated and uncoordinated, and includes two signal phases: northbound/ southbound and eastbound/westbound. Right turns on red (RTOR) are allowed on all four approaches; the right turns from Shirley Avenue eastbound are the highest in volume (110 vehicles in the AM peak hour, 150 in the PM peak hour). There is an exclusive pedestrian phase which lasts 25 seconds, more than enough time to cross each approach. There are functioning pedestrian buttons on all four corners.

This is a very popular pedestrian location because of the park, beach, and ocean nearby. It was observed from field visits that the pedestrian phase was automatically activated during each cycle (in the PM peak period), whether or not the pedestrian buttons were pushed.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

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FIGURE 12-1

Revere: Ocean Avenue at Shirley Avenue

2007 AM and PM Peak Hour Turning Movements
(number of vehicles)

AM Peak Hour (7:30–8:30)											
Ocean Avenue						Shirley Avenue					
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
10	100	4	7	670	40	30	20	110	4	8	5
114 (total approach)			717 (total approach)			160 (total approach)			17 (total approach)		

- Ocean Avenue, NB + SB approaches combined: 831 vehicles
- Shirley Avenue, EB + WB approaches combined: 177 vehicles
- Pedestrians (all approaches): 52
- Bicycles (all approaches): 1

PM Peak Hour (5:00–6:00)											
Ocean Avenue						Shirley Avenue					
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
20	240	10	50	480	40	20	60	150	10	10	4
270 (total approach)			570 (total approach)			230 (total approach)			24 (total approach)		

- Ocean Avenue, NB + SB approaches combined: 840 vehicles
- Shirley Avenue, EB + WB approaches combined: 254 vehicles
- Pedestrians (all approaches): 131
- Bicycles (all approaches): 9

The approach with the greatest AM peak hour volumes was Ocean Avenue southbound, 717 total vehicles. In the PM peak hour, the approach with the greatest volumes was again Ocean Avenue southbound, 570 vehicles. The Shirley Avenue westbound approach had the lowest volumes during both the AM and PM peak hours, 17 and 24 vehicles, respectively.

It should be noted that it is atypical that the peak direction is the same for both the AM and PM peak hours, as in this case for Ocean Avenue southbound. Usually, one direction has the highest volumes in the AM peak hour, while the opposite (return) direction has the highest volumes in the PM peak hour.

One explanation for this situation is that a major roadway exists immediately to the east, Revere Beach Parkway. This parkway is one-way northbound; therefore, it stands to reason that much of the northbound traffic that would have traveled on Ocean Avenue instead travels on the parkway, creating artificially low northbound peak hour volumes on Ocean Avenue. Further study of Revere Beach Parkway counts would be required to confirm this speculation.

Crashes

The vehicle crash rate for this location was 4.14 crashes per million vehicles entering the intersection. This is the highest crash rate of any of the 15 intersections included in this study, and by far exceeds the most recent average crash rate of 0.88 for Mass-Highway District 4 area signalized intersections. Specific characteristics include:

- 69% of crashes were angle. This is well above the 15-intersection average for this study, 51%. Examination of the RMV data revealed that northbound vehicles were involved in 26 of the 38 angle crashes recorded (68%). Of these, the most common combination involved northbound vehicles colliding with southbound vehicles, which occurred 14 times. The likely cause for these angle crashes appeared to be the limited sight distance for both northbound and southbound vehicles approaching the intersection. The intersection is on a pronounced crest, making it difficult to notice vehicles approaching from the opposite direction, even if the vehicles are traveling within the speed limit.

- 11% of crashes were rear-end. This type of crash suggests congested, stop-and-go traffic. However, this is not a congested intersection (see the Level of Service section below), and the 11% rate corroborates this since it is significantly below the 15-intersection average for rear-end crashes for this study, 27%.

- 2% of crashes were head-on.

- 18% of crashes were other/undetermined.

Additionally:

- 4% of crashes (2 of 55) involved pedestrians. Of these:

    a. One occurred at 6 PM on a March afternoon under cloudy and icy road conditions, and resulted in personal injury.

    b. The other occurred at 2 PM on a May afternoon under clear and dry road conditions, and also resulted in personal injury.

- 0% of crashes involved bicyclists.

- 42% of all crashes resulted in personal injuries. This is above the average for the 15 intersections included in this study, 35%.

- 58% of crashes occurred during April–October (spring, summer, fall); 42% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (3 of 55 crashes, or 5%, occurred during rain, snow, or fog).

- 65% of crashes occurred during the daytime, 7 AM through 7 PM; 35% occurred during the night-time, 7 PM through 7 AM. No predominant darkness-related crash patterns were seen.

Land Use

The surrounding land use includes a narrow park to the east of Ocean Avenue. This park, perhaps 100 feet wide, is bounded by Revere Beach Parkway and the ocean further to the east. To the west of Ocean Avenue is the MGI Health Care Center, a five-story building occupying most of the northwest block of the intersection. There are taverns on the southwest and southeast corners. There are no public transportation buses traveling through this intersection. However, the MBTA Blue Line runs parallel to Ocean Avenue to the west, and Revere Beach Station is located one block to the north at Beach Street, where MBTA bus routes #s 110, 117, and 411 connect.

Level of Service (LOS)

Intersection LOS analysis showed that the AM peak hour operated at LOS B, while the PM peak hour operated at LOS C. These totals, by lane group and total approach, as shown below.

2007 Intersection LOS Summary (Existing Conditions)

	AM Peak Hour			PM Peak Hour		
Existing Conditions	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing*	B	17	13	C	23	18

Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

2007 LOS by Lane Group, Total Approach (Existing Conditions)

AM Peak Hour (7:30–8:30)											
Ocean Avenue						**Shirley Avenue**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
	B			B			C			C	
B (total approach)			B (total approach)			C (total approach)			C (total approach)		
PM Peak Hour (5:00–6:00)											
Ocean Avenue						**Shirley Avenue**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
	B			B			D			C	
B (total approach)			B (total approach)			D (total approach)			C (total approach)		

This reveals that there was very little congestion at this intersection during the AM and PM peak hours. Only on Shirley Avenue eastbound during the PM peak hour was there some congestion, with that approach operating at LOS D. As described above in the Traffic Volumes section, Revere Beach Parkway is located about 100 feet to the east, and likely carries some of the (northbound) traffic that would otherwise have used Ocean Avenue.

Conclusions/Significant Findings

- There are sight distance issues at this location. The intersection is located on a crest, and vehicles traveling northbound or southbound may have difficulty seeing traffic approaching from the opposite direction.

- 69% of all crashes were angle. Of these, 26 of 38 crashes (68%) involved at least one northbound vehicle colliding with a vehicle from one of the other three approaches.

- Peak period travel speeds appeared to sometimes be excessive, based on field observations, especially north of the intersection where there is a medical center and a mid-block (unsignalized) pedestrian crossing.

- Some signal heads are of the older, non-LED type.

Preliminary Conceptual Improvements

The following concepts for improving safety and traffic operations at this intersection were tested:

- Improvement Concept 1: <u>Implement split signal phasing.</u> In order to improve safety by reducing potential conflicts between the northbound and southbound traffic streams, a split phase signal scheme was analyzed. The northbound and southbound signal phases were split for both the AM and PM peak hours. This created four distinct phases: northbound only; southbound only; eastbound and westbound; and, an exclusive pedestrian phase.

  The intersection levels of service for both the existing scheme and for Improvement Concept 1 are shown below.

Intersection LOS Summary: Existing Conditions and Improvement Concept 1 (2007 Traffic Volumes)

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing* (95 secs. cy. le.)	B	17	13	C	23	18
Imp. Concept 1 *Split phasing NB/SB* (AM: 80 secs., PM: 75 secs.)	C	28	17	D	43	21

cy. le. = cycle length
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

- Improvement Concept 2: Improve/add signage on all approaches stating “Medical Area,” “Pedestrian Crossing.” This would raise driver awareness of potential pedestrian traffic and reduce the potential for vehicle-pedestrian conflicts.

- Improvement Concept 3: Add an LED signal a few hundred feet south of the intersection warning drivers of “(Red) Signal Ahead.” This would raise drivers’ awareness that they are approaching a signalized intersection.

- Improvement Concept 4: Reduce the speed limit from 35 to 25 miles per hour on Ocean Avenue near the intersection. Due to the compromised sight distance northbound (as well as southbound), it is important to use all means necessary to reduce excessive speeds of vehicles approaching the intersection. This is especially true at this location, which is used heavily by pedestrians, both at the intersection proper, as well as at a mid-block crosswalk just to the north in order to access the medical center and the MBTA Blue Line station.

- Improvement Concept 5: Upgrade/replace older signal heads with LED types.

Discussion and Recommendations

CTPS sought feedback from Revere officials and MassHighway District 4 staff regarding traffic operations and likely improvements at this intersection. The comments received are shown in Appendix A-12.

Staff feel that the safety concerns at this intersection do not stem from lack of capacity, inappropriate geometry, or traffic signal design. Instead, the intersection’s being on the crest of the hill impairs driver visibility of the opposing traffic. The result is apparently angle crashes between northbound and southbound vehicles, in most cases.

Improvement Concepts 2 through 5 are all appropriate to help remedy the limited sight distance concerns. In fact, these should be implemented first, and, if the safety situation does not improve, then Improvement Concept 1 should also be implemented. This split phase signal design concept, which would completely eliminate northbound-southbound turning/through traffic conflicts, would yield somewhat higher intersection delays and lower levels of service. Therefore, if not absolutely necessary from a safety standpoint, implementation of the split phase signal design should be avoided.

13. STONEHAM: Main Street (Route 28) at William Street

Existing Conditions

Geometry/Physical Characteristics

This is a signalized intersection, and is under local (Town of Stoneham) jurisdiction. Main Street (Route 28) has two general-purpose lanes on both the northbound and southbound approaches, as well as short (one car length), channelized right-turn storage pockets. In addition, the southbound approach has an exclusive left-turn lane with storage for approximately 10 cars. On the northbound approach, there is a 4-foot wide rumble strip/median, more or less opposite the southbound exclusive left turn lane.

The William Street eastbound approach has two general-purpose lanes, while the westbound approach has an exclusive right-turn lane and a through/left-turn lane. The posted speed limit on all approaches is 30 miles per hour. Field reconnaissance in May, September, and December of 2007 showed that the crosswalks on all four approaches and roadway lane markings were very faded.

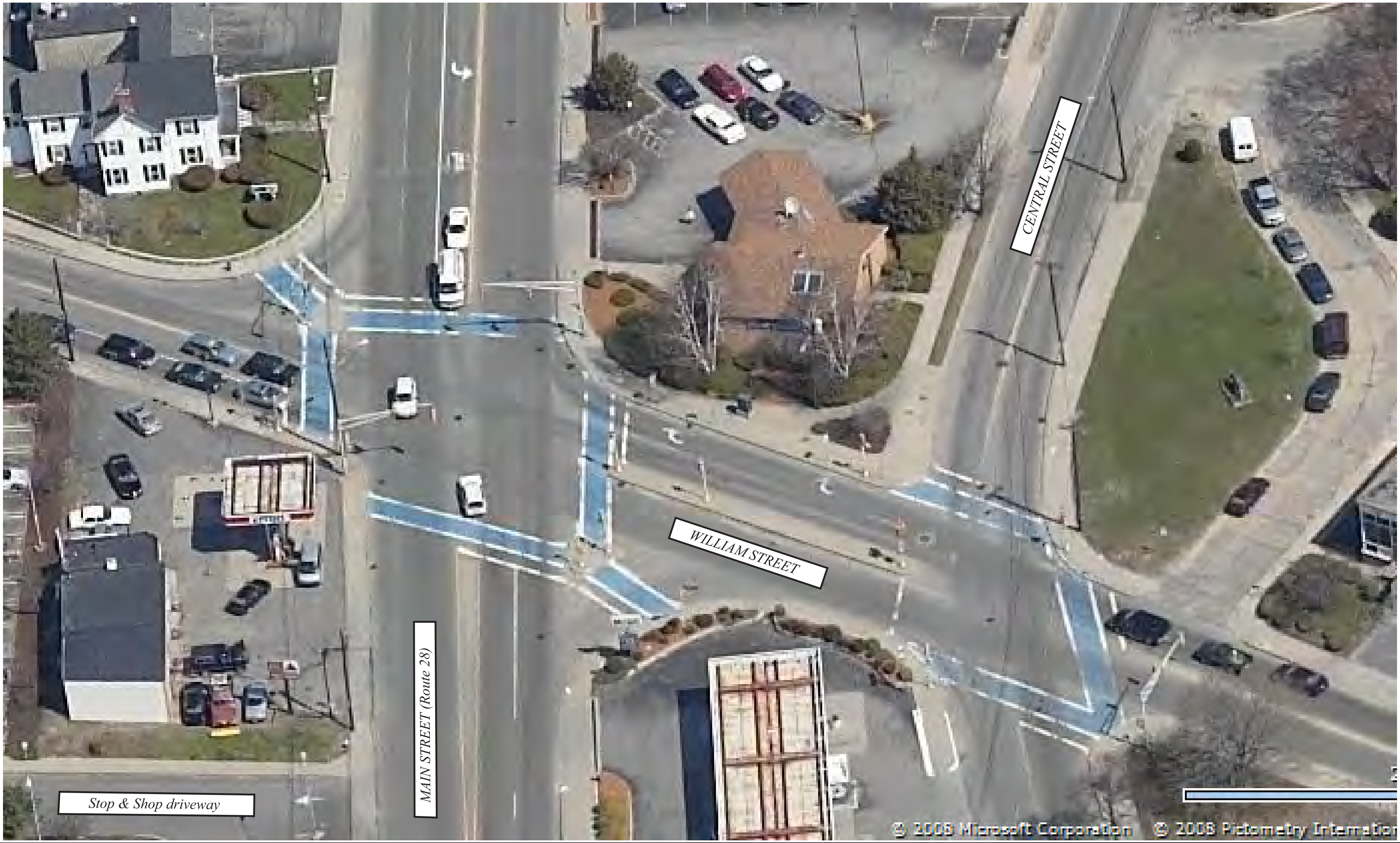
It should also be noted that a mere 75 feet to the east there is a busy signalized intersection of William Street and Central Street. A middle school is located on the northeast corner of that intersection, which contributes to the overall traffic volumes and operations at Main Street at William Street. The two signals are coordinated (see Figure 13-1).

Traffic Control

This is an actuated, coordinated signal that has three distinct signal phases during both the AM and PM peak periods: (1) leading southbound, (2) northbound/southbound, and (3) eastbound/westbound. There is no exclusive pedestrian phase; rather, the pedestrian signals display "WALK" concurrently with the parallel green signal phase for vehicles. There are pedestrian buttons on the southwest and northeast corners, as well as on small islands in the northwest and southeast areas of the intersection. However, they seemed to have no function since no exclusive pedestrian phase was actuated when the buttons were pushed. Right turns on red (RTOR) are allowed on all except the William Street eastbound approach. The signal is coordinated with the signal at William Street at Central Street.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows (Main Street at William Street only—not William Street at Central Street):



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Safety and Operational Improvements at Selected Intersections

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FIGURE 13-1

Stoneham: Main Street (Route 28) at William Street

SOISI/Stoneham/Figure 13-1

2007 AM and PM Peak Hour Turning Movements
(vehicles)

AM Peak Hour (7:15–8:15)											
Main Street (Route 28)						**William Street**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
50	360	20	130	1,070	50	30	160	30	20	250	140
430 (total approach)			1,250 (total approach)			220 (total approach)			410 (total approach)		

- Main Street, NB + SB approaches combined: 1,680 vehicles
- William Street, EB + WB approaches combined: 630 vehicles
- Pedestrians (all approaches): 94
- Bicycles (all approaches): 3

PM Peak Hour (5:00–6:00)											
Main Street (Route 28)						**William Street**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
40	840	30	140	690	100	70	280	40	6	240	220
910 (total approach)			930 (total approach)			390 (total approach)			466 (total approach)		

- Main Street, NB + SB approaches combined: 1,840 vehicles
- William Street, EB + WB approaches combined: 856 vehicles
- Pedestrians (all approaches): 16
- Bicycles (all approaches): 8

The approach with the greatest AM peak hour volumes was Main Street southbound, 1,250 total vehicles. The highest AM peak hour turning movements were William Street westbound right turns, 140 vehicles, and Main Street southbound left turns, 130 vehicles. In the PM peak hour, the approaches with the greatest volumes were Main Street southbound, 930 vehicles, and northbound, 910 vehicles. The single highest PM peak hour turning movement was William Street westbound right turns, 220 vehicles.

Crashes

The vehicle crash rate for this location was 1.69 crashes per million vehicles entering the intersection. This exceeds the most recent average crash rate of 0.88 for Mass-Highway District 4 area signalized intersections. Specific characteristics of the vehicle crashes include:

- 58% of crashes were angle. Examination of the RMV data revealed no distinct patterns for these crashes. Individual collisions involved combinations of vehicles from all approaches. This “non-pattern” of angle crashes was confirmed somewhat during field reconnaissance. When observing turning movements during both the AM and PM peak hours, numerous near-collisions were seen involving turning and through vehicles from all directions.

The likely cause(s) for the angle crashes that do occur appeared from field observations to be vehicles from all approaches attempting to "beat the yellow light," as well as vehicles attempting to turn left during very short gaps in the opposing through traffic stream.

- 20% of crashes were rear-end. This suggests that one-fifth of all crashes occurred during congested, stop-and-go traffic conditions. The only distinct pattern seen in the data involved vehicles traveling northbound. Of the 11 rear-end crashes recorded, 8 (73%) occurred when a northbound vehicle rear-ended another northbound vehicle. Six of the 11 rear-end crashes (55%) occurred during either the AM (7:00–9:00) or PM (4:00–6:00) peak periods.

- 2% of crashes were head-on.

- 20% of crashes were other/undetermined.

Additionally:

- 5% of crashes (3 of 55) involved pedestrians. Of these:

    a. One occurred at 2 PM on an April afternoon and did not result in personal injury, just property damage.

    b. Another occurred at 8 PM on an August evening under clear, dry, and dark (but lighted) road conditions and resulted in personal injury.

    c. The third occurred at 8 AM on an October morning under clear and dry road conditions and resulted in personal injury.

- 0% of crashes involved bicyclists.

- 27% of all crashes resulted in personal injuries. This is somewhat below the 15-intersection study average of 35%.

- 55% of crashes occurred during April–October (spring, summer, fall); 45% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (9 of 55 crashes, or 16%, occurred during rain, snow, or fog).

- 87% of crashes occurred during daytime, 7 AM through 7 PM; 13% occurred during night-time, 7 PM through 7 AM. No predominant darkness-related crash patterns were seen.

Land Use

This is a very busy, suburban intersection. Main Street (Route 28) is a north-south arterial used both as a commuter route and as a feeder route to I-95 (Route 128) to the north, and to I-93 to the southwest.

The surrounding land use is very active. On the southwest corner is a gas station, and behind it, a Stop and Shop plaza. On the southeast, northeast, and northwest corners are another gas station, bank, and small office building, respectively. There is mostly commercial land use away from the intersection in the northbound/southbound directions, while eastbound/westbound it is mostly residential.

One short block to the east (about 75 feet) on William Street (at Central Street) there is a middle school on the northeast corner. As a result, there are many pedestrians crossing through both intersections during the AM and PM peak periods. MBTA bus # 132 runs north-south on Main Street, and stops at the intersection as well.

Level of Service (LOS)

Intersection LOS analysis was only performed for the signal at Main Street and William Street. The analysis showed that both the AM and PM peak hours had cycle lengths of 100 seconds and operated at LOS C. These measures are broken down further by lane group and total approach, as the tables below show.

2007 Intersection LOS Summary (Existing Conditions)

	AM Peak Hour			PM Peak Hour		
Existing Conditions	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing*	C	26	25	C	28	29

Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

2007 LOS by Lane Group, Total Approach (Existing Conditions)

AM Peak Hour (7:15–8:15)											
Main Street (Route 28)						**William Street**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
	B		E	A			D			E	B
B (total approach)			B (total approach)			D (total approach)			D (total approach)		
PM Peak Hour (5:00–6:00)											
Main Street (Route 28)						**William Street**					
Northbound			**Southbound**			**Eastbound**			**Westbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
	C		E	A			E			D	B
C (total approach)			B (total approach)			E (total approach)			C (total approach)		

This reveals that most approaches do not experience significant delays and congestion. The Main Street northbound and southbound approaches both operated at LOS B or C during the AM and PM peak hours. William Street eastbound and westbound operated at LOS C, D, or E during the two peak hours. The Main Street southbound left turns experienced the most delay, operating at LOS E during the AM and PM peak hours. The William Street westbound through vehicles (AM only), and William Street eastbound, all traffic (PM only), also operated at LOS E. Overall queue lengths ranged from 3–10 vehicles per approach per cycle for both peak hours.

Conclusions/Significant Findings

- From field observation, much “turbulence” was seen at this intersection that was not captured in the level of service analysis. Vehicles turning left from the two Stop and Shop plaza driveways on the southwest corner interfere with Main Street, and to a lesser degree, with William Street, traffic flows. There are a number of additional driveways on properties adjacent to this intersection on the remaining corners that also affect traffic operations. However, although the gas station on the southeast corner and the bank on the northeast corner each have three curb cuts—two on Main Street, one on Central Street, respectively—there are posted signs which properly prohibit left turns onto Main Street from each of the driveways closest to the intersection. Finally, although the two signals are coordinated, from field observations there seemed to be some impact on traffic operations at Main Street at William Street from the adjacent William Street at Central Street intersection, such as traffic backing up between the two locations.

- Drivers do not willingly allow pedestrians to proceed before them during concurrent pedestrian and parallel vehicle phases. In fact, only one approach has a sign warning drivers: “STATE LAW: STOP for pedestrians in crosswalk” (approaching Main Street in the William Street westbound direction).

- Northbound traffic backs up into the intersection from the downstream signal located near the Walgreen’s plaza a few hundred feet to the north.

- Numerous children on bicycles were seen riding concurrently with traffic through the intersection during both the AM and PM peak periods.

- Although the southbound departure lanes are wide enough (perhaps 10 feet wide each) to accommodate through vehicles from the two general-purpose lanes from the north for a distance of about 100 feet, southbound traffic moves tentatively, usually proceeding as though there were only one departure lane, since there are no visible lane markings to help drivers.

Preliminary Conceptual Improvements

At the outset, it is suggested that a complete intersection collision diagram be performed. This should be based on local police accident reports, and would provide an insight into exact crash patterns at and near this intersection.

The following concepts for improving safety and traffic operations at this intersection were tested:

- Improvement Concept 1: <u>Add an exclusive pedestrian signal phase.</u> Since peak hour delays and congestion are not extreme at this intersection, there would seem to be room for this improvement. It would increase safety for the large number of middle school students, MBTA bus commuters, and other pedestrians crossing the four approaches, especially during the AM and PM peak hours. An exclusive pedestrian signal phase of 18 seconds was tested.

- Improvement Concept 2: <u>Add a leading eastbound signal phase.</u> There is already a leading southbound signal phase which helps to reduce the potential for crashes between northbound and southbound left-turning and through vehicles. Likewise, implementing a leading eastbound signal phase—since there are more eastbound than westbound left turns—would help to reduce potential crashes between eastbound and westbound turning, and through, vehicles. This improvement concept also included an 18-seconds exclusive pedestrian signal phase.

The LOS results for existing conditions and for Improvement Concepts 1 and 2 are shown in the following table.

Intersection LOS Summary: Existing Conditions and Improvement Concepts 1 and 2 (2007 Traffic Volumes)

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing* (100 secs. cy. le.)	C	26	25	C	28	29
Imp. Concept 1 *Exclusive pedestrian phase* (AM: 90 secs. PM: 100 secs.)	D	36	30	D	38	32
Imp. Concept 2 *Exclusive pedestrian phase+leading EB phase* (AM: 90 secs. PM: 100 secs.)	D	37	32	C	34	32

cy. le. = cycle length
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

The LOS analyses showed that with the addition of an exclusive pedestrian phase in Improvement Concept 1, the intersection would deteriorate slightly, to LOS D. Improvement Concept 2 would add a leading eastbound signal phase, and traffic operations would operate at LOS D during the AM peak hour, and at LOS C during the PM peak hour. Improvement Concept 1 was *explicitly safety-oriented for pedestrians* through adding an exclusive pedestrian phase. Improvement Concept 2 builds on that concept, and adds an improvement which was *explicitly safety-oriented for vehicles and for reducing potential angle crashes*, through adding a leading (protected) eastbound vehicle signal phase.

- Improvement Concept 3: <u>Post signs prohibiting vehicles exiting the Stop and Shop plaza from turning left (northward) onto Main Street during the AM and PM peak periods.</u> This improvement would help to reduce the "turbulence" and interruptions in traffic flow south of the intersection. There is already a street about 100 feet further to the south (Lindenwood Road) which connects the shopping plaza to Main Street, and where vehicles can exit and turn northward and thereby minimize impacts near the intersection. Possible time frames for prohibiting left turns from the plaza driveway could be 7:00–9:00 AM (which are also the key school arrival hours) and 4:00–6:00 PM.

- Improvement Concept 4: Add signs warning drivers: "STATE LAW: STOP for pedestrians in crosswalk." Through field observations it was seen that three of the four approaches lacked this type of sign which is designed to protect pedestrians. Only the William Street westbound approach has this sign.

- Improvement Concept 5: Restripe all lane markings and crosswalks in the intersection. In particular, create two official departure lanes for southbound through vehicles.

Discussion and Recommendations

CTPS staff received feedback from Stoneham officials and MassHighway District 4 staff regarding the analysis and recommendations for this intersection. Comments are available in Appendix A-13 for review.

For the reasons stated in the analysis above, it makes sense to incorporate a leading eastbound phase into the traffic signal design (Improvement Concept 2). This phase would help protect the heavier eastbound left turns, and, hopefully, improve vehicle safety. If this change is implemented, the offset and other coordination parameters between this intersection and the adjacent one at William Street at Central Street must be reconsidered.

At this time, Improvement Concept 1—introducing an exclusive pedestrian phase—may not be necessary. Were this measure to be implemented in conjunction with Improvement Concept 2, traffic operations would improve to LOS C. Besides, from a safety point of view, just three out of 55 crashes involved pedestrians.

Constructing a collision diagram would supply detailed information about the exact location of crashes within the boundaries of the intersection. In fact, as the definition of these boundaries can be within 60 to 100 feet radius from its center, it would be easy to identify how many of the angle crashes happen at each of the approaches, including at the Stop and Shop driveway, as well as the intersection of William Street at Central Street, about 75 feet to the east. The diagram would provide a refined analysis of the causes of accidents based on their location, and steer the appropriate mitigation.

If a collision diagram reveals the presence of crashes between left-turning vehicles from the Stop and Shop driveway and Main Street vehicles, then Improvement Concept 3 should be considered. Concepts 4 and 5 are important to implement for the protection of pedestrians as well as of motorists.

14. WAYLAND: Commonwealth Road (Route 30) at Main Street (Route 27)

Existing Conditions

Geometry/Physical Characteristics

This is a signalized intersection, and is under local (Town of Wayland) jurisdiction. Commonwealth Road (Route 30) has one general-purpose lane on both the eastbound and westbound approaches. Main Street (Route 27) northbound has an exclusive left-turn lane and a through/right-turn lane. Main Street southbound has one general-purpose lane (see Figure 14-1).

Although Commonwealth Road eastbound and westbound and Main Street southbound each have one general-purpose lane, through and right-turning vehicles were at times observed squeezing by queued left-turning vehicles. For capacity analysis purposes, however, this study assumes one general-purpose lane each on the westbound and southbound approaches, respectively. On Commonwealth Road eastbound, however, there is a slightly widened area of the travel lane, creating a short left-turn storage pocket (2–3 car lengths). Consequently, this approach is analyzed as having two 9-foot wide lanes. Since the actual traffic operations do not exactly match the capacity analysis input parameters, overall level of service (LOS) results presented below are therefore likely to be slightly worse than in reality.

The posted speed limit in the area ranges from 25 miles per hour on Main Street to 35 miles per hour on Commonwealth Road. Field reconnaissance in May, September, and December of 2007 showed that the crosswalks and roadway lane markings on all four approaches were faded.

Traffic Control

This is a pre-timed signal, which has four distinct signal phases during both the AM and PM peak periods: (1) leading eastbound, (2) eastbound/westbound, (3) northbound/southbound, and (4) a manually activated, exclusive pedestrian phase which lasts 20 seconds, sufficient time for most pedestrians to cross any of the approaches. There are functioning pedestrian buttons on all corners, located on each of four approximately 12-foot high posts. The pedestrian phase signal is of the old variety, where a moving vehicle-direction yellow phase is followed by a red-and-yellow in all four directions. The current peak period cycle length is 97 seconds.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

CTPS

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FIGURE 14-1

Wayland: Commonwealth Road (Route 30) at Main Street (Route 27)

SOISI/Wayland/Figure 14-1

2007 AM and PM Peak Hour Turning Movements (vehicles)

AM Peak Hour (7:45–8:45)											
Commonwealth Road (Route 30)						**Main Street (Route 27)**					
Eastbound			**Westbound**			**Northbound**			**Southbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
90	470	200	90	310	10	120	320	80	20	400	60
760 (total approach)			410 (total approach)			520 (total approach)			480 (total approach)		

- Commonwealth Road, EB + WB approaches combined: 1,170 vehicles
- Main Street, NB + SB approaches combined: 1,000 vehicles
- Pedestrians (all approaches): N.A.
- Bicycles (all approaches): N.A.

PM Peak Hour (5:00–6:00)											
Commonwealth Road (Route 30)						**Main Street (Route 27)**					
Eastbound			**Westbound**			**Northbound**			**Southbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
80	490	160	60	380	40	120	390	90	50	320	80
730 (total approach)			480 (total approach)			600 (total approach)			450 (total approach)		

- Commonwealth Road, EB + WB approaches combined: 1,210 vehicles
- Main Street, NB + SB approaches combined: 1,050 vehicles
- Pedestrians (all approaches): N.A.
- Bicycles (all approaches): N.A.

The approach with the greatest AM peak hour volumes was Commonwealth Road eastbound, 760 total vehicles. The single highest AM peak hour turning movement was Commonwealth Road eastbound right turns, 200 vehicles. In the PM peak hour, the approach with the greatest volumes was again Commonwealth Road eastbound, 730 vehicles. The single highest PM peak hour turning movement was, yet again, Commonwealth Road eastbound right turns, 160 vehicles.

Crashes

The vehicle crash rate for this location was 2.59 crashes per million vehicles entering the intersection. This significantly exceeds the most recent average crash rate of 0.84 for Mass-Highway District 3 area intersections. Specific characteristics of the vehicle crashes include:

- 45% of crashes were angle. Examination of the RMV data revealed no distinct crash patterns for these crashes. Individual collisions involved combinations of vehicles from all approaches. This “non-pattern” of angle crashes was confirmed somewhat during field reconnaissance. When observing turning movements during both the AM and PM peak hours, numerous near-collisions were seen involving turning and through vehicles from all directions.

Based on field observations, the likely cause(s) for the angle crashes appeared to be vehicles from all approaches attempting to “beat the yellow light,” as well as vehicles attempting to turn left during very short gaps in the opposing through traffic stream.

- 41% of crashes were rear-end, well above the 15-intersection study average of 27%. This suggests that less than half of all crashes occurred during congested, stop-and-go traffic conditions. The only somewhat distinct pattern seen in the data involved vehicles traveling southbound. Of the 29 rear-end crashes recorded, ten (34%) occurred when a southbound vehicle rear-ended another southbound vehicle. Eleven of the 29 total rear-end crashes (38%) occurred during either the AM (7:00–9:00) or PM (4:00–6:00) peak periods.

- 3% of crashes were head-on.

- 11% of crashes were other/undetermined.

Additionally:

- 1% of crashes (1 of 71) involved pedestrians. This one crash ocurred at 1 PM on a May afternoon under clear and dry road conditions and resulted in personal injury,

- 0% of crashes involved bicyclists.

- 24% of all crashes resulted in personal injuries. This is somewhat below the 15-intersection study average of 35%.

- 54% of crashes occurred during April–October (spring, summer, fall); 46% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (13 of 71 crashes, or 18%, occurred during rain, snow, or fog).

- 85% of crashes occurred during daytime, 7 AM through 7 PM; 15% occurred during night-time, 7 PM through 7 AM. No predominant darkness-related crash patterns were seen.

Land Use

This is a very busy, suburban intersection in the southernmost section of Wayland. Commonwealth Road (Route 30) is an east-west arterial used as a commuter route, as well as a feeder route to the Shopper’s World area on Route 9, and to the Massachusetts Turnpike interchange located in Framingham (Exit 13), 1.3 miles to the west. Main Street (Route 27) runs north-south, and the intersection is 0.1 mile north of the Natick line, and 1.2 miles north of Route 9 and the numerous shopping centers in that area.

The immediate surrounding land use consists of a post office and a bank on the northwest corner; a Starbucks, pet supply store, and bagel shop on the southwest corner; an auto dealership on the northeast corner; and, a small plaza including a Rite Aid Pharmacy, a small supermarket, and a Bank of America branch on the southeast corner. Adjacent to the plaza are also a small office building and a gas station. There are mostly single-family residences away from the intersection in all directions. There are no public transportation bus routes that service this location.

Level of Service (LOS)

Intersection LOS analysis showed that both the AM and PM peak hours operated at LOS F. These measures are broken down further by lane group and total approach, as the tables below show.

2007 Intersection LOS Summary (Existing Conditions)

	AM Peak Hour			PM Peak Hour		
Existing Conditions	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing*	F	* (452)	83	F	* (1,690)	103

* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

2007 LOS by Lane Group, Total Approach (Existing Conditions)

AM Peak Hour (7:45–8:45)											
Commonwealth Road (Route 30)						**Main Street (Route 27)**					
Eastbound			**Westbound**			**Northbound**			**Southbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
E	E			F		F	E			F	
E (total approach)			F (total approach)			F (total approach)			F (total approach)		
PM Peak Hour (5:00–6:00)											
Commonwealth Road (Route 30)						**Main Street (Route 27)**					
Eastbound			**Westbound**			**Northbound**			**Southbound**		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
D	E			F		F	F			F	
E (total approach)			F (total approach)			F (total approach)			F (total approach)		

This reveals that most approaches experienced significant delay. Three of the four approaches operated at LOS F during both the AM and PM peak hours; only Commonwealth Road eastbound operated at LOS E during both peak hours.

Conclusions/Significant Findings

- Peak period delays are significant. Essentially, there is not enough intersection capacity for the amount of traffic attempting to travel through this location during the AM and PM peak periods. There are long queues on all approaches, and occasional cycle failures where queued vehicles need more than one cycle to pass through the intersection.

The Commonwealth Road westbound and Main Street southbound approaches are particularly congested during the AM and PM peak periods. Each (one-lane) approach experiences on average about 25–30 queued vehicles during a signal cycle. Commonwealth Road eastbound and Main Street northbound, due to their additional capacity, experience slightly shorter queues, approximately 15–25 vehicles per approach during each signal cycle. On a few occasions during the PM peak hour, westbound traffic was seen blocking the intersection and thereby preventing southbound (in particular) and even northbound vehicles from moving forward during a green signal. This queueing of westbound traffic is possibly related to the manually activated signal at the T.J.X. offices, just over one mile downstream to the west on Route 30.

- Numerous near-collisions were observed on all four approaches at this congested intersection. Turning vehicles nearly crashed with through vehicles as well as with other turning vehicles.

- The pedestrian signal phase is activated by functioning buttons on all four corners. However, the simultaneous red-and-yellow display in all four directions is outdated and potentially confusing to non-local drivers.

- The signal posts, approximately 12 feet in height, appeared to be old. At least one of the posts was tilting slightly to one side.

Preliminary Conceptual Improvements

The following concepts for improving safety and traffic operations at this intersection were tested:

- Improvement Concept 1: Change the current pretimed signal timing to fully actuated, and optimize the signal splits and cycle length. This was tested to determine whether a re-allocation of green time and change in cycle length would reduce queueing and alleviate congestion on some approaches. Two variations of this concept were performed.

  Improvement Concept 1a used the current cycle length of 97 seconds for both the AM and PM peak hours when optimizing only the signal splits. Improvement Concept 1b yielded a cycle length of 120 seconds for both the AM and PM peak hours when optimizing the signal splits and cycle lengths.

- Improvement Concept 2: Replace the exclusive pedestrian phase with a concurrent pedestrian phase. Two variations of this concept were performed:

  a. Most of the approaches at this intersection have relatively low left- and right-turning volumes, with the exception of Commonwealth Road eastbound right turns and Main Street northbound left turns. “Crash data consistently show that crashes with pedestrians occur far more often with turning vehicles than with straight-through traffic. Left-turning vehicles are more often involved in pedestrian collisions than right-turning vehicles, partly because drivers are not clearly able to see pedestrians on the left."[21]

It should also be noted that based on three field visits during the AM and PM peak periods, very few pedestrians or bicycles were observed crossing through the intersection, even with the exclusive pedestrian phase in place. Additionally, the 4-hour AM and PM peak period manual turning movement count, performed in May, 2007, recorded no pedestrians and just one bicycle.

With this in mind, the existing exclusive pedestrian phase stops traffic on all approaches while pedestrians are allowed to cross in any direction. Replacing the exclusive phase with a concurrent one would allow pedestrians to cross parallel with vehicles that have a green signal. This would then provide more time for vehicles to travel through the intersection. This improvement concept was optimized to a 100 second cycle length for the AM peak hour, and to a 120 second cycle length for the PM peak hour (Improvement Concept 2a).

b. Replace the exclusive pedestrian phase with a concurrent pedestrian phase; however, implement a Leading Pedestrian Interval (LPI) by extending the all-red signal phase to four or more seconds. For the approach about to receive a green signal, the LPI "illuminates the pedestrian WALK signal, while the motor vehicle signal remains red for the first few seconds of the cycle. The LPI gives pedestrians an opportunity to start walking and establish a presence in the crosswalk before drivers can begin their turn."[22] This improvement concept was analyzed with an LPI of 4 seconds for the all-red phase, and was optimized to a 120 second cycle length for both the AM and PM peak hours (Improvement Concept 2b).

- Improvement Concept 3: Widen the intersection, and add 12-foot wide exclusive left-turn lanes to the Commonwealth Road eastbound and westbound approaches and to the Main Street southbound approach. Depending on available right-of-way, a three-lane cross section on both roadways would be created. This could be accomplished by taking strips of land from the four corners, approximately 150–200 feet in length along the roadways. Two variations of this concept were analyzed:

  a. Leading eastbound/westbound, and northbound/southbound, left-turn phases were tested. Each was followed by a phase accommodating through and right-turning vehicles, respectively, and the analysis was optimized to 120 seconds for both the AM and PM peak hours. The exclusive pedestrian phase of 20 seconds was retained (Improvement Concept 3a).

[21] From U.S. Department of Transportation, Federal Highway Administration, *Intersection Safety Issue Briefs, No. 9, Pedestrian Safety at Intersections*, p. 2, April 2004.
[22] See www.saferoutesinfo.org/guide/engineering/traffic_signals.cfm, *Reduce the Number of Motor Vehicle Movements that Conflict with Pedestrians*. For a case study, go to: www.walkinginfo.org/pedsafe/casestudy.cfm?CS_NUM=66.

b. Same as variation 3a just described. However, the exclusive pedestrian phase would be replaced by an LPI of 4 seconds for the all-red phase, and then optimized to a 110 second cycle length for the AM peak hour, and to a 120 second cycle length for the PM peak hour (Improvement Concept 3b).

- Improvement Concept 4: Widen the intersection in order to create two general-purpose lanes on each of the four approaches. Depending on available right-of-way, a four-lane cross section on both roadways would be created. This could be accomplished by taking strips of land from the four corners, approximately 150–200 feet in length along the roadways. Improvement Concept 4 was analyzed with (a) an exclusive pedestrian phase of 20 seconds (Improvement Concept 4a), and (b) a concurrent pedestrian phase, with an LPI and 4 seconds all-red (Improvement Concept 4b). Improvement Concept 4a was optimized to a 90 second cycle length, Improvement Concept 4b to a 60 second cycle length. See Figure 14-2 for details.

  The LOS results of existing conditions, and of Improvement Concepts 1, 2, 3, and 4 are shown in the table on page 143. The LOS analyses showed that when Improvement Concepts 1, 2, or 3 were analyzed, delays were reduced and queues became shorter, but the intersection would still operate at LOS E or F. Only Improvement Concept 4, the widening of each of the four approaches to two general-purpose lanes, would improve traffic operations significantly, to LOS B or C, and would result in substantially shorter queues.

- Improvement Concept 5: Replace the old signal posts, either with new posts or with overhead mast arms. The overhead mast arms improvement should be implemented, particularly if either of the widening improvements are pursued (Improvement Concepts 3 or 4).

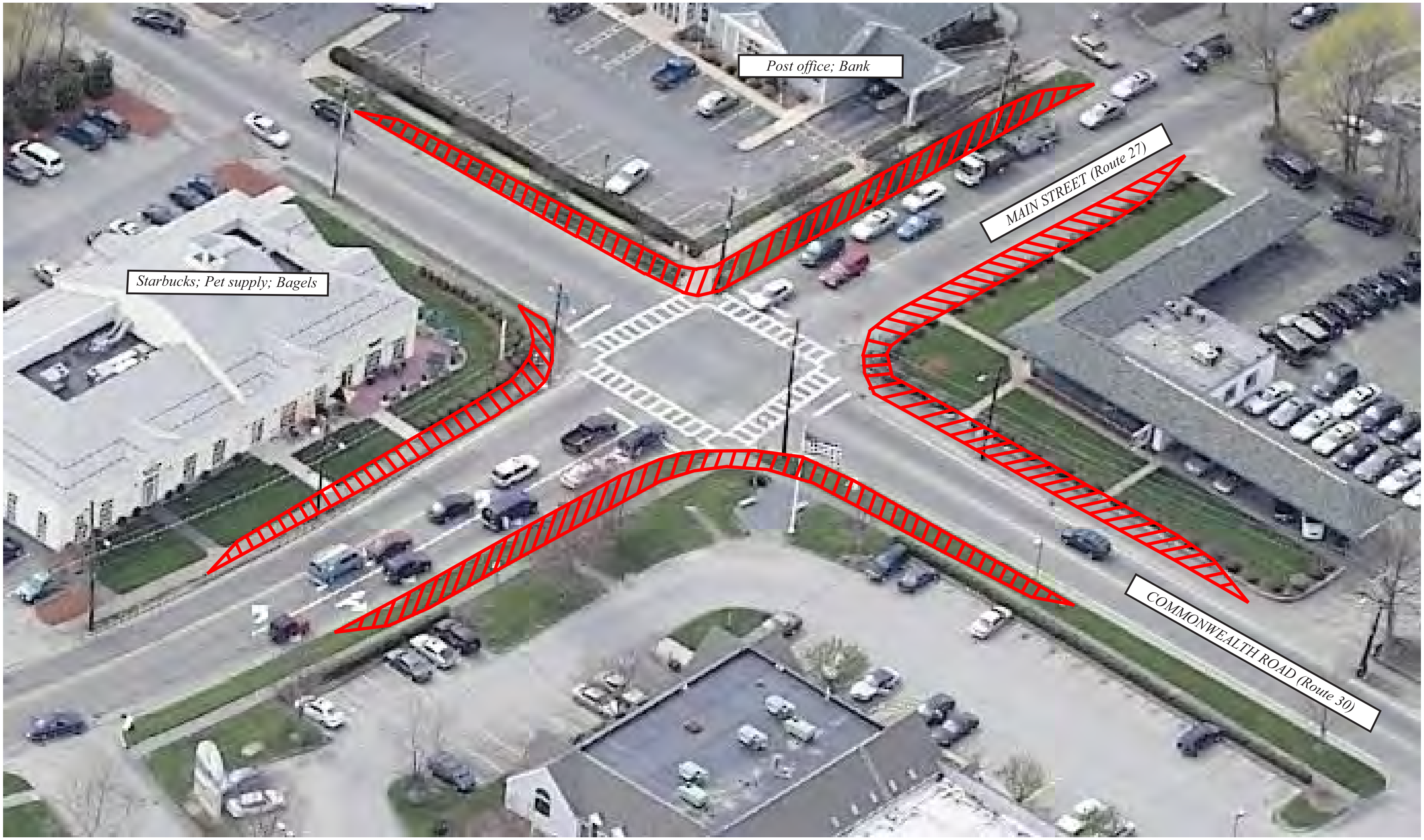
Discussion and Recommendations

CTPS staff sought feedback from Wayland officials and MassHighway District 3 staff. The comments received are in Appendix A-14.

Pedestrian safety, motorist safety, and aesthetics at this location are very important goals for the Wayland Route 30 Intersections Committee, formed more than seven years ago. With that in mind, the Improvement Concept 1 analysis indicated that level of service and, likely safety, would not improve much.

Analysis of Improvement Concept 2 yielded additional overall operational benefits, but did not meet the goal for enhanced pedestrian safety.

Improvement Concept 3a, where all approaches would have exclusive/protected left-turn lanes, and would retain the exclusive pedestrian phase, may be the preferred scenario for this intersection. MassHighway District 3 and the Town of Wayland have had initial conversations on improvements at this location, and this design appears to be favored. Improvement Concept 3b is not recommended, as the Leading Pedestrian Interval (LPI) may be confusing and potentially unsafe to pedestrians.



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Safety and Operational Improvements at Selected Intersections

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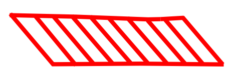
FIGURE 14-2

Improvement Concept 4



= **area of geometric changes**

SOISI/Wayland/Figure 14-2

Improvement Concept 4 is a rather "big build" idea that is likely difficult to implement because of the high demand for right-of-way takings.

Finally, Improvement Concept 5, improving the signal posts/mast arms, would be considered as part of the reconstruction of the intersection in any recommendation implemented.

Intersection LOS Summary: Existing Conditions and Improvement Concepts 1, 2, 3, and 4 (2007 Traffic Volumes)

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
2007 *Existing* (97 secs. cy.le.)	F	* (452)	83	F	* (1,690)	103
Imp. Concept 1a *Optimized splits* (97 secs. cy.le.)	F	* (127)	49	F	* (327)	66
Imp. Concept 1b *Optimized splits, cycle lengths* (120 secs. cy.le.)	F	* (108)	62	F	* (286)	84
Imp. Concept 2a *Concurrent ped. phase* (AM: 100 secs. PM: 120 secs.)	E	69	60	F	* (196)	96
Imp. Concept 2b *Concurrent ped. phase + LPI* (120 secs. cy.le.)	F	* (97)	77	F	* (264)	102
Imp. Concept 3a *Excl. l. turn lane* (120 secs. cy.le.)	E	74	60	F	* (82)	70
Imp. Concept 3b *Excl. l. turn lane + LPI* (AM: 110 secs. PM: 120 secs.)	E	69	66	E	76	86
Imp. Concept 4a *2 GP lanes* (90 secs. cy. le.)	C	22	14	C	24	17
Imp. Concept 4b *2 GP lanes + LPI* (60 secs. cy.le.)	B	19	12	C	22	16

cy. le. = cycle length
* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

15. WEYMOUTH: Pleasant Street at Pine Street/Tall Oaks Drive

Existing Conditions

Geometry/Physical Characteristics

This is an unsignalized intersection located almost under, just to the south of, the limited-access Route 3 highway in Weymouth. The intersection is under local (Town of Weymouth) jurisdiction, although Tall Oaks Drive is a private road. Pleasant Street has one general-purpose lane on each of the northbound and southbound approaches. Pine Street is stop-controlled, has one general-purpose lane, and approaches the intersection from the east. Where Pine Street meets Pleasant Street, it is possible for two vehicles to line up side-by-side (one to two cars deep) and turn left or right, respectively. About 50 feet south of Pine Street, there is a second one-lane street intersecting Pleasant Street. Tall Oaks Drive is also stop-controlled, and approaches Pleasant Street from the west, and has one general-purpose lane (see Figure 15-1).

The posted speed limit on Pleasant Street is 30 miles per hour, and 25 miles per hour on Pine Street and Tall Oaks Drive. Field reconnaissance in May and September of 2007 showed that the one existing crosswalk across Pleasant Street (south of Tall Oaks Drive) was clear and visible. However, all other lane markings, stop lines, and center lines were faded. There are sidewalks on both sides of Pleasant Street, but they tend to be narrow (3–4 feet wide) and in rather poor shape. It should be noted that there are obscured sight lines both northbound and southbound on Pleasant Street. From the north, it is difficult to see Tall Oaks Drive on the right, while from the south, Pine Street is similarly obscured on the right side.

Traffic Control

The only traffic controls at this intersection are stop signs for Pine Street westbound and Tall Oaks Drive eastbound traffic.

Traffic Volumes

The 2007 turning movements and total approach volumes for the AM and PM peak hours were as follows:

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Safety and Operational Improvements at Selected Intersections

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FIGURE 15-1

Weymouth: Pleasant Street at Pine Street/Tall Oaks Drive

2007 AM and PM Peak Hour Turning Movements
(number of vehicles)

AM Peak Hour (7:45–8:45)											
Pleasant Street						Tall Oaks Drive			Pine Street		
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
10	810	10	170	590	10	100	N.A.	30	4	N.A.	360
830 (total approach)			770 (total approach)			130 (total approach)			364 (total approach)		

- Pleasant Street, NB + SB approaches combined: 1,600 vehicles
- Tall Oaks Drive, EB/Pine Street, WB approaches: 494 vehicles
- Pedestrians (all approaches): N.A.
- Bicycles (all approaches): N.A.

PM Peak Hour (4:30–5:30)											
Pleasant Street						Tall Oaks Drive			Pine Street		
Northbound			Southbound			Eastbound			Westbound		
Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
40	690	9	350	970	60	40	N.A.	30	4	N.A.	210
739 (total approach)			1,380 (total approach)			70 (total approach)			214 (total approach)		

- Pleasant Street, NB + SB approaches combined: 2,119 vehicles
- Tall Oaks Drive, EB/Pine Street, WB approaches: 284 vehicles
- Pedestrians (all approaches): N.A.
- Bicycles (all approaches): N.A.

The approach with the greatest AM peak hour volumes was Pleasant Street northbound, 830 total vehicles. In the PM peak hour, the approach with the greatest volumes was Pleasant Street southbound, 1,380 vehicles, including 350 left turns onto Pine Street. The greatest single turning movement count was on Pine Street, where right-turning vehicles totaled 360 during the AM peak hour.

Crashes

The vehicle crash rate for this location was 0.88 crashes per million vehicles entering the intersection. This exceeds the most recent average crash rate of 0.63 for Mass-Highway District 4 area unsignalized intersections. Specific characteristics of the vehicle crashes include:

- 52% of crashes were angle. Examination of the RMV data revealed that individual angle collisions involved combinations of vehicles from all approaches, and no distinct pattern was seen.

- 24% of crashes were rear-end. This suggests that one-fourth of all crashes occurred in congested, stop-and-go traffic. As with the angle crashes, no distinct pattern was seen in the distribution of rear-end crashes by approach.

- 0% of crashes were head-on.

- 24% of crashes were other/undetermined.

Additionally:

- 0% of crashes involved pedestrians.

- 0% of crashes involved bicyclists.

- 32% of all crashes resulted in personal injuries.

- 56% of crashes occurred during April–October (spring, summer, fall); 44% occurred November–March (winter). There seemed to be no predominant weather-related crash patterns (1 of 25 crashes, or 4%, occurred during rain, snow, or fog).

- 48% of crashes occurred during daytime, 7 AM through 7 PM; 52% occurred during night-time, 7 PM through 7 AM. This percentage (52%) of crashes occurring during the evening/ night-time was by far the highest of all 15 study area intersections. It is conceivable that there is not enough street lighting at or near the intersection. Combined with poor sight lines in the northbound and southbound directions, these conditions may thereby contribute to the proportion of darkness-related crashes.

Land Use

The surrounding land use is varied. To the south, it is mostly single-home residential, with elementary and middle schools located within three-fourths of a mile. North of the intersection, and of Route 3, there is a mix of office buildings and warehouses in the Libbey Industrial Park, as well as residential neighborhoods. There is JBL Bus Lines service to Braintree Station (Red Line, commuter rail) along Pleasant Street in this section of Weymouth.

Level of Service (LOS)

LOS analysis for this unsignalized intersection, by approach, is shown below.

2007 LOS Summary, by Approach (Existing Conditions)

	AM Peak Hour: LOS / Delay				PM Peak Hour: LOS / Delay			
Existing Conditions	Pleasant St		Tall Oaks	Pine St	Pleasant St		Tall Oaks	Pine St
	NB	SB	EB	WB	NB	SB	EB	WB
2007 *Existing*	A / 1	A / 8	F / * (530)	C / 17	A / 2	B / 13	F / * (245)	B / 14

* = 50 or more seconds total delay per vehicle. When unsignalized intersection approach delay is 50 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.

This reveals that the Pleasant Street northbound and southbound approaches operated at LOS A or B during the AM and PM peak hours. The Pine Street westbound approach operated at LOS C and B during the AM and PM peak hours, respectively. Tall Oaks Drive eastbound operated at LOS F during both peak hours.

Conclusions/Significant Findings

- The Pine Street and Tall Oaks Drive approaches are offset by approximately 50 feet. The crash data indicates that 64% of all crashes (16 of 25) occurred at Pleasant Street at Tall Oaks Drive. 36% of the crashes occurred at Pleasant Street at Pine Street, despite the substantially higher traffic volumes on Pine Street. The higher incidence of crashes at Tall Oaks Drive may be related to the higher number of left turns there than at Pine Street (140 versus 8, during the AM and PM peak hours, combined).

- There are sight distance issues at this intersection, both from the north and south on Pleasant Street. When traveling southbound, the Tall Oaks Drive approach appears suddenly on the right. While traveling northbound, it is likewise difficult to see Pine Street on the right until the last moment.

- This intersection had the highest percentage of darkness-related crashes of all 15 study area intersections. 52% of all crashes occurred between 7 PM and 7 AM; the next highest intersection had 36% of crashes occur during the evening or night-time (Central Street at Tremont Street in Peabody). A possible explanation could be inadequate street lighting at the intersection, combined with the poor sight lines, which contributed to the incidence of crashes.

- Sidewalks along Pleasant Street are narrow and substandard. The crosswalk markings (across Pleasant Street, south of Tall Oaks Drive) were clear and visible, but all other stop lines and lane stripings had become faded.

Preliminary Conceptual Improvements

The following concepts for improving safety and traffic operations at this intersection were tested:

- Improvement Concept 1: <u>A warrant analysis for installing a traffic signal was performed.</u> From this analysis, the following warrants were met:

Warrant	Met?
1. Eight-hour vehicular volume	Probably *(more count data needed)*
2. Four-hour vehicular volume	Yes
3. Peak hour	Yes
4. Pedestrian volume	No
5. School crossing	Not tested
6. Coordinated signal system	N.A.
7. Crash experience	Probably *(more field trials needed)*
8. Roadway network	Yes

If it is determined that a new traffic signal is appropriate, it would provide increased safety for vehicles, pedestrians, and bicyclists wishing to turn from Pine Street and Tall Oaks Drive onto Pleasant Street. Table 1 above showed that this location had the third highest Crosswalk Pedestrian Intersection Safety Index (Ped ISI) of all 15 study intersections, an index of 3.6. As Table 1 and the source below describe, the higher the Ped ISI, the greater the "priority for an indepth safety assessment."[23] Although no pedestrian-related crashes or bicycle-related crashes were seen in the data, the intersection has a high Ped ISI due to the high intersection traffic volumes, the posted speed limits, and the absence of a traffic signal.

An LOS analysis was performed for a hypothetical new traffic signal, assuming the current intersection geometry, lane allocation, and peak hour volumes. Three variations of this improvement concept were examined (Improvement Concepts 1a, 1b, and 1c).

Improvement Concept 1a tested a fully actuated signal. The phasing scheme included four phases: (1) leading Pleasant Street southbound, all turns; (2) Pleasant Street northbound/ southbound, all turns; (3) leading Pine Street westbound, all turns; and (4) Pine Street westbound, right turns only, left turns prohibited; Tall Oaks Drive eastbound, all turns. The signal splits and cycle lengths were optimized, yielding an AM peak hour cycle length of 100 seconds, and a PM peak hour cycle length of 120 seconds. There would be no exclusive pedestrian phase; rather, the pedestrian movements would be concurrent with parallel vehicle traffic. Right turns on red (RTOR) would be allowed.

In Improvement Concept 1b, in addition to the new signal, the Pleasant Street southbound approach was restriped to include an exclusive left turn lane and a through/right-turn lane, both 10 feet wide. It appears that there is enough roadway width to accommodate two 10-feet wide southbound lanes and one 12-feet wide northbound lane without removing the sidewalks on either side. The phasing scheme was the same as for Improvement Concept 1a, and was optimized to a 120 second cycle length for the AM peak hour, and to 90 seconds for the PM peak hour. Again, the pedestrian movements would be concurrent with parallel vehicle traffic, and RTOR would be allowed.

Improvement Concept 1c also included the restriped, exclusive left-turn lane on the southbound approach. The phasing scheme was different than Improvement Concepts 1a

[23] U.S. Department of Transportation, Federal Highway Administration, *Pedestrian and Bicyclist Intersection Safety Indices*, Publication No. FHWA–HRT–06–129, p. 1, April 2007; see www.tfhrc.gov/safety/pedbike/pubs/06129/06129.pdf

and 1b in that a split phase was introduced for the eastbound and westbound approaches. The four phases tested were: (1) leading Pleasant Street southbound, all turns; (2) Pleasant Street northbound/ southbound, all turns; (3) Tall Oaks Drive eastbound only, all turns; and (4) Pine Street westbound only, all turns. In addition, RTOR would be prohibited on all four approaches. In essence, although pedestrian movements would still be concurrent with parallel vehicle traffic, it is still overall a safer improvement concept in that all the potential eastbound/westbound vehicle conflicts, as well as RTOR conflicts, have been eliminated.

The LOS results for the existing conditions as well as for Improvement Concepts 1a, 1b, and 1c are shown in the following tables.

2007 LOS Summary, by Approach (Existing Conditions)

Unsignalized

	AM Peak Hour: LOS / Delay				PM Peak Hour: LOS / Delay			
Existing Conditions	Pleasant St		Tall Oaks	Pine St	Pleasant St		Tall Oaks	Pine St
	NB	SB	EB	WB	NB	SB	EB	WB
2007 *Existing*	A / 1	A / 8	F / * (530)	C / 17	A / 2	B / 13	F / * (245)	B / 14

* = 50 or more seconds total delay per vehicle. When unsignalized intersection approach delay is 50 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.

Signalized

Existing Cond./ Improvement Concept	AM Peak Hour			PM Peak Hour		
	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)	LOS	Intersection Delay (sec.)	Total Avg. Queue (# veh.)
Imp. Concept 1a *New signal* (120 secs. cy.le.)	E	55	56	F	* (177)	69
Imp. Concept 1b *New signal w. SB left-turn lane* (100 secs. cy. le.)	C	29	34	C	27	29
Imp. Concept 1c *New signal w. SB left-turn lane; EB/WB split phase* (120 secs. cy. le.)	F	* (124)	79	F	* (165)	86

cy. le. = cycle length
* = 80 or more seconds total delay per vehicle. When signalized intersection delay is 80 seconds or higher, the delay estimate becomes unreliable because the calculation is beyond the limits of the associated equation.
Note: Total average queue is the average number of queued vehicles at the intersection during a given signal cycle.

The analysis showed that in Improvement Concept 1a (the installation of a new, four-phase traffic signal), the AM peak hour would operate at LOS E, and the PM peak hour would operate at LOS F. Both peak hours were optimized to a 120 second cycle length. The longest queues would occur on the Pleasant Street southbound approach, around 35 vehicles per signal cycle during the AM peak hour, and about 60 vehicles per signal cycle during the PM peak hour.

Improvement Concept 1b also included the installation of a new, four-phase signal; however, the southbound approach was restriped to include an exclusive left-turn lane. When the cycle length was optimized to 100 seconds for both peak hours, LOS improved to C for both the AM and PM peak hours. The longest AM peak hour queues occurred on the Pleasant Street northbound approach, 20 vehicles per signal cycle. The PM peak hour queues improved markedly, to highs of only about 13–15 vehicles on each of the Pleasant Street northbound and southbound approaches.

Improvement Concept 1c included a split phase in order to eliminate all eastbound/westbound vehicle conflicts. It also eliminated all RTOR conflicts. The AM and PM peak hour cycle lengths were optimized to 120 seconds, and traffic operations were LOS F during both peak hours. All individual approaches operated at LOS F during both peak hours, except for Pleasant Street southbound, which operated at LOS C in the AM peak hour, and LOS D in the PM peak hour. The longest AM peak hour queues were on Pleasant Street northbound, about 35 vehicles per signal cycle. During the PM peak hour, the longest queues were on the Pleasant Street northbound and southbound approaches, also around 35 vehicles per signal cycle.

- Improvement Concept 2: <u>Ensure that lighting is sufficient at and near the intersection.</u> Since this location had the highest percentage of darkness-related crashes of all 15 study intersections, it is conceivable that there may be insufficient lighting. This could therefore contribute to an increase in crashes, and should be addressed, whether or not a new traffic signal is installed.

Discussion and Recommendations

CTPS sought input on the analysis of this intersection from the Town of Weymouth and MassHighway District 4. Their comments are included in Appendix A-15.

This intersection actually consists of two three-legged unsignalized intersections located about 50 feet apart, just south of the Route 3 overpass. The predominant crash pattern was angle collisions. In addition, 50% of the crashes occurred in the evening hours. The crash data indicated the need for better lighting at night, and the separation of conflicting traffic flows within the intersection using a traffic signal that would be appropriately designed to reflect the geometric layout of this location.

Traffic signal warrant analysis indicated that the installation of a signal could be appropriate. Four signal designs were examined: Improvement Concepts 1a, 1b, and 1c allow for various degrees of movement priority and protection; Improvement Concept 1d allows for a complete isolation of conflicting movements. Depending on the availability of right-of-way, the construction of southbound and northbound exclusive left-turn lanes would de desirable to facilitate the application signal designs 1b, 1c, or 1d. All in all, Improvement Concept 1b would yield the best level of service, and 1d would yield the best safety improvement results. Unless the right-of-way for an exclusive northbound left-turn lane is not available, staff recommends that the Town implement Improvement Concept 1d in order to maximize overall safety levels.

Finally, enhanced lighting at this location is crucial, and it is highly recommended in order to address crashes that happen at night.

APPENDIX A

Provided here are communications to CTPS from local officials of the study communities, as well as from MassHighway Districts 3 and 4 staff, with respect to the improvement concepts developed by CTPS. The order of the communications corresponds to the order of the intersection analyses in this memo.

APPENDIX A–10 *(pp. 170)*	Quincy: Hancock Street (Route 3A) at East/West Squantum Street **Roy C. LaMotte, Jr., Quincy Director of Traffic and Parking** **Connie Raphael, MassHighway District 4 Planning Coordinator**
APPENDIX A–11 *(p. 172)*	Randolph: North Main Street (Route 28) at Reed/Pond/Old Streets **Stephen P. Levreault, Randolph Department of** **Public Works Engineer** **Connie Raphael, MassHighway District 4 Planning Coordinator**
APPENDIX A–12 *(p. 173)*	Revere: Ocean Avenue at Shirley Avenue **Connie Raphael, MassHighway District 4 Planning Coordinator**
APPENDIX A–13 *(p. 174)*	Stoneham: Main Street (Route 28) at William Street **Robert E. Grover, Director, Stoneham Department of Public Works** **Connie Raphael, MassHighway District 4 Planning Coordinator**
APPENDIX A–14 *(p. 175)*	Wayland: Commonwealth Road (Route 30) at Main Street (Route 27) **Andrew Paul, MassHighway District 3**
APPENDIX A–15 *(p. 176)*	Weymouth: Pleasant Street at Pine Street/Tall Oaks Drive **Georgy Bezkorovainy, Weymouth Traffic Engineer** **Connie Raphael, MassHighway District 4 Planning Coordinator**

APPENDIX A-1: BEVERLY, Rantoul Street (Route 1A) at Elliott Street (Route 62)

From Michael P. Collins, P.E., Beverly Director of Public Services:

The timing of the study was excellent. We are finalizing a contract with our design engineer for the total reconstruction of Rantoul Street. The information in the study has been forwarded to our engineer for incorporation into the design of the roadway. The information is highly detailed and, most importantly, current.

I will leave it up to the engineer of record to choose the final design of the intersection but I do like option 2a. It seems to achieve the highest level of service with the smallest impact to the surrounding parking.

I greatly appreciate the opportunity to be part of the study and I am very impressed with the results. This level of detail would have cost the City a great deal of money. It is having a direct impact on the cost of the design work for Rantoul Street reconstruction.

Let me know if you need more information from us. We hope to be in construction within approximately two years.

Thanks again,

Michael P. Collins P.E.,
Director of Public Services

APPENDIX A-2: BOSTON, Hyde Park Avenue at River Street (Cleary Square)

From James Gillooly, Assistant Commissioner, Boston Transportation Department (BTD):

Thank you for submitting your analysis of the Hyde Park Avenue & River Street intersection (Cleary Square) to BTD for review. BTD offers the following comments:

1. We have reviewed the Synchro model used to analyze this intersection. Currently, the model is inconsistent with our central computer control of this intersection. We recommend the following changes to the existing conditions model and then apply to all improvement scenarios:
    a. The controller type should be Actuated-Coordinated (timing window).
    b. The intersection operates as a single ring: Phase 1 is River St (both directions), Phase 2 is the exclusive pedestrian phase of 23 seconds, Phase 5 is Hyde Park Ave NB lead, Phase 6 is Hyde Park Ave (both directions), Phase 7 is River St EB lead.
    c. Set recall mode for Phase 1 to 'C-Max' (phasing window). All other phases should have recall set to 'None.'
    d. Set Ring and Barrier Design to the following (Options-Ring and Barrier Designer): Ring A, Barrier 1: Phase 1, Phase 2 (Phase 2 MUST be the last phase in Barrier 1). Ring A, Barrier 2: Phase 5, Phase 6, Phase 7. This will have any unused pedestrian time per cycle extend phase 1, as well as giving phase 1 extra time from other phases not called or gapped out.
    e. Set Yield Point to 'By Phase' (timing window).
    f. Set reference phase to 1-EBWB (timing window).
    g. For EBL and NBL movements, set phase detectors to 1,7 and 5,6, respectively (timing window).
    h. Reduce ped calls per hour to reflect 50% activation of exclusive pedestrian phase for both time periods (phasing window).
    i. Add right turn pocket of 100 ft. on Hyde Park Ave SB for PM Peak, due to PM restrictions (lane window).
    j. Add left turn pocket of 25 ft. on River St WB to model that through vehicles can get around a single left-turning vehicle (lane window).
    k. Make Hyde Park NB left turn pocket a full left-turn only lane since the width of the NB Hyde Park Ave allows for two lanes, rather than having the left turn pocket overflow into the thru lane (lane window).
    l. Timings are as follows:
    AM Peak – Cycle Length= 110 sec. Offset = 90
    Phase 1 = 24 green, 3 yellow, 1 AR.
    Phase 2 (excl. ped) = 10 Walk, 10 Flashing Don't Walk, 2 yellow, 1AR.
    Phase 5 = 6 green, 3 yellow, 1 AR
    Phase 6 = 30 green, 3 yellow, 1 AR
    Phase 7 = 11 green, 3 yellow, 1 AR

    PM Peak – Cycle Length= 110 sec. Offset = 90
    Phase 1 = 19 green, 3 yellow, 1 AR.
    Phase 2 (excl. ped) = 10 Walk, 10 Flashing Don't Walk, 2 yellow, 1AR.
    Phase 5 = 6 green, 3 yellow, 1 AR
    Phase 6 = 34 green, 3 yellow, 1 AR
    Phase 7 = 12 green, 3 yellow, 1 AR

2. BTD does not believe the proposed removal of the exclusive pedestrian phase is a viable option at this intersection due to safety and neighborhood concerns. BTD Design Guidelines states if there are more than 250 conflicting vehicles per hour for a concurrent pedestrian movement, then an exclusive pedestrian phase is warranted. Leading pedestrian phases (LPI's) are only considered for borderline cases and concurrent pedestrian crossings are used where conflicting vehicles less than 250 per hour. Several crosswalks at this location experience conflicting vehicle movements far above the 250-vehicle threshold for both the AM and PM peaks.

3. Due to the low amount of left-turning vehicles from Hyde Park Ave SB to River Street EB, BTD would like CTPS to investigate the possibility of converting the Hyde Park Ave. SB left turn lane into a left-through lane with the adjacent lane being a through-right lane, then having the two lanes taper back into one lane on the south (departing) side of the intersection. Another alternative BTD would like investigated is the installation a curb bump-out on the southwest corner of the intersection that would allow the crossing time for both the east and south crosswalks to be reduced and increasing green times for traffic.

4. For safety improvement, BTD would like CTPS to investigate whether the current yellow + all red times for each approach meet current MUTCD standards.

5. BTD, under its traffic signal timing program, is currently studying / developing optimized traffic signal timing plans along Hyde Park Avenue between Forest Hills and Cleary Square, as well as between Cleary Square and River/Gordon/Business Streets. We will forward your final recommendations to our consultant for consideration and possible incorporation.

Thank you again for your efforts and allowing BTD to provide feedback. Should you have any questions on these comments, please do not hesitate to contact Keith Bynum of BTD (617-635-1391).

Regards,

James Gillooly, Assistant Commissioner, Boston Transportation Department (BTD)

Cc: Thomas J. Tinlin, Commissioner, BTD
John DeBenedictis, P.E., Director of Engineering, BTD
Don Burgess, Supervising Traffic Engineer, BTD
Keith Bynum, Sr. Traffic Engineer, BTD

From Connie Raphael, MassHighway District 4 Planning Coordinator:

This looks like there may be some improvements that could help. We would recommend that the businesses by consulted on any changes to the parking restrictions. Perhaps parking restrictions could be limited to the AM peak hour when some of the businesses may be closed. The City should also carefully consider the pedestrian phasing. If there are elderly or children crossing the concurrent phase may not be the best idea. As we discussed before, the leading pedestrian interval is an intriguing idea but it probably isn't safer than an exclusive pedestrian phase.

APPENDIX A-3: BRAINTREE, Grove Street at Columbian Street

From Robert P. Campbell, P.E., Town Engineer, Braintree Department of Public Works:

(see letter on next pages)

From Connie Raphael, MassHighway District 4 Planning Coordinator:

MassHighway will look at the yellow and all red timing and adjust as needed. We will also add a second yield sign (on the left) for the Grove Street right hand turn. While the crash rate is over the average, it is not extremely high. So the geometric changes would not be on our priority list. We will keep in mind the relocation of the driveway if and when then property is redeveloped. We will also keep in mind pedestrian and bicycle accommodations when the area is reconstructed. Our traffic section was concerned about the proposed geometrics. They prefer the existing slip lanes perhaps with some tightening of the radii. The right turn from Columbian Street and the shared left/right from Grove Street WB were particularly concerning.

BRAINTREE DEPARTMENT OF PUBLIC WORKS

Robert P. Campbell, P.E. Town Engineer
Rcampbell@townofbraintreegov.org
John J. Morse, Assistant Town Engineer
Jmorse@townofbraintreegov.org

ENGINEERING DIVISION

April 14, 2008

Mr. Robert E. Sievert
Transportation Planner, CTPS
10 Park Plaza, Suite 2150
Boston, MA 02116

Re: Grove Street at Columbian Street, Braintree

Dear Mr. Sievert:

Thank you for your efforts to improve traffic operations and safety in Braintree.

I have reviewed the data analyses and conclusions on the subject project dated February 20th and received March 6th and have the following comments:

1. I believe that the development of "Southfield" at the former Weymouth Naval Air Station will significantly affect traffic volumes on Columbian and Grove Streets ("Old Route 128"). Has that traffic been anticipated in the analyses?

2. Improvement Concept 1 – Optimizing the signal timing to a shorter cycle length is an easy improvement, and could lead to motorists being willing to wait rather than enter the intersection during the red clearance interval. The red clearance interval timing should be checked for conformity with current standards and revised as appropriate.

3. Improvement Concept 2a may make the intersection safer, but the loss of capacity would not be acceptable to patrons.

4. Improvement Concept 2b would appear to improve both safety and capacity, and would also address the problem of extended WB left turn queues blocking WB right turn movements. However, I see no reason to restrict RTOR, especially given the absence of pedestrian traffic in this area.

5. Improvement Concept 3, moving the driveway further to the east is a good idea to avoid conflicts between driveway traffic and that in the channelized right turn lane, but implementation of Improvement 2a may make it less necessary and less desirable. NB right turners that may be delayed at the signal would quickly notice that the relocated driveway would line up to create an inviting short-cut

5. con't

through "Jamie's" parking lot. The steepness of the proposed driveway could also be problematic. So relocate if no Improvement Concept 2a, don't relocate if Improvement Concept 2a is implemented.

6. Improvement Concept 4. The Town would be in favor of the state installing the suggested sidewalk, and would commit to future maintenance in conformity with current practice. Our immediate concern, though, is to structurally improve the existing roadway pavement and delineation, as anticipated in the "Old Route 128" resurfacing project, project is #086901.

Thank you, again, for your efforts on this project, and for this opportunity to comment.

Very truly yours,

Robert P. Campbell

Robert P. Campbell, P.E.

RPC:ai

90 Pond Street, Braintree, MA 02184 Telephone: 781-794-8010 Fax: 781-794-8401

APPENDIX A-4: HOLLISTON, Washington Street (Routes 16/126) at Hollis Street

From Paul D. Le Beau, Town Administrator, Town of Holliston:

Thank you for the opportunity to comment on the CTPS analysis of the Washington/Hollis/Charles intersection in Holliston.

The Town is in the process of making significant improvements to that portion of Washington Street from Hollis Street to beyond Green Street and Exchange Street. The improvements include new paving, new roadway markings, relocated and raised pedestrian crosswalks, new pedestrian crosswalk signals, curbing and sidewalks. We feel that these improvements enhance safety for both vehicles and pedestrians in the area of the work and at the Washington/Hollis/Charles intersection. The work will be completed in May.

We suggest that you plan to review your analysis in light of the changes that have been made by the Town once those changes are completed.

Paul D. Le Beau
Town Administrator
Town of Holliston
Town Hall
703 Washington Street
Holliston, MA 01746
Tel.: 508.429.0608
Fax: 508.429.0684
Email: lebeaup@holliston.k12.ma.us
Web Site: www.townofholliston.us

From Andrew Paul, MassHighway District 3:

This location may not meet the necessary warrants for signal installation. Proper analysis should be done before a signal is considered.

In District 3 there are few examples of *Leading Pedestrian Intervals*. Due to that fact this may lead the pedestrian into a false sense of security when entering the crosswalk. It would be more standard to use an exclusive pedestrian phase at this location.

The District supports all other proposed improvements at this location and adds the following:

Due to the large pavement widths and no apparent physical constraints within the immediate vicinity of the intersection, a modern roundabout should be considered at this location. Some benefits of the modern round about are reduction of crossing distances for pedestrians, slower vehicle speeds and decreased delays. With a Ped ISI (Pedestrian Intersection Safety Index) of 3.8 (the highest of all the 15 locations in the state wide study) this would be a safety benefit.

APPENDIX A-5: LEXINGTON, Massachusetts Avenue (Routes 4/225) at Maple Street (Route 2A)

From David Cannon, P.E., Assistant Town Engineer, Town of Lexington:

Thank you for the opportunity to comment on the CTPS proposal. The Town of Lexington has reviewed the information supplied regarding the above referenced intersection. The Development Review Team, the Transportation Mitigation Group, the Planning Board, and the Engineering Division, have discussed the plans. We are pleased to make the following comments:

- This intersection is a few hundred yards south of the intersection of Massachusetts Avenue and Marrett Road; this intersection is integral to the function of the study intersection. The Massachusetts Avenue and Maple Street intersection cannot be considered in isolation. Traffic queues for each of these intersections routinely extend to the other intersection during peak hours.
- The Town of Lexington has recently funded the study of a section of Massachusetts Avenue that includes this intersection. Our study area is along Massachusetts Avenue from Pleasant Street to Marrett Road. We see this as an opportunity to work together with CTPS.
- Although the analysis indicated a roundabout might have a better level of service, a roundabout will have major property impacts. Specifically, the service station's business will be affected as will the access to the residential driveways that are on the intersection. Alternatives to a roundabout need to be considered.
- There are several bus stops in close proximity to the intersection and at least three bus lines that service this area. Provisions for safe transit and pedestrian access need to be factored into the concepts.
- This location is very close to a major access point to the Minuteman Bike Trail, a regional network, and as a result there is significant amount of bicycle traffic utilizing the intersection. Safe sight distances for bicycles need to be assured.
- The intersection is within a zoned historic district. Any structures would need a Certificate of Appropriateness from the Historic Districts Commission.

The Town looks forward to continuing to work with you toward solutions for this part of Massachusetts Avenue.

Yours truly,

David Cannon P.E.
Assistant Town Engineer

From Connie Raphael, MassHighway District 4 Planning Coordinator:

I agree with all of your recommendations for this location. This is a town location. Each alternative should be examined for impacts to driveways. The driveways to the gas station are especially concerning. We at the District generally like the idea of the roundabout but again driveway treatment is an issue. We believe a roundabout can be designed to be safe for pedestrians but it would obviously not be as safe as exclusive pedestrian phases at a signal. This the Town should weigh in making decisions.

We would also suggest the Town consider any historic issues early in the option selection process given that Mass Ave is an historic route (Paul Revere/William Dawes). Let me know if you have any questions.

APPENDIX A-6: LITTLETON, Great Road (Routes 2A/119) at King Street (Routes 2A/110)

From Keith A. Bergman, Town Administrator, Town of Littleton:

Thank you for the opportunity to provide input to the "Safety and Operational Improvements at Selected Intersections" study regarding the Route 110/119 intersection in Littleton.

Comments:

1. The report should reflect that this intersection is also Route 2A.

2. Traffic volumes reported are significantly lower than past reports on this interchange.
For example, using the "AM Peak Hour" data from several prior studies, this drastic difference is shown on the table below.

AM Peak Hour	King Street combined approaches (N/S)	Great Road combined approaches (E/W)
2007 CTPS Study	582	852
1999 "Andrews Crossing"	1002	1138
1993 "Meeting House Commons"	730	1133
1987 "Townwide Traffic Study"	660	1060

3. Further, the LOS for the "existing conditions" at this intersection has been shown to be "F" in several prior studies. (The town would be happy to share these prior reports.)

4. The 1999, 1993, and 1987 studies were conducted when the office park at 550 King Street was occupied. The CTPS study reflects the fact that the 550 King Street office park is currently under renovation, with no existing office use at the site. In addition, numerous office, retail, and warehouse buildings along Route 110 in Westford (that directly feed to this intersection) are currently empty. These factors, combined with the general economic downturn are the most likely reasons for the current lower traffic levels. However, this situation will soon change significantly.

IBM is scheduled to fully occupy the 550 King Street office park by mid-year 2009, with an estimated 2300 employees, plus associated contractors and services. IBM will also have an estimated 1100 employees at Route 110 in Westford. Westford also has had a significant increase in development along the Route 110 corridor, with more in the planning stages.

5. The Town fully agrees with the statement that "the roadway surface appeared to be uneven and in need of repaving."

Recommendations: CTPS recommends two signalization improvement concepts. The Town would prefer "Improvement Concept 1", as "Improvement Concept 2" actually reduces the LOS in the PM peak hour.

Conclusions: While these signalization improvements are much needed and appreciated, they are only the first step in solving the traffic problems at this intersection. We look forward to continuing to work with the State on the ultimate solutions to the problems at the intersection of Routes 110, 119, and 2A.

Sincerely,

Keith A. Bergman
Town Administrator
Town of Littleton, MA
bergman@littletonma.org
978-952-2311

Bob-
Below are additional comments forwarded from MAPC transportation planner Jim Gallagher to Littleton Planning Administrator/Permit Coordinator Maren Toohill.
Thanks very much.
Keith

Keith A. Bergman
Town Administrator
Town of Littleton, MA
bergman@littletonma.org
978-952-2311

From: Maren Toohill [mailto:toohill@littletonma.org]
Sent: Friday, April 04, 2008 8:57 AM
To: 'Gallagher, Jim'
Cc: 'Lucas, Barbara'; 'Racicot, Mark'; 'Keith Bergman'
Subject: RE: Littleton - King Street (Rt. 110) at Great Road (Rt. 119) - Safety and Operational Improvements at Selected Intersections study

Jim – thanks so much for your time on this site. The Town appreciates your assistance.
Please note that there is no “turn arrow” on the signals at this intersection, causing confusion on when there is a protected left turn. (Only for vehicles approaching from the east and only when the signal is activated by a waiting vehicle!).
It sounds like new signal heads are a must with the additional traffic coming soon. Yes, the Town feels keeping this intersection “walk-able” is a priority.
Again, thanks.
Maren

From: Gallagher, Jim [mailto:jgallagher@MAPC.ORG]
Sent: Thursday, April 03, 2008 5:23 PM
To: toohill@littletonma.org
Cc: Lucas, Barbara; Racicot, Mark
Subject: RE: Littleton - King Street (Rt. 110) at Great Road (Rt. 119) - Safety and Operational Improvements at Selected Intersections study

Maren,
Thanks for sending along the town's comments. I've looked at them and Bob Sievert's study and I agree with all of your comments and suggestions. I think there are a few additional improvements you might suggest.

I think the separated left turn phases (Concept 1) is better from both a congestion and a safety standpoint. The crashes involving left turning vehicles may result from poor sight distances and confusing left-turn arrows, as Bob Sievert suggests, as well as left-turning vehicles rushing to complete their turn because they are unwilling to wait through another cycle. Separating the turns from the thru traffic, and reducing the cycle length from 123 seconds to 80 or 75 seconds will separate the conflicting movements and reduce the desire to "beat the light". I would also suggest increasing the yellow time between phases by an additional 1 or 23 seconds to provide further separation between moves. The order of the phases (left turns before or after E/W thrus) should probably be based on whether these lefts have better sight distances to see the thru vehicles along Great Road or King Street (i.e. turns before better sight distance).

This approach should work for existing conditions, but, as you point out, volumes are expected to significantly increase in 2009. Given the location of the new jobs, I would expect the pattern of the turning movements in the intersection to change once the IBM plant is open, with more turns to/from the northern side of the intersection. It's possible at that point that there may be some need to change the phasing to separate left turns on King Street as well. I think this is another argument for using some of the older counts at the intersection that you reference. My suggestion – if you believe one of the past counts would be most like what you expect to happen when IBM opens, then request CTPS to do additional analysis on those volumes as if those are the 2009 conditions, and make recommendations for additional improvements, if needed.

Concept #3 on replacing signal heads should also help, and since the charge of the CTPS study was low cost improvements, probably appropriate. But a better solution for both congestion and safety would be new signal equipment, which would be more visible and allow signal timings to be changed based on changing volumes. Obviously more money, which could come from IBM mitigation or state/federal funds.

Keeping and upgrading the pedestrian signals is a good idea if you wish the area to be walkable. Since the report notes that the crosswalks are faded their repainting should be the minimum improvement requested. If you are upgrading signal equipment, other pedestrian improvements in the area should be part of that project.

I hope this helps. Please let me know if you have any questions.
Jim Gallagher

From Eric Nascimento, MassHighway District 3, Traffic Engineering:

The District supports all of the proposed improvements at this location and adds the following comments:

- The District thinks that changing the lane use on both Kings Street approaches will improve safety and traffic flow beyond what is shown in Concept 1 and Concept 2. The northbound approach could be converted into an exclusive left-turn lane and a shared through/ right lane. The southbound approach could then be modified into three lanes, with an exclusive left-turn lane, a through lane, and an exclusive right-turn lane. Both northbound and southbound would have only one departure lane. As part of this improvement, the signal timings and phasing at the intersection would have to be modified. Consider making the left turns protected on both Great Road approaches, and making the King Street northbound approach protected-permissive.

APPENDIX A-7: MARLBOROUGH, Bolton Street (Route 85) at Union Street

From Ronald LaFreniere, P.E., Commissioner of Public Works, City of Marlborough:

Mr. Seivert,

For some reason the information that we put together on this in early January did not get sent out to you. I will be forwarding you 3 e-mails containing information on this intersection. Once you've had a chance to look at the attachments in each of these e-mails, please get back to me if you have any questions.

Ron

E-mail number 1:

From: Cullen, Thomas
Sent: Thursday, January 10, 2008 2:47 PM
To: LaFreniere, Ron
Subject: Marlborough - Route 85 (Bolton Street) Corridor Study by MAPC / CTPS

Ron,

Attached herewith is one (1) of the three (3) e-mails that I will be forwarding to you regarding the Route 85 (Bolton Street) corridor studies and plan preparation that appears to have been done around the mid-1990s by VHB.

This report appears to be for Hudson and Bolton Streets.

Tom Cullen
City Engineer

E-mail number 2:

From: Cullen, Thomas
Sent: Thursday, January 10, 2008 2:50 PM
To: LaFreniere, Ron
Subject: Marlborough - Route 85 (Bolton Street) Corridor Study by MAPC / CTPS

Ron,

Attached herewith is the second of the three (3) e-mails that I will be forwarding to you regarding the Route 85 (Bolton Street) corridor studies and plan preparation that appears to have been done around the mid-1990s by VHB.

This report appears to be for Union and Bolton Streets.

Tom Cullen
City Engineer

E-mail number 3:

From: Cullen, Thomas
Sent: Thursday, January 10, 2008 2:55 PM
To: LaFreniere, Ron
Subject: Marlborough - Route 85 (Bolton Street) Corridor Study by MAPC / CTPS

Ron,

Attached herewith is the third of the three (3) e-mails that I will be forwarding to you regarding the Route 85 (Bolton Street) corridor studies and plan preparation that appears to have been done around the mid-1990s by VHB.

These .pdfs include the following:

1) The cover of the Draft Environmental Impact Report;
2) Three intersection plan sheets for the Union/Bolton intersection;
3) Plan sheet at Fitchburg & Route 85 connector.

Tom Cullen
City Engineer

[NOTE: These e-mails had attachments which contained numerous pages from the 1999 VHB traffic study of the Bolton Street at Union Street intersection. Those pages are not included here.]

From Andrew Paul, MassHighway District 3:

The District agrees with all the proposed improvements at this location and adds the following:

- Due to the fact that 81% of all angle crashes involved the southbound through traffic and left turning northbound traffic it may be in the best interest of safety to propose making the left turns protected and not permissive.
- In addition it may be in the best interest of safety to run a protected left turn phase in the south bound direction. Depending on the geometry this may be able to run concurrent with the northbound left turn.

APPENDIX A-8: MEDFIELD, Main Street (Route 109) at North Meadows Road/ Spring Street (Route 27)

From Eric Nascimento, MassHighway District 3, Traffic Engineering:

- The District has some concerns with Concept 2. This concept would decrease safety while trying to improve capacity through the intersection. The increase in capacity would be relatively small and does not seem to justify the decrease in safety. Also, there are only a few locations that use Leading Pedestrian Intervals (LPI) in District 3. Because there are so few locations like this, it may lead pedestrians into a false sense of security when entering the crosswalk. It would be more standard to continue using the exclusive pedestrian phase at this location.

The District supports all of the other proposed improvements at this location and adds the following:

- For Concept 3 we prefer option A (EB/WB exclusive right-turn lane, exclusive pedestrian phase) over option B (EB/EB exclusive right-turn lane, LPI pedestrian phase).

- Consider a modern roundabout at this location. Although there are right-of-way constraints surrounding the intersection, the implementation of a roundabout would help decrease the overall delay at intersection while improving the overall safety.

If you have any questions regarding these comments please feel free to contact me at (508) 929-3875 or Mark Johnson, P.E., District Traffic Engineer, at (508) 929-3831.
Thanks,
Eric

Eric Nascimento
MassHighway District 3
Traffic Engineering
Phone: (508) 929-3875
Fax: (508) 799-9763

APPENDIX A-9: PEABODY, Central Street at Tremont Street

From Jack Brennan, Peabody Department of Public Services:

[NOTE: There was no e-mail correspondence with Mr. Brennan. There was a telephone conversation, and from that interaction staff was able to borrow the "Bayside Engineering, Functional Design Report, Traffic and Safety Improvements for The Central Street at Tremont Street and Warren Street Intersection," February 2001. The discussion and recommendations in Chapter 9 are based in part on the findings in that report.]

From Connie Raphael, MassHighway District 4 Planning Coordinator:

I would not recommend a concurrent pedestrian phase since there are a large number of turns. Also the existing "free-for-all" mentality may persist and result in a hazardous condition for pedestrians. I would also recommend looking at this location in conjunction with the intersection at Warren Street.

Note - The intersection of Central, Warren and Tremont was earmarked in the 2000 TBB.

APPENDIX A-10: QUINCY, Hancock Street (Route 3A) at East/West Squantum Street

From Roy C. LaMotte, Jr., Quincy Director of Traffic and Parking:

(see letter on next page)

[NOTE: Mr. LaMotte was succeeded very late in the study by Mr. Jack Gillon, P.E. There was some very fruitful discussions and interaction by staff with Mr. Gillon as well; however, as it was very late in the study there was no need to substantially re-visit the improvement concepts already analyzed, or try to develop new concepts altogether.]

From Connie Raphael, MassHighway District 4 Planning Coordinator:

I agree that the work required to improve operations is extensive and requires significant ROW acquisition. I would be careful about installing a fence in a median on West Squantum Street. The median would need to be wide enough to place a sign (4 feet at least) and offsets would be needed, 2 feet each side. Also the fence may obstruct sight distance for vehicles and pedestrians at the intersection.

CITY OF QUINCY, MASSACHUSETTS
Department of Public Works

William J. Phelan
Mayor

Stephen T. O'Donnell
Commissioner

City of Quincy
DPW

December 10, 2007

Mr. Robert E. Sievert
Transportation Planner
CTPS
10 Park Plaza, Suite 2150
Boston, MA. 02116

Re : **Hancock Street (Rt.3A) at East/West Squantum St. Intersection**

Dear Mr. Sievert:

I wish to thank you and your team for taking the time to assess the above named intersection for operational & safety improvement concepts. It appears after reviewing the report that some of the concepts (i.e. Restrictive Signage) are easy to implement, while others (Involving Land Taking) are extremely expensive and require Legal Dept. involvement. It is my intent to discuss all presented concepts to the new City Administration and City Council shortly and then advise you of how we intent to proceed.

RECEIVED
DEC 12 2007
CTPS

I also look forward to additional input from the Massachusetts Highway Department on these concepts and the identification of any funding sources, which may assist the City in implementing the proposed improvements.

Sincerely,

Roy C. LaMotte, Jr.
Director of Traffic & Parking

Cc: Stephen T. O'Donnell-Commissioner of Public Works
File

APPENDIX A-11: RANDOLPH, North Main Street (Route 28) at Reed/Pond/Old Streets

From Stephen P. Levreault, Randolph Department of Public Works Engineer:

In response to your letter of February 29, 2008, we have finally had time to review your information provided regarding conceptual transportation improvements at the above referenced intersection. We are in agreement with your recommendations and concur with your observations. We would like to offer the following comments:

1. The re-allocation and widening shown in Improvement Concept 3 has been studied by us in the past. There is adequate sidewalk area to allow cutting back the sidewalk to construct a larger curbline radius for the right turn from Pond Street onto North Main Street northbound. This sharp corner is the reason the southbound lane stop line at this intersection on North Main Street was moved so far northerly to allow trucks the very wide radius needed to make this turn and clear cars waiting at the lights heading southerly on North Main Street.
2. We would additionally suggest that this same concept be incorporated on Reed Street easterly lane as it enters North Main Street.
3. We are agreement with the other 4 improvement concepts and these changes should be incorporated irregardless of Improvement Concept 3, possibly as conditions of local development impact improvements.

Thank you for your cooperation and work. If you have any other questions, do not hesitate to contact me.

Sincerely,

Stephen P. Levreault
DPW Engineer

From Connie Raphael, MassHighway District 4 Planning Coordinator:

We recently adjusted the timing at this location. The location will need detectors. It appears that the restriping of Pond Street will require widening and it is not clear that there is adequate ROW. We would usually need a 14-15 foot receiving lane on Pond Street to allow for truck turning movements. This would need to be looked at more carefully.

APPENDIX A-12: REVERE, Ocean Avenue at Shirley Avenue

From Connie Raphael, MassHighway District 4 Planning Coordinator:

[NOTE: There was no e-mail correspondence; however, from a telephone conversation, there was general agreement with the improvement concepts analyzed and recommended in this study:

- *Possibly reducing the speed limits on Ocean Avenue near the intersection.*
- *Adding an LED signal warning sign south of the intersection.*
- *Perhaps painting the signal posts in the intersection with a bright (yellow) color in order to more easily alert drivers of the signal ahead.]*

APPENDIX A-13: STONEHAM, Main Street (Route 28) at William Street

From Robert E. Grover, Director, Stoneham Department of Public Works:

Thank you for your request---the Town of Stoneham is very much interested in improving this intersection. Last week there was another accident which included personal injuries. The Town would like to recommend Concept 2 in conjunction with Concept 6 .The Town will add the pedestrian crossing signs this spring as part of our annual sign program and we will evaluate the left turn from Stop & Shop [Concept 4].

Bob Grover

From Connie Raphael, MassHighway District 4 Planning Coordinator:

I agree with your suggestions. The Town should consider restricting turns at the Stop & Shop driveway at all times especially for the left turn out toward Route 28 NB.

APPENDIX A-14: WAYLAND, Commonwealth Road (Route 30) at Main Street (Route 27)

From Andrew Paul, MassHighway District 3:

The District is currently in ongoing discussions with the town about improvements at this location and would support going forward with Concept 3.

If you have any further questions regarding these comments feel free to contact the district traffic office at 508-929-3831.

Regards,

Andrew Paul
MassHighway
mobile 617.799.0552
office 508.929.3875
fax 508.799.9763

APPENDIX A-15: WEYMOUTH, Pleasant Street at Pine Street/Tall Oaks Drive

From Georgy Bezkorovainy, Weymouth Traffic Engineer:

Tall Oaks Drive serves the Alexan residential development, which has been build over several decades, and there is a proposal to expand it further. The project is currently in litigation, and the town cannot take a position on the merits of the improvements, because the developer's mitigation plan is part of the litigation process.

Your crash analysis pointed out that we have a nighttime accident problem at the intersection. This is something that we are interested in pursuing and are working with the DPW in addressing this issue.

George

Georgy Bezkorovainy
Traffic Engineer
Town of Weymouth
75 Middle Street
E.Weymouth, MA 02189
Phone: 781-682-3638
Fax: 781-335-3283

From Connie Raphael, MassHighway District 4 Planning Coordinator:

I would suggest that the Town consider additional highway lighting and possibly brush trimming or other methods to increase visibility first. A speed study on Pleasant Street may also be a good idea. Perhaps the Town can try increased speed limit enforcement. I would only recommend that the signal option be pursued if there is public support for this option.