Subject	**The Great Road Traffic Optimization Study**	**Project Name**	Bedford Mitigation & Traffic Calming Study
Attention	J. Rebecchi, Town of Bedford	**Project No.**	E2X89300
From	L. Rabito, B. Isler, J. Gauvin		
Date	May 24, 2023		
Copies to			

1. Executive Summary

The Town of Bedford initiated the Great Road Traffic Optimization Study to examine the functionality of the Great Road/Route 4 corridor and its 11 intersections between Shawsheen Road and Carlisle Road/Route 225/North Road/Route 4. The goal of the Study is to improve safety and traffic operations on Great Road by evaluating operational and safety deficiencies and providing recommendations for short term and long-term improvements. Reducing travel delays along Bedford's main thoroughfare will improve residents' quality of life, lower vehicle emissions, and reduce cut-through traffic through residential neighborhoods.

Within Bedford, the Great Road is a significant connector to the I-95/Route128 corridor and several significant regional destinations such as the VA Hospital. Moreover, there are several major local destinations that Great Road provides access to such as Bedford Marketplace, Stop&Shop Plaza, and Bedford's Town Campus. According to the 2020 US Census, Bedford's residential population is about 14,400, whereas the daytime population is estimated to be approximately 25,000. Traffic data compiled for this Study indicates:

- A relatively significant portion of the traffic on Great Road is likely attributable to local destinations.
- Vehicles are likely using other collector roads in Town (South Road, Page Road, etc.) to bypass the heavily congested Great Road corridor.

A safety and traffic operational analysis was conducted to identify deficiencies with existing conditions and recommend improvements to the roadway layout and intersection controls. The following major findings/recommendations are included in the Study, and if implemented, should reduce congestion and improve safety on Great Road:

- A well-timed, coordinated signal system along Great Road would permit continuous movement through the corridor, and reduce congestion by minimizing stops and delays. Upgraded signal equipment would be needed in most cases.
- The following intersections meet engineering standards (MUTCD Signal Warrants) for signalization:
  - Brooksbie Road/Great Road
  - Willson Park (Concord Road/Great Road)
  - North Road/Carlisle Road
- Geometric improvements are recommended for some intersections to address specific deficiencies.

- Additional recommendations for crash clusters are included, and recommendations from previous plans and studies are brought forward as well.

Suggested timeframes for improvements are Interim (2029) or Long-Term (2040 or later). The recommendations include budgetary level, order-of-magnitude, probable construction costs. The total for the Interim Improvements is anticipated to be approximately $220,000; the total for the Long-Term Improvements is anticipated to be $4.7M (in 2022 dollars, respectively). The improvements would be eligible for the MassDOT Local Bottleneck Reduction Program, which targets delays that are created from poor traffic signal timing, outdated equipment, lack of adequate vehicle detection, or geometric deficiencies, and can be used on individual intersections or on small corridors. The program provides $500,000 maximum for construction costs in a single fiscal year.

2. Introduction

The Great Road Traffic Optimization Study considers how to improve safety and operations on Great Road/Route 4 between Shawsheen Road and Carlisle Road/Route 225/North Road/Route 4 in Bedford, and to prevent traffic from cutting through adjacent neighborhoods. This project evaluates the corridor and its 11 intersections (Figure 1) using proven engineering methodologies and software to recommend adjustments to the roadway cross section and intersection controls.

This memorandum presents the Improvement Plan, as well as summaries of the analyses that serve as the basis for the Improvement Plan; the full analyses are included as appendices. The memorandum is organized by intersection, beginning with a discussion of the Potential for Cut-Through Traffic. Each of the intersection sections presents existing conditions, safety analysis, a traffic operational analysis, and recommended improvements.

Given the large volumes of traffic diverting through residential areas to avoid the queues on Great Road, there are benefits to encouraging traffic to use Great Road instead as the main arterial route through town. The suggested improvements also address ongoing safety concerns and focus on signal efficiency instead of adding capacity through additional lanes.

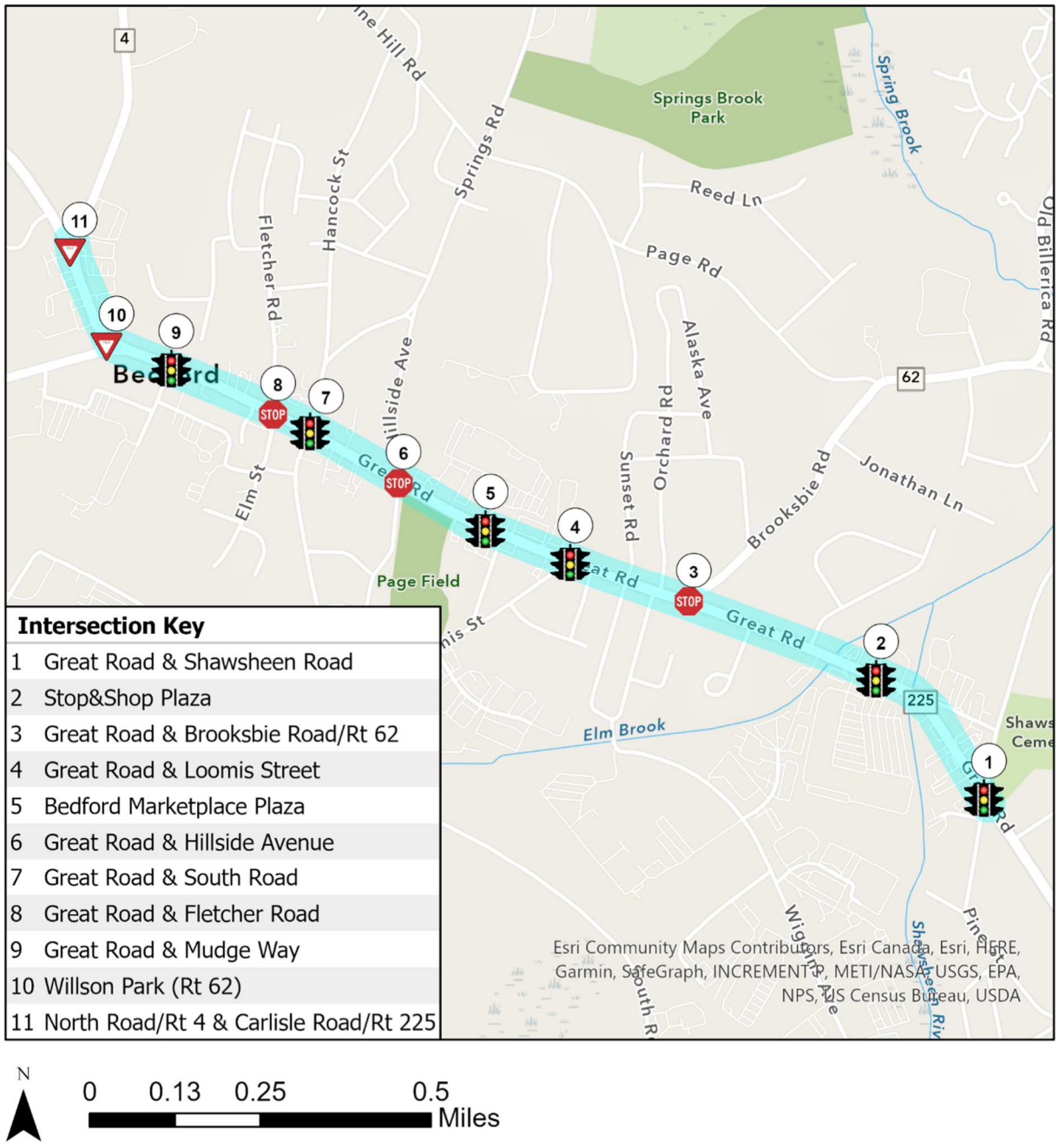


Figure 1 Great Road Study Corridor and Intersections (all signals are owned by the Town except for #1 at Shawsheen Road and #2 at Stop&Shop Plaza, which are owned by MassDOT)

2.1 Goal

The goal of the study is to improve safety and traffic operations for all roadway users on Great Road by evaluating operational and safety problems or deficiencies and providing recommendations for short-term and long-term improvements. Reducing travel delay would improve residents' quality of life, lower vehicle emissions, and prevent cut-through traffic through residential neighborhoods.

2.2 Context

This study considers the 1.5-mile segment of Great Road/Route 4 between the Carlisle Road/Route 225-North Road/Route 4 intersection and Shawsheen Road (Figure 2). The corridor runs roughly east-west between Shawsheen Road at the east/south end and Carlisle Road/Route 225 and North Road/Route 4 at the west/north end.

There are several commercial uses between Concord Road/Route 62 and the northern end of the corridor at Carlisle Road/Route 225 and North Road/Route 4, including Bedford Farms Ice Cream and Minuteman Volkswagen. Moving south/east along the corridor, the Bedford Free Library and Bedford High School are on the south side of Great Road and are accessible via Mudge Way. John Glenn Middle School is accessed via Loomis Street, South Road, or Concord Road/Route 62. The Bedford Historical Society, Police Department, Town Hall, and Fire Department are also on the south side of Great Road between Mudge Way and Elm Street. The Narrow Gauge Rail Trail crosses Great Road at Bacon Road. The Bedford Marketplace is located on the north side of the corridor between Bacon Road and Loomis Street. Stop&Shop Plaza and the Bedford Department of Public Works are just north of the Shawsheen Avenue intersection, and there are several other commercial uses in this area. Aside from these areas, residential neighborhoods surround the corridor.

In addition, three regional rail trails converge just south of the corridor at Depot Park: the Narrow Gauge Rail Trail (which runs north out of Depot Park and crosses Great Road), the Reformatory Branch Trail (which heads west out of Depot Park), and the Minuteman Commuter Bikeway (which heads south), which is metropolitan Boston's most popular bicycle route.

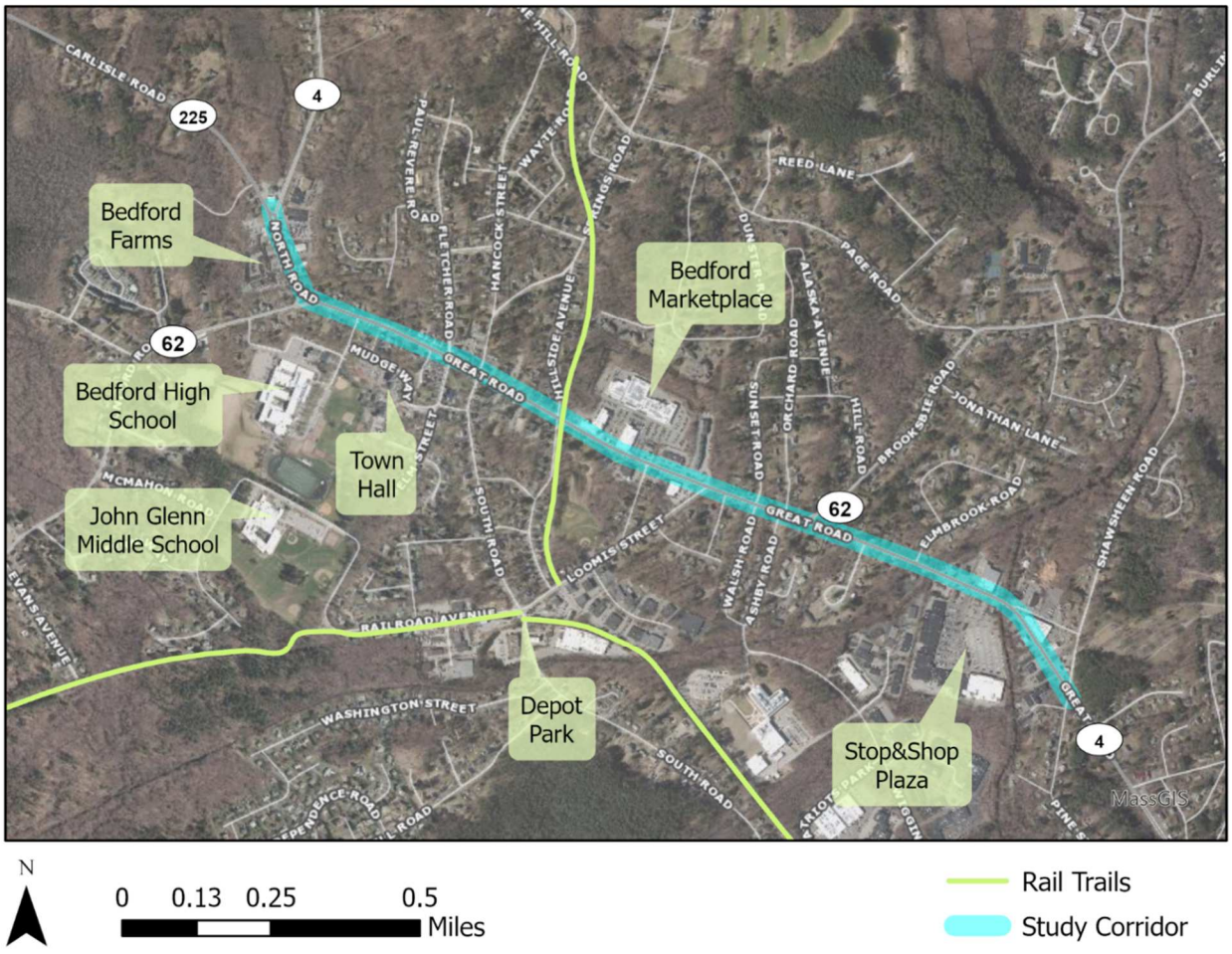


Figure 2 Study Area Landmarks

2.3 Methodology

To complete this study, previous plans were reviewed and new data were collected to establish an understanding of existing conditions (the full Existing Conditions analysis is presented in Appendix A). Observations of the corridor and each of the eleven study intersections were made during site visits in summer 2022. Traffic data were gathered from 24-hour Automatic Traffic Recorders (ATRs) and turning movement counts (TMCs) in October 2021. Crash data were gathered from MassDOT and the Bedford Police Department (the complete Safety Analysis is presented in Appendix B). Traffic volumes were forecasted to 2029 and 2040 and the existing, interim, and future traffic volumes were analyzed to estimate operational performance. Complete details and results for the operational analysis are included in Appendix C and E.

This technical analysis was balanced with public input to ensure that observations from people who live, work, and travel through the study corridor were taken into account. A preliminary draft of this study was

presented at a joint meeting of the Transportation Advisory Committee and Bicycle Advisory Committee on November 9, 2022 and their feedback was incorporated. The public was invited to share comments on the draft memorandum in January 2023. While this study is essentially signal upgrades and maintenance (which typically don't undergo a public process), there will be additional opportunities for public input when recommendations (such as reconstructing various intersections) are implemented, as those projects will have their own public process.

The results and findings of the public input, existing conditions assessment and the 2022/2029/2040 operations evaluations were used to identify deficiencies and potential improvements, as described in the Improvement Plan. The Improvement Plan recommends changes that will improve safety and traffic flow so that drivers will not look for alternate routes through residential neighborhoods. The Improvement Plan focuses on the findings of the safety analysis, adjustments that can be made to optimize traffic signals (including improvements for people walking to make the pedestrian phases more demand responsive), and changes to intersection geometries, such as turning lanes. Proposed signal phasing and timing plans are included in Appendix E.

Recommendations from the *Great Road Streetscape Master Plan* and the *Bedford Pedestrian + Bicycle Plan* have also been brought forward in the Improvement Plan to revisit next steps and help to add momentum to their implementation.

Suggested timeframes for improvements are Interim (2029) or Long-Term (2040 or later). The recommendations include budgetary level, order-of-magnitude, probable construction costs for recommended capital improvements.

2.4 Relevant Plans and Studies

The point of departure for this study was to review past planning documents to bring forth work that has already been vetted and may be relevant to this project. In particular, relevant recommendations from the *Great Road Streetscape Master Plan* and the *Bedford Pedestrian + Bicycle Plan* are revisited in the Recommendations for each intersection.

A Plan for Improvement and Development of the Central Business District of Bedford, Massachusetts (1967)

The Town commissioned a study of the Great Road business district back in 1967. The Plan raised concerns regarding traffic even 50 years ago stating, "Great Road is being asked to perform too many functions at once, with the result that all of them suffer." Recommendations were made warning that "failure to undertake circulation improvements now, while they are still relatively easy to do, will result in high traffic congestion and inconvenience and much greater expense in the end." Some of these recommendations were implemented such as building an Industrial Road (Wiggins Avenue), and prohibiting on-street parking on Great Road east of South Road. Others are still relevant today, and are explored more in this study.

TOPICS Project Functional Design Report (1971)

The Town of Bedford was selected by the Massachusetts Department of Public Works to participate in the Federal Highway Administration TOPICS (Traffic Operations Program to Increase Capacity and Safety) program. The Design Report, prepared by an outside engineering firm, recommended improvements to nine intersections throughout Town and the stretch of Great Road from North Road/Carlisle Road to

Shawsheen Road. At the time, there was much debate regarding the proposed four lane widening and signalization of Great Road. In September 1974, a Special Town Meeting article called for the appropriation of a sum of money to finance appraising strips of land along Great Road for eminent domain takings. However, voters defeated the article, thus effectively withdrawing Bedford from the TOPICS grant program.

The Great Road Streetscape Master Plan (2012)

This plan addresses the section of Great Road between Veterans Memorial Park (east of Bacon Road/Hillside Avenue) to Wilson Park and then north on North Road to Carlisle Road. The master plan makes recommendations to improve pedestrian and bicycle access and circulation, and traffic improvements while celebrating the historic Town Center of Bedford through the use of gateway treatments, and context appropriate streetscape materials, lighting, and landscaping. Phases 1 & 2 have already been constructed.

Bedford Pedestrian + Bicycle Plan (2015)

The *Pedestrian + Bicycle Plan* commits the Town to the following vision:

Bedford will be a well-connected community where walking and bicycling are convenient and attractive to residents and visitors alike. Pedestrians and bicyclists will feel safe and respected on Bedford's streets and trails, which will connect residential neighborhoods, shopping, employment centers, public services, and recreational areas.

Town of Bedford Complete Streets (2016)

The Complete Streets Policy adopted in 2016 is the first step towards funding from MassDOT's three-tier Complete Streets program. The policy commits the Town "to the maximum extent practical, [to] plan, design, construct, maintain, and operate all streets to provide for a comprehensive and integrated network of facilities for all users."

In addition to the policy (Tier 1), Bedford submitted a Complete Streets Prioritization Plan to MassDOT in April 2017 (Tier 2). MassDOT's approval of this plan qualifies the Town to submit an application (which it did in 2018) for Tier 3 Construction Funding for the projects included in the approved Tier 2 Plan. Relevant to Great Road, the fourth ranked project in the Prioritization Plan was for crossing enhancements at the Narrow Gauge Rail Trail and bike lanes along both sides from Memorial Park to Springs/South Road and from the Fire Station to Mudge Way. This project is complete.

Bedford Traffic Calming Policy (2022)

The Traffic Calming Policy was approved by the Select Board to reduce speeding, high traffic volumes, aggressive driving, and unnecessary vehicular traffic through local neighborhoods. The policy includes a process for conducting traffic calming studies and a Toolkit of Town-approved traffic calming measures.

Lexington: Hartwell Avenue/Bedford Street Commercial Corridor (in progress)

This Town of Lexington study is considering new zoning for the Hartwell Avenue business district, and changes to the traffic patterns on Routes 4/225 including the Route 128 interchange. Preliminary data

shared by the Town of Lexington expects the majority of Hartwell Avenue traffic to use Interstate 95, and impacts to Bedford's Great Road will likely be small, as reflected in the traffic analysis in Section 5. However, as of September 2022, several questions and assumptions have yet to be determined by Lexington for the Hartwell Avenue Plan, so the Great Road Traffic Optimization Study may eventually need to be revisited.

3. Potential for Cut-Through Traffic: Regional and Local Patterns

In an effort to understand the potential for cut-through traffic, this study considers regional and local origins and destinations and the routes drivers are likely to take between them.

Regionally, Bedford is positioned between Interstate 495 and Interstate 95 (Route128) and is adjacent to Route 3, so travel through Bedford often occurs to access (or avoid) these major roadways, particularly for travelers from Carlisle. In addition, Bedford is proximate to major regional destinations (the Hartwell Avenue Corridor, Hanscom Air Force Base, the Burlington Mall, Lahey Hospital, and Crosby Drive/Middlesex Turnpike, as shown in Figure 3 below) and therefore experiences some of the traffic associated with them. These factors contribute to the perception of Bedford as a "cut-through" town.

While the residential population of Bedford is about 14,400 (per the 2020 US Census), the daytime population is estimated to be approximately 25,000. The number of jobs located in Bedford is estimated at slightly over 20,000, generally clustered around Hanscom Air Force Base, Crosby Drive/Middlesex Turnpike, and along Route 3 and Interstate 95 (Route128).

Within Bedford, there are several major local destinations that the Great Road provides access to: the VA Hospital, Bedford Marketplace, Stop&Shop Plaza, Bedford Town Campus, and the commercial areas on Wiggins Avenue. Even without its role in the regional transportation network, the Great Road would experience significant traffic associated with these local destinations.

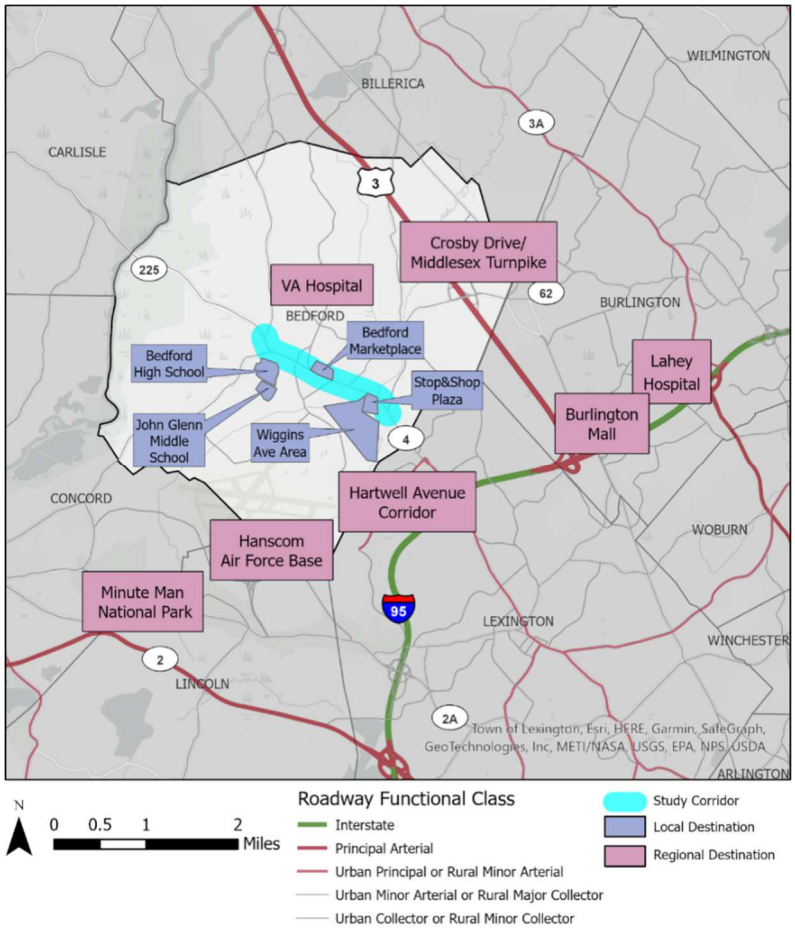


Figure 3 Regional and Local Destinations In and Near Bedford

The 2021 average daily traffic (ADT) on Great Road (as measured by the Automatic Traffic Recorders (ATRs) used for this study) varies from 14,260 vehicles per day (vpd) in the west end of the study area to 17,889 in the east end, with a high of 21,927 between Bedford Marketplace and Route 62/Brooksbie Road.

Figure 4 shows the 2009-2016 average annual daily traffic (AADT) of other arterials in the region. Similar to Great Road/Route 4, Routes 2 and 3 also run northwest-southeast and provide access to I-95/Route 128, but they are designed for and carry much more traffic than Great Road. Aside from Route 3, Great Road is the most heavily traveled road in Bedford. Figure 4 also shows a dramatic increase in volumes on Route 4/Bedford Street southeast of Hartwell Avenue in Lexington.

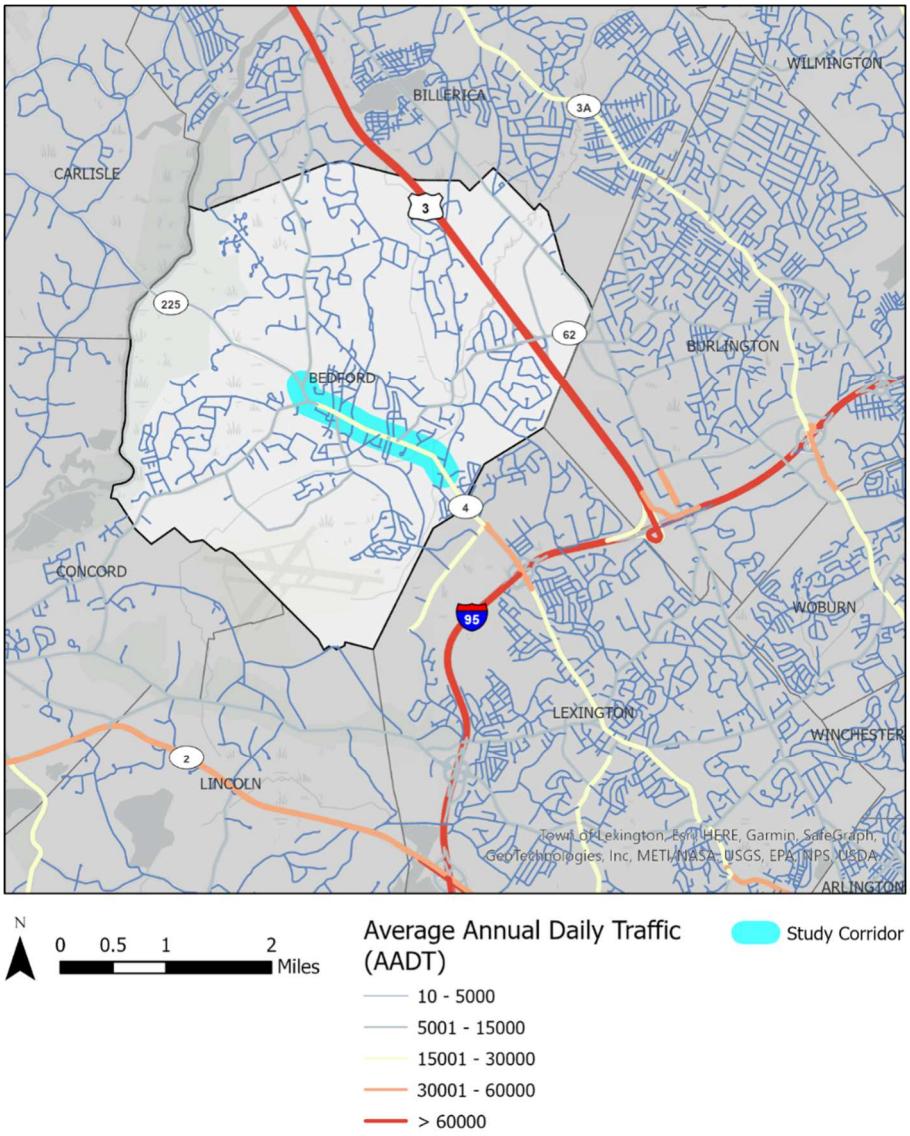


Figure 4 2009-2016 Average Annual Daily Traffic (source: MassDOT 2017 Road Inventory)

3.1 Findings

Within Bedford, Great Road is a significant connector to the I-95/Route128 corridor and several significant regional destinations, as well as the VA Hospital. Moreover, there are several major local destinations that Great Road provides access to: Bedford Marketplace, Stop&Shop Plaza, and Bedford's middle and high schools. Even without its role in the regional transportation network, Great Road would experience relatively significant traffic associated with these local destinations.

The difference between traffic volumes within the Great Road study corridor (between 14,000 and 22,000 vehicles per day) and on Route 4 between Hartwell Ave/I-95 (approximately 54,000 vehicles per day)

suggests that vehicles are likely using other neighborhood streets/collector roadways to bypass the heavily congested Great Road (Route 4) corridor.

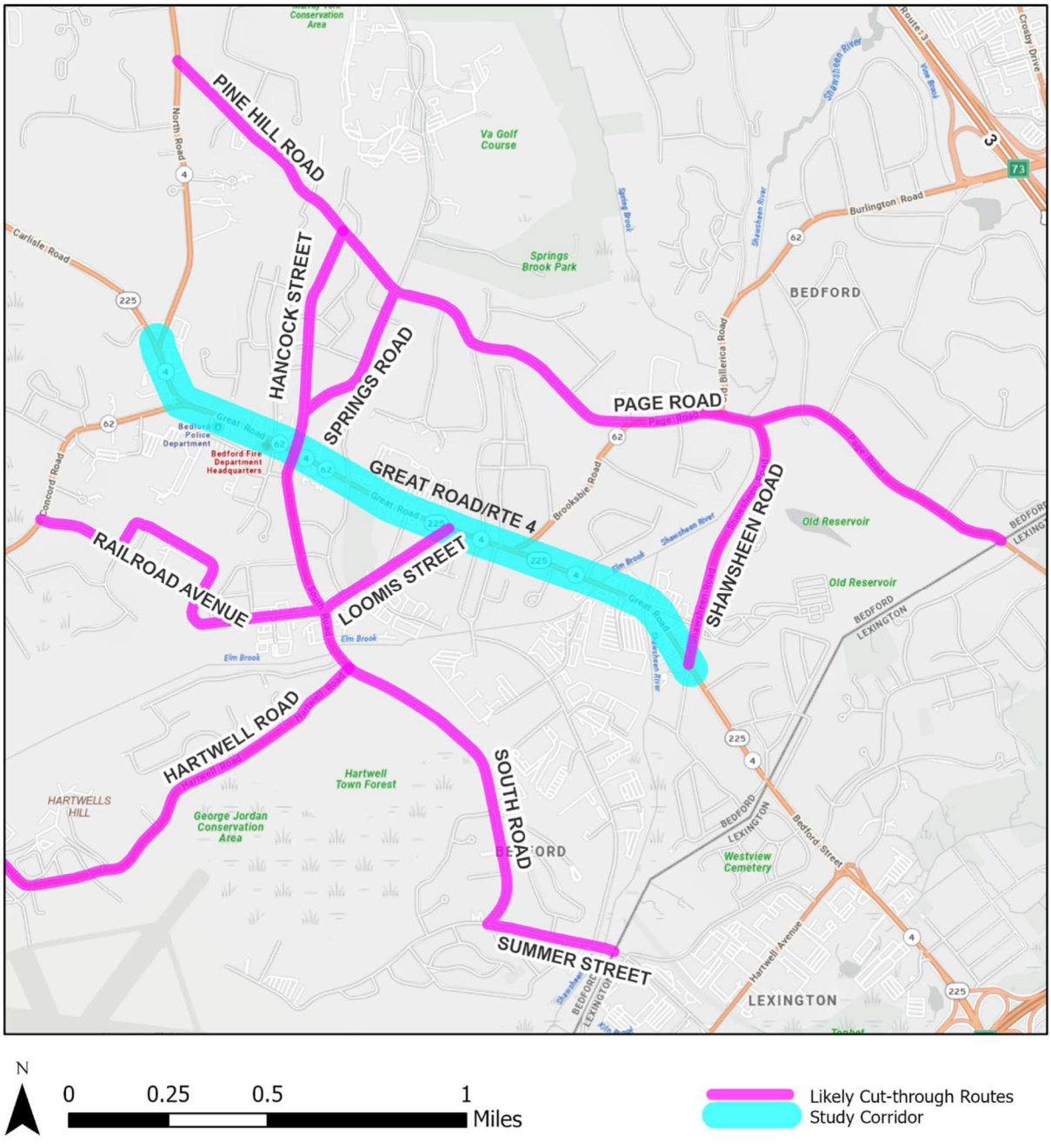
The ADT pattern indicates that a relatively significant portion of the traffic on Great Road is likely attributable to local destinations.

The increase in volumes on Route 4/Bedford Street southeast of Hartwell Avenue (approximately 54,000 vehicles per day) suggests that a relatively large number of vehicles may be using local neighborhood streets as cut-throughs to bypass the Great Road (Route 4) corridor. (Note that the increase is partly due to the Hartwell Avenue volumes (approximately 16,000 vehicles per day) combining with Route 4/Bedford Street volumes, but there is additional traffic that is unaccounted for and possibly coming from neighborhood cut-throughs.) One potential cut-through route to the south of Great Road could be South Road to Summer Street to Hartwell Avenue. Another potential route could be McMahon Road and Railroad Avenue to either Loomis Street or South Road, depending on destination. To the north of Great Road, a potential cut-through route could be Pine Hill Road to either Hancock Street/Springs Road or Page Rd/Shawsheen Road.

Cut-through traffic in Bedford is likely using local roadways to bypass the Great Road corridor. MassDOT AADTs are the only data source that is readily available to confirm this hypothesis, but the data are issued with the caveat that they are derived from estimates[1] and are not reliable for an analysis such as this. For example, all local roads in Bedford are assigned an AADT of 1,154 vpd, so the data cannot confirm which roads might actually be carrying cut-through traffic. To verify if and how much cut-through traffic is using the local roadways, additional data (gathered using ATRs) would need to be collected on the following roadways, which are well-known alternate routes (Figure 5):

- South Road
- Summer Street
- McMahon Road
- Railroad Avenue
- Loomis Street
- Hartwell Road
- Pine Hill Road
- Hancock Street
- Springs Road
- Page Rd
- Shawsheen Road

[1] MassDOT Road Inventory Data Dictionary: https://www.mass.gov/doc/road-inventory-data-dictionary/download



All data are public records and may be used in public and private applications. See metadata for more details., Town of Lexington, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA

Figure 5 Likely Cut-Through Routes

Sections 4 through 14 summarize Existing Conditions, Safety, the Traffic Operational Analysis for 2022, 2029, and 2040, and Recommendations for each of the study intersections.

The Traffic Operational Analysis was completed for the following weekday AM and PM peak hour scenarios:

- 2022 Existing
- 2029 Interim (No-Build and with Mitigation)
- 2040 Future (No-Build and with Mitigation)

The analysis is based on 2021 counts of traffic data that were subsequently adjusted for seasonal variations, Covid impacts, and development projections to estimate 2022 volumes. The 2029 and 2040 traffic volumes were projected using an annual background growth rate. "No-Build" describes operating conditions if no improvements are made, while "Mitigation" indicates operations if the suggested recommendations are implemented.

Level of Service (LOS) is a term used to denote different operating conditions that occur under various traffic volume loads. It is a qualitative measure of vehicle traffic operations affected by factors including geometrics, speed, travel delay, freedom to maneuver, and safety. LOS is divided into a range of six letter grades, with A being the least vehicle delay and F being the most vehicle delay. LOS E and F are generally considered inadequate for traffic operations. For urban/suburban conditions such as the Great Road study corridor, LOS D or better is acceptable. A description of the operating condition under each level of service is provided below:

- LOS A – little to no delay to motorists
- LOS B – relatively low delay to motorists
- LOS C – average delays to motorists
- LOS D – congestion becomes more noticeable, delays are still within an acceptable range
- LOS E – high level of delay, considered by many agencies to be the limit of acceptable delay
- LOS F – unacceptable delays that often occur, arrival flow rates often exceed the intersection capacity

Appendix C provides complete details on the Traffic Operational Analysis.

4. Great Road & Shawsheen Road

4.1 Existing Conditions

Full details on existing conditions are provided in Appendix A. Walking conditions (particularly for people crossing the Shawsheen Road/southbound approach) could be improved at this location. As this signal is under MassDOT's jurisdiction, any changes would be at the agency's discretion.

4.2 Safety

The Safety Analysis did not indicate any specific issues to be addressed.

4.3 Traffic Operational Analysis: 2022, 2029 and 2040

- This intersection operates at overall LOS C during both the 2022 AM and PM Peak Hours. The southbound approach experiences the greatest delay.
- The volume on the Shawsheen Road (southbound) approach is relatively high with most vehicles turning left towards I-95 (approximately 85% of total approach volumes in both Weekday AM and PM peak hours). The northbound Pine Street approach is low volume.
- The proposed signal timing and phasing adjustments under the 2029 Interim with Mitigation Conditions improve overall intersection operations during the weekday AM and PM peak hours mainly by reducing average vehicle delays and congestion along the Great Road approaches.
- Under the 2040 No-Build Conditions, the overall intersection operates at sufficient levels of service with an LOS C during the weekday AM peak hour and LOS C during weekday PM peak hour. However, the Great Road approaches experience relatively long vehicle queues with 95th percentile queue lengths ranging from 750 feet to 975 feet (30 to 40 vehicle lengths) during the weekday peak hours.
- Under the 2040 with Mitigation Conditions, the overall intersection continues to operate at LOS C and LOS B during the weekday AM and PM peak hours, respectively, with the average delay per vehicle entering the intersection decreasing by approximately 7-10 seconds. During the weekday AM peak hour, 95th percentile queue lengths along the Great Road eastbound approach are significantly reduced from 914 feet (approximately 36 to 37 vehicle lengths) to 188 feet (approximately 7 to 8 vehicle lengths). During the weekday PM peak hour, 95th percentile queue lengths along the Great Road approaches decrease by approximately 3 to 4 vehicle lengths.
- The crossing distance across the Shawsheen Road (southbound) approach is considerable and there is a high volume of westbound vehicles on Great Road turning right onto Shawsheen Road. This can make crossing the Shawsheen Road approach difficult for people walking.

4.4 Recommendations

Interim (2029) Recommendations

Traffic Signals

- Adjust signal timings to prioritize the higher volume Great Road approaches and reduce overall signal cycle length to reduce vehicle idling time and overall congestion at the intersection.
- Remove existing 4-section signal head for Pine Street northbound lead phase which consists of a bi-modal (green/yellow left arrow) on the bottom indication (this is not compliant with current MUTCD). Install a new 4-section signal head (3 circular indications w/ bottom green left arrow).
- Revise pedestrian phasing from exclusive (as it is currently programmed) to concurrent pedestrian phasing to be more responsive to pedestrians and reduce the amount of time pedestrians have to wait to cross.
    - Provide 10 second Leading Pedestrian Interval (LPI) for crossing the north leg of Shawsheen Road (will first need to confirm the existing controller can support LPI by reaching out to the signal technician).

Long-Term (2040+) Recommendations

Traffic Signals

- Full signal replacement including all new mast arms, signal posts, pedestrian signal heads with countdown feature, Accessible Pedestrian Signal (APS) pushbuttons, signal heads with backplates and retroreflective borders, controller and cabinet.
- Coordinate all signals along project corridor and prioritize safety, improving traffic flow, and reducing congestion along Great Road.
- Revise signal phasing to provide lead protected southbound (Shawsheen Road) phase instead of the current northbound (Pine Street) lead phase. This will require a new 4-section signal head (3 circular indications w/ bottom green left arrow) and R10-12 sign for the southbound approach to indicate the lead protected phase and removal of the existing 4-section signal head and R10-12 sign provided for the northbound approach.
    - Prioritizing the higher volume southbound approach rather than the low volume northbound approach provides more efficient overall traffic operations at the intersection. In addition, these recommendations are expected to better accommodate additional traffic expected to be added to the intersection once the Hartwell Avenue commercial corridor project is complete.
- Provide westbound (Great Road) right turn overlap during the lead protected southbound phase. This will require a new 5-section "doghouse" signal indication for westbound right turn lane.

Table 1 Cost Estimate Summary for Great Road & Shawsheen Road

1. Great Road & Shawsheen Road	Recommendations	Estimate (in 2022 dollars)
Interim Improvements	Signal phasing/timing updates and equipment (including updating to video detection[2])	$30,000
Interim Total		*$30,000*
Long-Term Improvements	Full signal replacement and coordination	$300,000
Long-Term Total		*$300,000*

[2] To be responsive to traffic, a signal needs to be able to detect the presence of vehicles on various approaches. One method of detection is in-pavement inductive loops, but these are typically not as reliable as newer systems which use video cameras.

5. Great Road at Stop&Shop Plaza

5.1 Existing Conditions

Walking conditions (particularly for people crossing the Stop & Shop driveway) could be improved at this location. As this signal is under MassDOT's jurisdiction, any changes would be at the agency's discretion.

5.2 Safety

The Safety Analysis indicated a trend of crashes immediately west of this intersection that are noted in Section 15 below.

5.3 Traffic Operational Analysis: 2022, 2029 and 2040

- This intersection operates at overall LOS C during both the 2022 AM and PM Peak Hours. The northbound left turn experiences the greatest delay.
- The signal has a protected eastbound left turn phase into the employee-only entrance of Bedford Department of Public Works, which is a very low volume turning movement (1 left turn during the weekday AM and PM peak hours).
- The proposed signal timing and phasing adjustments under the 2029 Interim with Mitigation Conditions improve overall intersection operations by reducing the average delay per vehicle by approximately 7 seconds during the weekday AM and PM peak hours. Queues along the Great Road approaches are significantly reduced as well, with queue reductions ranging from 12 to 17 vehicles along the Great Road eastbound and westbound approaches, respectively.
- The proposed signal timing and phasing adjustments under the 2040 with Mitigation Conditions focus on improving traffic flow and efficiency along the Great Road approaches by reducing average vehicle delays and queues during the weekday AM and PM peak hours.
- The crossing across the Stop & Shop driveway is approximately 100 feet long, which is very long for anyone walking and there are high volumes of eastbound vehicles on Great Road turning right into the Stop & Shop Plaza.

5.4 Recommendations

Interim (2029) Recommendations

Traffic Signals

- Revise pedestrian phasing from exclusive (as it is currently programmed) to concurrent pedestrian phasing. Implement LPI's for both concurrent pedestrian phases due to high turning volumes.
  - Consider installing R10-15 (left/right turns yield to pedestrians) signs.
- Eliminate the lead protected eastbound left turn phase into the employee-only entrance of Bedford Department of Public Works, which is a very low volume turning movement. Revise the current lagging westbound left turn phase to be a lead protected phase.
  - Provide 4 section signal head with flashing yellow arrow for westbound (Great Road) left turn lane.

Long-Term (2040+) Recommendations

Traffic Signals

- Full signal replacement including all new mast arms, signal posts, pedestrian signal heads with countdown feature, APS pushbuttons, signal heads with backplates and retroreflective borders, controller and cabinet.
- Coordinate all signals along project corridor and prioritize safety, improving traffic flow, and reducing congestion along Great Road.

Geometrics

- Shorten pedestrian crossing across Stop & Shop driveway (currently approximately 100 feet long).
  - Tighten corner radii as turning movements allow. Potentially relocate commercial sign and reconstruct median to provide pedestrian refuge area (Figure 6).

Figure 6 Crossing Improvements at Stop&Shop Plaza

Table 2 Cost Estimate Summary for Great Road at Stop&Shop Plaza

2. Great Road at Stop&Shop Plaza	Recommendations	Estimate (in 2022 dollars)
Interim Improvements	Signal phasing/timing updates and equipment (including updating to video detection)	$35,000
Interim Total		*$35,000*
Long-Term Improvements	Full signal replacement and coordination Geometrics (tighten corner radii, reconstruct median on Stop&Shop approach)	$300,000 $300,000
Long-Term Total		*$600,000*

6. Great Road & Brooksbie Road/Route 62

6.1 Existing Conditions

The southbound left-turn from Brooksbie Road onto Great Road is extremely skewed and places drivers at a very awkward angle from which to make a left-turn. Related, the angle for right-turning vehicles may discourage drivers from stopping completely. These two issues may contribute to crashes.

6.2 Safety

The Safety Analysis notes a cluster of sideswipe crashes at the three-way intersection of Route 62/Brooksbie Road with Great Road involving eastbound drivers. There are two eastbound lanes from Loomis Street. On approach to the Brooksbie Road/Route 62 intersection, the inner eastbound lane becomes a left-turn only lane approximately 150 feet before the intersection. During the site visit it was observed that eastbound drivers seemed to be caught off guard by the left-turn only lane and make a sudden shift to the right in order to continue through. This may be contributing to the cluster of crashes.

6.3 Traffic Operational Analysis: 2022, 2029 and 2040

- This intersection operates at overall LOS A and C during the 2022 AM and PM Peak Hours, respectively. The southbound approach, particularly the left turn, experiences the greatest delay.
- Operationally, there is considerable delay on the Brooksbie Road approach, especially for drivers turning left, in all No-Build and 2029 Interim with Mitigation Conditions where the intersection remains unsignalized. This is typical for stop-controlled approaches to relatively high-volume roadways where traffic operates freely through the intersection.
- The westbound right-turn lane is needed to provide sufficient capacity during the weekday PM peak hour. Similarly, two eastbound travel lanes are needed between Loomis Street and Brooksbie Road. Reducing to one eastbound travel lane would still provide acceptable LOS; however, it increases

congestion along Great Road, particularly during the AM peak hour when eastbound volumes are higher.[3] Still, the benefits of removing an eastbound lane (added space for bicyclists, potential reduction in sideswipes) may be worth the increased delay.

- The intersection meets the *Manual of Uniform Traffic Control Devices*[4] (MUTCD) Signal Warrants 1 (Eight Hour Vehicular Volume), Warrant 2 (Four Hour Vehicular Volume), and Warrant 3 (Peak Hour Volume).
- Under the proposed signal in the 2040 with Mitigation scenario, operating conditions along the Brooksbie Road southbound approach (with a shared left-right turn lane) are significantly improved relative to No-Build Conditions with the approach improving from LOS F to LOS C and LOS B during the weekday AM peak hour and PM peak hours, respectively.

6.4 Recommendations

Interim (2029) Recommendations

Other

- Trim vegetation on north side of Great Road to improve sight distance lines for vehicles exiting Brooksbie Road.
- Install a post-mounted R3-8 series sign on eastbound Great Road between Loomis Street and Brooksbie Road and a wide dotted white lane line to warn drivers that there will be a lane drop in which the inner through lane is going to become left-turn only.[5]

Long-Term (2040+) Recommendations

Traffic Signals

- Install a fully-actuated, coordinated traffic signal at the intersection.

Geometrics (Figure 7)

- Reduce the number of eastbound lanes carrying through traffic along Great Road between Loomis Street and Brooksbie Road (Route 62) from two lanes down to one. A left turn storage lane with storage length of approximately 400 feet will be provided for eastbound left turns onto Brooksbie Road. This is expected to improve safety along the corridor for all roadway users, provide additional space for streetscape and bicycle accommodations and reduce driver confusion as they approach the intersection with Brooksbie Road.

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[3] During the 2040 Weekday AM peak hour operations on eastbound Great Road at the Loomis Street intersection go from LOS B (in the two lane scenario) to LOS D in the one lane scenario, with delays increasing by 30 seconds per vehicle. A single lane would be almost at full capacity with a volume-to-capacity ratio of 0.91 (a ratio greater than one is considered over capacity). While LOS also worsens during the 2040 PM peak hour from LOS B to LOS C, the increases in delays are not quite as high.
[4] Federal Highway Administration (FHWA) 2009 MUTCD with Revisions 1, 2, and 3, July 2022.
[5] See MUTCD Section 2B.19.05B, Section 3B.04.16, and Drawing A of Figure 3B-11 for additional information.

- Remove short left turn pocket on southbound Brooksbie Road approach and install shared left-right lane.
- Remove median island and modify alignment of southbound Brooksbie Road approach to provide a more typical 'T' type intersection: reduce skew of approach and tighten the northwest corner radii (this will shorten the pedestrian crossing distance as well).

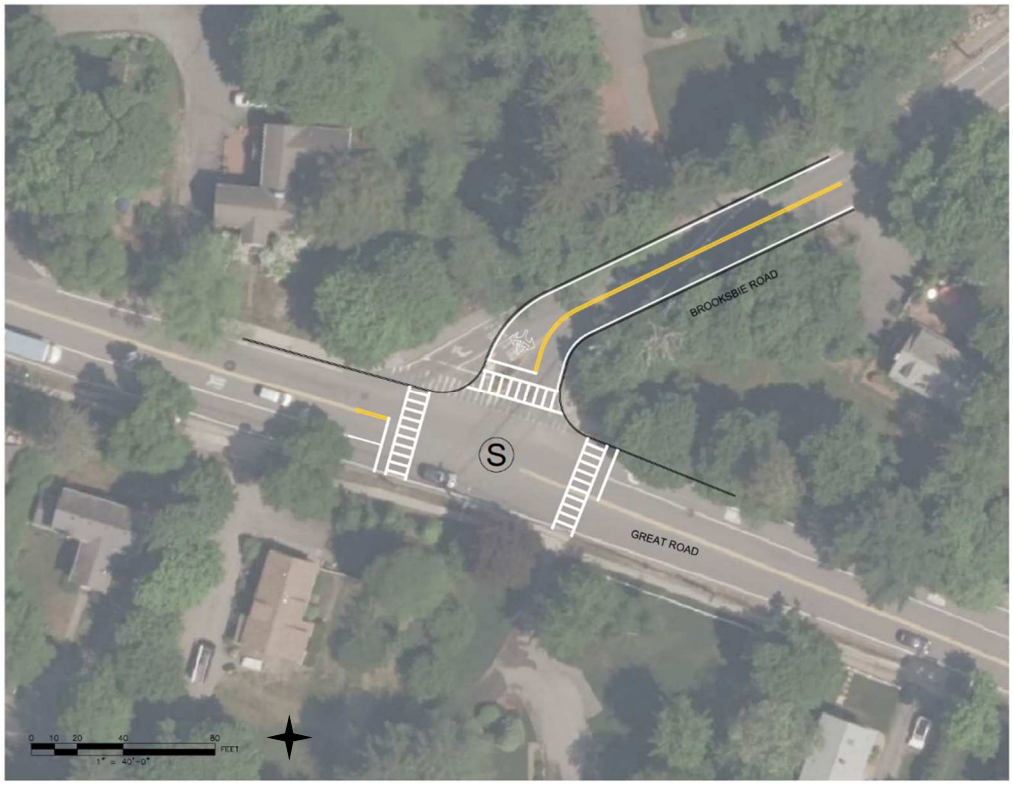

Figure 7 Updates to Brooksbie Road Approach

Table 3 Cost Estimate Summary for Great Road & Brooksbie Road/Route 62

3. Great Road & Brooksbie Road/Route 62	Recommendations	Estimate (in 2022 dollars)
Interim Improvements	Trim vegetation Signs and pavement markings	N/A $10,000
Interim Total		*$10,000*
Long-Term Improvements	New signal with coordination Geometrics (realign Brooksbie Road/Route 62 approach and remove one eastbound lane from Loomis Street and instead provide a left-turn lane with 400′ of storage (cost estimate for removing one eastbound lane included in Loomis Street recommendations)	$300,000 $300,000
Long-Term Total		*$600,000*

7. Great Road & Loomis Street

7.1 Existing Conditions

The Existing Conditions analysis did not indicate any deficiencies that require mitigation.

7.2 Safety

The Safety Analysis notes a cluster of crashes at this intersection, although the causes are not clear. The data did not indicate any trends except that sideswipe crash types tended to involve eastbound drivers. It is possible that some drivers don't realize that there are two eastbound through lanes, or that they are beginning to position themselves for left-turns or through movements at the Brooksbie Road/Route 62 intersection.

7.3 Traffic Operational Analysis: 2022, 2029 and 2040

- This intersection operates at overall LOS B during both the 2022 AM and PM Peak Hours. The northbound left turn movement experiences the greatest delay.
- Two eastbound travel lanes are needed between the Marketplace and Loomis Street. Reducing to one eastbound travel lane would still provide acceptable LOS; however, it increases congestion along Great Road, particularly during the AM peak hour when eastbound volumes are higher. The added congestion and queue lengths would make left turns out of the CVS parking lot more difficult as well.

Still, the benefits of removing an eastbound lane (added space for bicyclists, potential reduction in sideswipes) may be worth the increased delay.[6]

- The signal phase provided for eastbound left turns is longer than necessary given the low volume of left turning vehicles along the approach. The phase is currently 19 seconds long, but there are fewer than 10 left-turning vehicles in the weekday PM peak hour and 20 in the AM peak hour. This reduces the amount of cycle time available for westbound through movements, contributing to long westbound queues on Great Road.
- Similarly, the northbound and southbound concurrent phases are also longer than necessary and reduce the amount of cycle time available for the higher volume Great Road phases, decreasing the overall efficiency of traffic operations at the intersection.
- The proposed signal timing and phasing adjustments under the 2029 Interim with Mitigation and 2040 with Mitigation Conditions focus on improving traffic flow and efficiency along the Great Road approaches by reducing average vehicle delays and queues during the Weekday AM and PM peak hours.

7.4 Recommendations

Interim (2029) Recommendations

Traffic Signals

- Replace existing 3-section signal head for Great Road westbound left turn lane which consists of a bi-modal (green/flashing yellow left arrow) on the bottom indication (this is not compliant with current MUTCD). Remove existing, non-compliant 3-section signal head and install 4-section signal head with flashing yellow arrow.
- Eliminate existing protected eastbound (Great Road) left-turn phase due to low volumes.
- Reduce time for northbound and southbound concurrent phases.
- Revise pedestrian phasing from exclusive (as it is currently programmed) to concurrent pedestrian phasing.
    - Consider installing R10-15 (left/right turns yield to pedestrians) signs.

Lane Markings

- Repaint faded pavement markings and extend lane markings through the intersection with dashed lines to reinforce to drivers that there are two through lanes (Figure 8).

[6] During the 2040 Weekday AM peak hour operations on eastbound Great Road at the Loomis Street intersection go from LOS B (in the two lane scenario) to LOS D in the one lane scenario, with delays increasing by 30 seconds per vehicle and 95th percentile queues increasing by at least 80 feet to the Bedford Marketplace intersection. A single lane would be almost at full capacity with a volume-to-capacity ratio of 0.91 (a ratio greater than one is considered over capacity). While LOS also worsens during the 2040 PM peak hour from LOS B to LOS C, the increases in delays and queues are not quite as high.

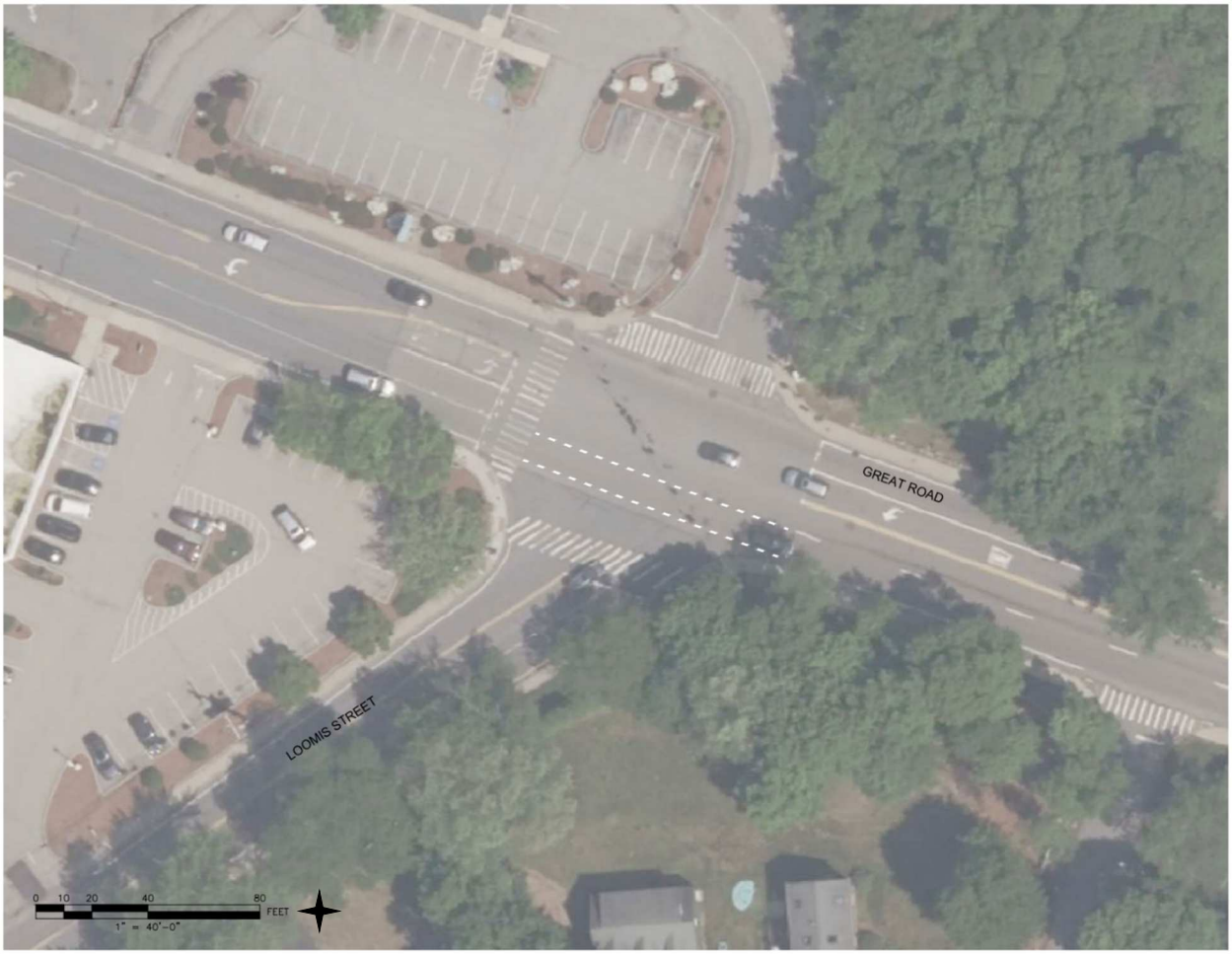

Figure 8 Interim Recommendations at Loomis Street

Long-Term (2040+) Recommendations

Geometrics

- Reduce the number of lanes along the Great Road eastbound approach from a left turn only, through only and shared through/right turn lane to a left turn only and a single shared through/right turn lane. This is expected to improve safety along the corridor for all roadway users, increase safety for vehicles entering and exiting the CVS driveway via Great Road and provide additional space for streetscape and bicycle accommodations. On the east side of the intersection, the eastbound through receiving lanes will also be reduced from two to one. (Figure 9.)
- Add crossing (including curb ramps and associated equipment) across the westbound approach.

Traffic Signals

- Full signal replacement including replacing existing span wire with mast arms, signal posts, pedestrian signal heads with countdown feature, APS pushbuttons, signal heads with backplates and retroreflective borders, controller and cabinet.
- Coordinate all signals along project corridor and prioritize safety, improving traffic flow, and reducing congestion along Great Road.

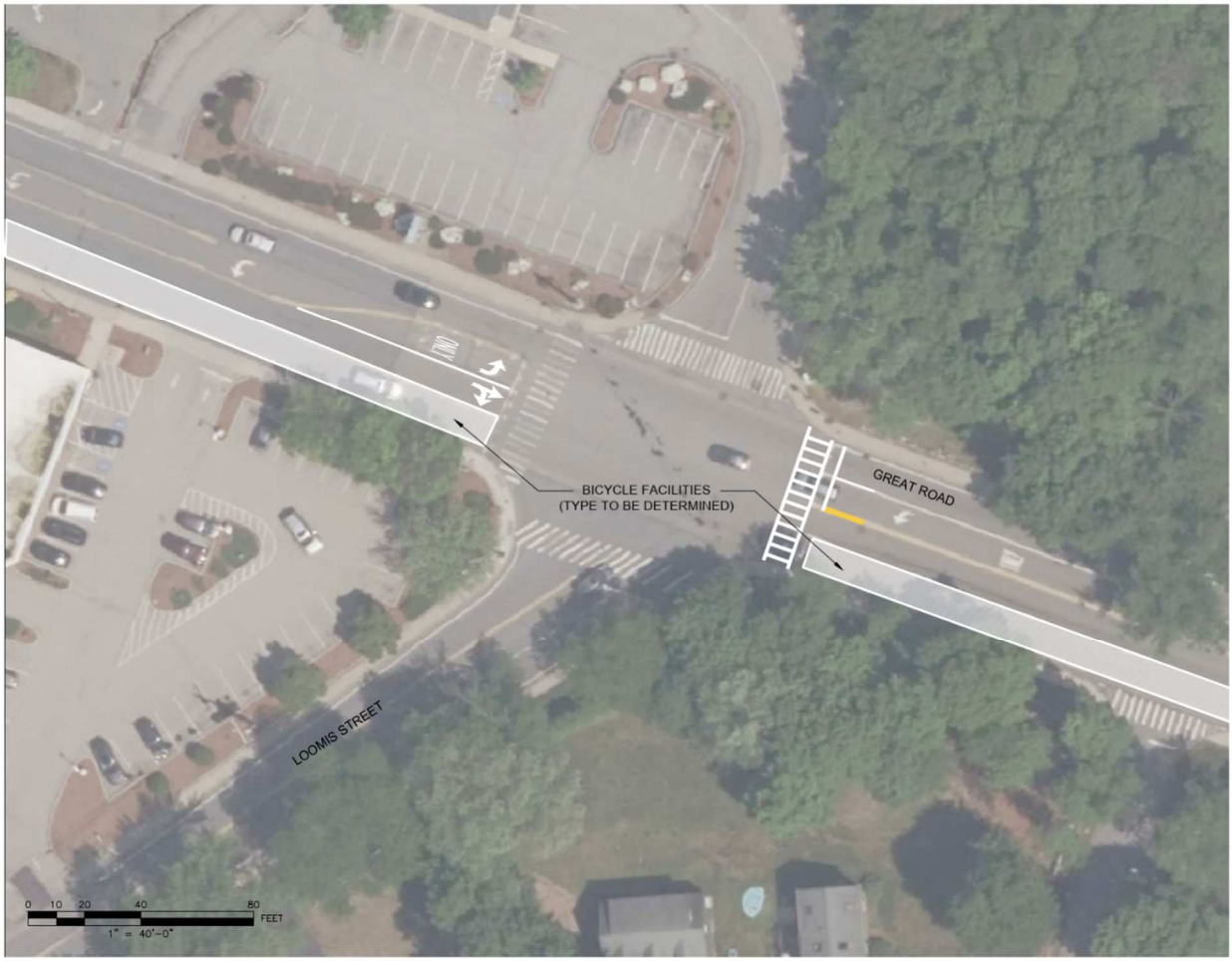

Figure 9 Long-Term Recommendations at Loomis Street

Table 4 Cost Estimate Summary for Great Road & Loomis Street

4. Great Road & Loomis Street	Recommendations	Estimate (in 2022 dollars)
Interim Improvements	Signal phasing/timing updates and equipment (including updating to video detection) Pavement markings	$35,000 $2,000
Interim Total		*$37,000*
Long-Term Improvements	Full signal replacement and coordination Reduce eastbound through lanes from two to one (approaching and receiving), add crossing (including associated curb ramps) across westbound approach and build bicycle facilities	$1,000,000
Long-Term Total		*$1,000,000*

8. Great Road at Bedford Marketplace Plaza

8.1 Existing Conditions

The Existing Conditions analysis did not indicate any deficiencies that require mitigation.

8.2 Safety

The Safety Analysis did not indicate any specific issues to be addressed.

8.3 Traffic Operational Analysis: 2022, 2029 and 2040

- This intersection operates at overall LOS C and B during the 2022 AM and PM Peak Hours, respectively. The southbound left turn movement experiences the greatest delay.
- On the Great Road westbound approach, there is only one overhead signal head provided for the primary movement, but the MUTCD recommends (although does not require) *two* overhead primary through signal heads.
- The proposed signal timing and phasing adjustments under the 2029 Interim with Mitigation and 2040 with Mitigation Conditions increase the efficiency of traffic operations at the intersection by reducing average vehicle delays and queues along all approaches during the weekday AM and PM peak hours.

8.4 Recommendations

The recommendations below focus on improving safety and optimizing traffic signal timing.

Interim (2029) Recommendations

Traffic Signals

- Add westbound (Great Road) right turn overlap phase with southbound (Bedford Marketplace Plaza) phase.
- Evaluate if existing mast arm at the northwest corner is structurally sufficient to support additional load for a 5-section "doghouse" signal overhead for the westbound approach.
- Revise pedestrian phasing from exclusive (as it is currently programmed) to concurrent pedestrian phasing.
  - Consider installing R10-15 (left/right turns yield to pedestrians) signs.

R10-15

Long-Term (2040+) Recommendations

Traffic Signals

- Full signal replacement including all new mast arms, signal posts, pedestrian signal heads with countdown feature, APS pushbuttons, signal heads with backplates and retroreflective borders, controller and cabinet.
- Coordinate all signals along project corridor and prioritize safety, improving traffic flow, and reducing congestion along Great Road.

Table 5 Cost Estimate Summary for Great Road at Bedford Marketplace Plaza

5. Great Road at Bedford Marketplace Plaza	Recommendations	Estimate (in 2022 dollars)
Interim Improvements	Signal phasing/timing updates and equipment (including updating to video detection)	$35,000
Interim Total		*$35,000*
Long-Term Improvements	Full signal replacement and coordination	$300,000
Long-Term Total		*$300,000*

9. Great Road & Hillside Avenue/Bacon Road

9.1 Existing Conditions

- The fire station is planned to be relocated from the southwest corner of the Great Road & Fletcher Road/Elm Street intersection to 139 Great Road, near the Hillside Avenue/Bacon Road intersection.
- Sight distances from the side streets may be blocked by queued vehicles on Great Road.

9.2 Safety

- The Great Road-Hillside Avenue/Bacon Road intersection is a Highway Safety Improvement Program (HSIP) Crash Cluster based on 2017-2019 data. An HSIP cluster is a location where the combination of the number and severity of crashes is within the top 5% in the region. (Since the comparison of regional data is based on a weighted scale combining number and severity of crashes, it is possible that a location with fewer crashes may qualify as an HSIP cluster over a location with more, but less severe crashes.) As an HSIP cluster, the location is eligible to receive HSIP funds to address the safety problem.
- It is difficult for drivers on the southbound/Hillside Avenue approach to find an adequate gap in traffic to enter Great Road. Moreover, sight distances for these drivers may be obstructed due to vehicles queueing on Great Road.

9.3 Traffic Operational Analysis: 2022, 2029 and 2040

- This intersection operates at overall LOS F and C during the 2022 AM and PM Peak Hours, respectively. The southbound approach experiences the greatest delay.
- The minor approaches (Hillside Avenue and Bacon Road) experience significant delays when trying to exit onto Great Road, likely due to difficulty finding adequate gaps in traffic flow along Great Road. This is typical for stop-controlled approaches to relatively high-volume roadways where traffic operates freely through the intersection.
- Left turn lanes from Great Road on to either Hillside Avenue or Bacon Road do not seem necessary given the low volume of left turns (fewer than 25 left-turning vehicles during any given peak hour).

9.4 Recommendations

Interim (2029) Recommendations

Signs

- Existing commercial sign for Baer Chiropractic at the northwest corner of the intersection impacts driver sight lines along Hillside Avenue at the stop bar location looking to their right (west). Coordinate with property owner of Baer Chiropractic to potentially relocate existing commercial sign at the northwest corner of the intersection to eliminate conflicts with driver sight lines.

Long-Term (2040+) Recommendations

Traffic Signals

- The 2012 *Great Road Streetscape Master Plan* considered two concepts that were eliminated mainly due to public input: the installation of a traffic signal and the removal of the left-turn lanes on Great

Road. The *Bedford Pedestrian + Bicycle Plan* also recommended installing a traffic signal, although as a medium priority. However, improvements to signal timing at other intersections and signal coordination throughout the corridor should reduce queuing, which should address the issue of queued vehicles on Great Road blocking sight distances for the side streets. Coordinating signals along the rest of Great Road may also regulate traffic flow on Great Road and provide more adequate gaps for drivers on the minor approaches (particularly those turning left from Hillside Avenue).

Geometrics

- Consider removing left-turn pockets on Great Road approaches (Figure 10). Left-turn lanes from Great Road onto the side streets are not expected to provide significant benefits at this intersection as left turn volumes are low and do not satisfy the criteria for dedicated left turn lanes at unsignalized intersections[7]. In addition, the crash data suggest that the left turn maneuver from Hillside Avenue onto Great Road is a difficult maneuver to execute. While the main reason for this is likely the lack of sufficient gaps along Great Road, the left turn lanes also add a degree of difficulty to this maneuver by adding another travel lane for these left turn movements to traverse when turning onto Great Road from the side streets and increasing the distance required to complete the maneuver. In addition, if eastbound left turns queue in the left turn lane they could block driver sight lines for vehicles at the stop line on the Hillside Avenue southbound approach looking to their right (west). If these left turn lanes are removed, the additional right-of-way could be used for bicycle accommodations such as buffered or separated bike lanes in both directions.

[7] Based on Exhibit 6-23 in the *MassDOT Project Development and Design Guide.*

Figure 10 Great Road & Hillside Avenue/Bacon Road without Left Turn Lanes

Table 6 Cost Estimate Summary for Great Road & Hillside Avenue/Bacon Road

6. Great Road & Hillside Avenue/Bacon Road	Recommendations	Estimate (in 2022 dollars)
Interim Improvements	Signs (potential relocation of existing commercial sign)	$3,000
Interim Total		*$3,000*
Long-Term Improvements	Geometrics (remove left turn lanes)	$10,000
Long-Term Total		*$10,000*

10. Great Road & Springs Road/South Road

10.1 Existing Conditions

The Existing Conditions analysis did not indicate any deficiencies that require mitigation.

10.2 Safety

The Safety Analysis revealed a cluster of crashes at this intersection, although the data suggest that it is largely the result of congestion and stop-and-go driving. Improving traffic flow along the corridor (while maintaining a pedestrian-friendly atmosphere) is likely the most effective way to reduce these crashes.

10.3 Traffic Operational Analysis: 2022, 2029 and 2040

- This intersection operates at overall LOS F and D during the 2022 AM and PM Peak Hours, respectively. The eastbound approach experiences the greatest delay.
- Right-turn volumes from eastbound Great Road onto South Road are high, particularly during the AM peak hour. There is a sign that permits drivers to use the parking lane on the south side of Great Road to make right turns from 6-9AM on weekdays.

- The overall intersection operates at LOS F under the 2040 No-Build Conditions during both the Weekday AM and PM peak hours. This poor LOS is largely due to significant delays along the Great Road eastbound and westbound approaches.
- The proposed signal timing and phasing adjustments and the addition of a right turn storage lane along the Great Road eastbound approach under the 2040 with Mitigation Conditions improve operations at the intersection significantly, improving overall operations from LOS F under the No-Build Conditions to LOS C and LOS D during the weekday AM and PM peak hours, respectively.
- The proposed improvements under the 2040 with Mitigation Conditions reduce vehicle delays along the Great Road eastbound approach during the weekday AM and PM peak hours by approximately 255 seconds and 110 seconds per vehicle. 95th percentile queues along the Great Road eastbound approach decrease by approximately 48 vehicles during the Weekday AM peak hour and 23 vehicles during the weekday PM peak hour.
- The proposed improvements under the 2040 Build Conditions also significantly improve operating conditions along the Great Road westbound approach, particularly during the Weekday PM peak hour where the approach improves from LOS F under the 2040 No-Build Conditions to LOS D. The average delay per vehicle decreases by approximately 120 seconds (2 minutes) and 95th percentile queues decrease by approximately 20 vehicles.

10.4 Recommendations

Interim (2029) Recommendations

Traffic Signals

- Revise signal timings to prioritize reducing vehicle delays and queues on Great Road:
  - AM peak hour – reduce time for side street phases (particularly for northbound left turn phase) and increase time for Great Road phases
  - PM peak hour- reduce time for side street concurrent phases and add time to Great Road phases
- Revise pedestrian phasing from exclusive (as it is currently programmed) to concurrent pedestrian phasing.
  - Consider installing R10-15 (left/right turns yield to pedestrians) signs.

Long-Term (2040+) Recommendations

Traffic Signals

- Coordinate all signals along project corridor and prioritize safety, improving traffic flow, and reducing congestion along Great Road.

Geometrics

- Consider providing a right turn lane on the south side of Great Road between Elm Street & South Road. Given the current configuration ("No Parking 6AM-9AM weekdays" so that drivers can use the parking lane as a right turn lane), this issue has presumably come up in the past (and perhaps still does). The current arrangement likely reflects a compromise between traffic flow, context, and parking. There are significant trade-offs to providing an exclusive right turn lane that would need to be weighed carefully:
  - If a right turn lane is added, the signal could be updated with an overlap phase for the eastbound right and a protected northbound left turn. This would improve traffic flow and likely address the congestion-related crashes occurring at this intersection.
  - An additional lane of traffic may impact walkability and bikeability.
  - Parking utilization in that area should be considered, as an additional lane of traffic could involve a loss of parking.
  - An additional lane of moving traffic could impact context by making the area feel more dominated by vehicles, although this might be a minor impact given that the parking lane currently accommodates moving traffic for a portion of the day.
  - Widening the roadway to accommodate a right turn lane may have significant impacts (or even be infeasible) due to right-of-way and historic district restrictions.

Table 7 Cost Estimate Summary for Great Road & Springs Road/South Road

7. Great Road & Springs Road/South Road	Recommendations	Estimate (in 2022 dollars)
Interim Improvements	Signal phasing/timing updates and equipment (including updating to video detection)	$35,000
Interim Total		*$35,000*
Long-Term Improvements	Signal coordination Road widening to accommodate right-turn lane	$30,000 $300,000
Long-Term Total		*$330,000*

11. Great Road & Fletcher Road/Elm Street

11.1 Existing Conditions

The Existing Conditions analysis did not indicate any deficiencies that require mitigation.

11.2 Safety

The Safety Analysis did not indicate any specific issues to be addressed.

11.3 Traffic Operational Analysis: 2022, 2029 and 2040

The analyses did not indicate operational deficiencies for this intersection (overall LOS A during both 2022 AM and PM Peak Hours). The Fletcher Road southbound approach experiences moderate delays during the Weekday PM peak hours under all scenarios. However, this is typical for stop-controlled approaches to relatively high-volume roadways where traffic operates freely through the intersection.

11.4 Recommendations

The analysis did not indicate any safety or operational deficiencies for this intersection. There are no recommendations.

12. Great Road & Mudge Way

12.1 Existing Conditions

The Existing Conditions analysis did not indicate any deficiencies that require mitigation. A traffic signal was installed at this intersection as recommended by the 2012 *Great Road Streetscape Master Plan*.

12.2 Safety

The Safety Analysis did not indicate any specific issues to be addressed.

12.3 Traffic Operational Analysis: 2022, 2029 and 2040

- This intersection operates at overall LOS C and B during the 2022 AM and PM Peak Hours, respectively. The northbound approach experiences the greatest delay.
- There is excessive queueing on Great Road: during the AM peak hour the eastbound direction is particularly long, while the westbound direction is worse in the PM peak hour.
- The proposed signal timing and phasing adjustments under the 2029 Interim with Mitigation and 2040 with Mitigation Conditions focus on improving traffic flow along Great Road by reducing average vehicle delays and queues along both Great Road approaches during the weekday AM and PM peak hours.

12.4 Recommendations

Interim (2029) Recommendations

Traffic Signals

- Reduce green time for westbound Great Road left turn phase to reduce vehicle queues on eastbound Great Road approach.
- Reduce overall cycle length to reduce vehicle dwelling times which contribute long vehicle delays and queues, particularly on Great Road.
- Revise pedestrian phasing from exclusive (as it is currently programmed) to concurrent pedestrian phasing. Include LPIs for concurrent pedestrian phases.

Long-Term (2040+) Recommendations

Traffic Signals

- Coordinate all signals along project corridor and prioritize safety, improving traffic flow, and reducing congestion along Great Road.

Table 8 Cost Estimate Summary for Great Road & Mudge Way

9. Great Road & Mudge Way	Recommendations	Estimate (in 2022 dollars)
Interim Improvements	Signal phasing/timing updates and equipment (including updating to video detection)	$35,000
Interim Total		*$35,000*
Long-Term Improvements	Signal coordination	$30,000
Long-Term Total		*$30,000*

13. Willson Park/Rte 62 (Concord Road/North Road/Great Road)

13.1 Existing Conditions

There are no crossings at Willson Park, and there is no sidewalk on the south/west side. The 'Yield' sign on eastbound Concord Road is obscured by trees and utility poles.

The 2012 *Great Road Streetscape Master Plan* reviewed several alternatives for this intersection but indicated that a preferred alternative was not agreed upon at the time. The alternatives considered (with the preferred one in **bold**) were:

1) Minor geometric modifications with no change to traffic control (eliminated)
2) **Minor geometric modifications with installation of new traffic signals at Great Road/Concord Road and North Road/Park Row**
3) Geometric and traffic circulation modifications with installation of new traffic signals at Great Road/Concord Road and North Road/Park Row
4) Installation of a roundabout (eliminated)
5) Major intersection reconstruction and park relocation resulting in a traditional T Intersection (eliminated)

As part of a gateway concept, the *Streetscape Master Plan* also recommends closing the sidewalk gaps at this intersection with sidewalks on each side of Willson Park and crossings. Although sight distances were not measured for this study, it is likely that signals are a prerequisite for the crossings in order to control approaching vehicles.

In many ways, Willson Park appears to be a good candidate for a roundabout, and this concept is repeatedly floated for consideration, most recently by the 2015 *Bedford Pedestrian + Bicycle Plan*. However, the *Streetscape Master Plan* determined that a roundabout (even a single lane version, which would have fewer impacts than a two-lane version) is infeasible due to

- Land impacts to historic Willson Park and to a private home;
- Construction costs; and
- Poor results of a preliminary traffic analysis.[8]

Jacobs concurs that a roundabout is infeasible at this location. A single lane roundabout would not provide acceptable levels of service at this location due to high traffic volumes entering and exiting the Great Road corridor during the Weekday AM and PM peak hours, respectively (overall, the intersection operates at LOS F during both Weekday AM and PM peak hours). In addition, the size of the single lane roundabout that would be needed to accommodate the necessary turning movements for large vehicles would result in impacts to Willson Park and the single family homes on the north side of Great Road/Concord Road. Increasing to a multi-lane roundabout would result in significant right-of-way impacts and construction costs on top of the impacts to Willson Park and the single family homes on the north side of Great Road/Concord Road.

13.2 Safety

- The west end of the study corridor (between North Road/Rte 4 & Carlisle Road/Rte 225 and approximately Mudge Way) is a Highway Safety Improvement Program (HSIP) Bicycle Crash Cluster based on 2010-2019 data. An HSIP cluster is a location where the combination of the number and severity of crashes is within the top 5% in the region. As an HSIP cluster, the location is eligible to receive HSIP funds (administered through the Boston Region Metropolitan Planning Organization's Transportation Improvement Program (TIP)) to address the safety problem.
- There is a cluster of nine crashes at the east point of Willson Park, where Routes 4 and 62 merge. The crashes likely stem from the lack of control on the intersection approaches; only eastbound Concord Road has a yield sign, while the other two points on the Willson Park triangle include a stop sign on one approach.

13.3 Traffic Operational Analysis: 2022, 2029 and 2040

- The North Road/Concord Road intersection (at the northwest corner of Willson Park) operates at overall LOS B and F during the 2022 AM and PM Peak Hours, respectively. The northbound left turn movement experiences the greatest delay. The intersection at the southwest corner operates at overall LOS B and A during the 2022 AM and PM Peak Hours, respectively, with the southbound right turn experiencing the greatest delay. As a minor yield-controlled intersection, the Great Road-Concord Road intersection (the east corner of Willson Park) was not evaluated.
- The analysis indicated that the northbound left turn from Park Row/Concord Road onto North Road/Route 4 (the northwest corner of the triangle) experiences significant delay and queueing in all No Build scenarios.
- MUTCD signal warrant analyses completed for the 2012 *Great Road Streetscape Master Plan* concluded that traffic volumes met the criteria defined in the MUTCD for justification of installing a traffic signal. For the current study, Jacobs completed signal warrant analyses using the traffic count data collected in October 2021. Traffic volumes at these locations meet MUTCD Signal Warrant 1

[8] VHB. 2012 *The Great Road Streetscape Master Plan*, page 28.

(Eight Hour Vehicular Volume), Warrant 2 (Four Hour Vehicular Volume), and Warrant 3 (Peak Hour), as shown in Appendix F.

- The proposed signalized operations under the 2040 with Mitigation Conditions improve operations at the northwest corner of the triangle by improving conditions for northbound left turns from Park Row/Concord Road onto North Road/Route 4. The northbound left turn improves from operating over capacity at LOS F under the 2040 No-Build weekday AM and PM peak hours to LOS E under the 2040 with Mitigation weekday AM and PM peak hours. Average delays per vehicle are significantly less under the proposed 2040 with Mitigation Conditions in addition to shorter queue lengths.

13.4 Recommendations

Interim (2029) Recommendations

- Install W3-2 (Yield ahead) sign on eastbound Concord Road approximately 100' in advance of yield sign.
- Install W1-10 (combination horizontal alignment/intersection) sign on westbound Great Road approximately 100' in advance of Concord Road (near the start of the left-turn lane).

Long-Term (2040+) Recommendations (Figure 11)

Traffic Signals

- Install two fully actuated, coordinated traffic signals (one at the northwest corner and one at the east corner of the triangle) along with a new southbound right turn lane (keep the existing westbound left turn lane) as shown in Figure 11. Jacobs concurs with the 2012 *Great Road Streetscape Master Plan* that a two-signal alternative is preferred. Installing two traffic signals at this location is anticipated to improve safety, provide much more efficient traffic operations relative to a single lane roundabout, have fewer impacts to Willson Park and the surrounding area, and be less expensive relative to a single lane or multi-lane roundabout.

Other

- Add sidewalks and crossings as proposed by the 2012 *Great Road Streetscape Master Plan.*

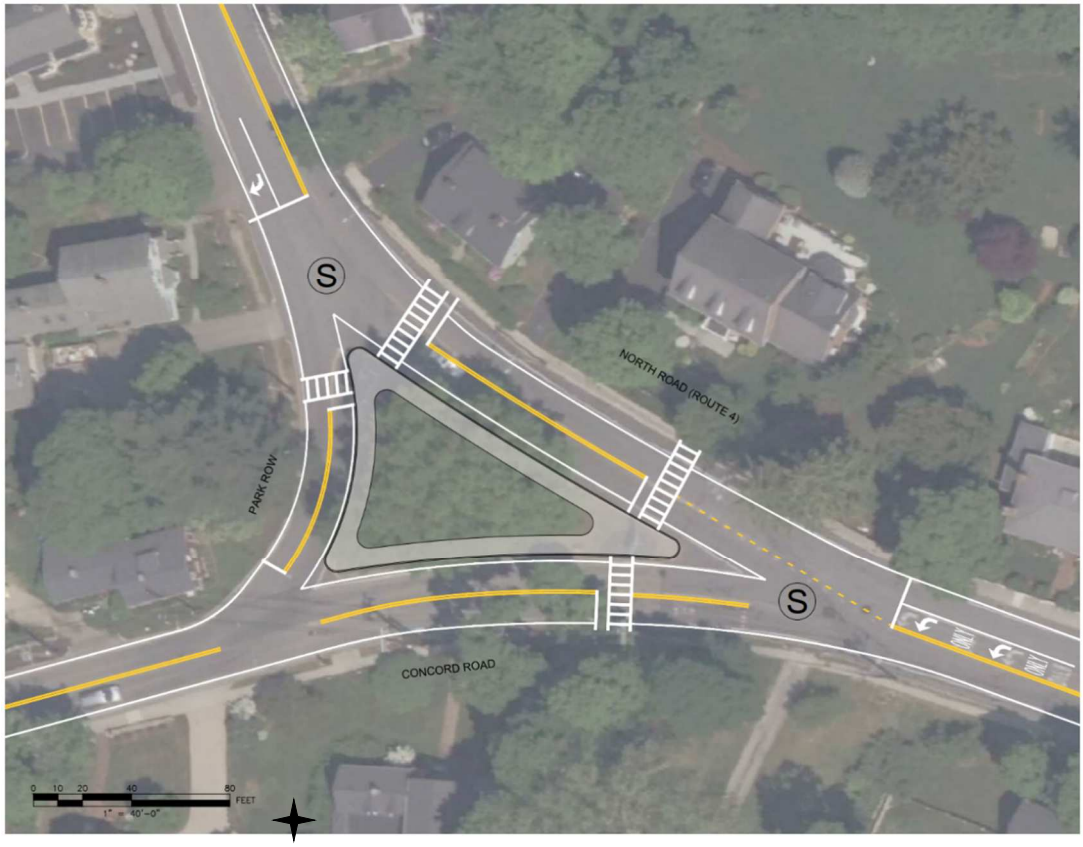

Figure 11 Willson Park Recommendations from the *Great Road Streetscape Master Plan*

Table 9 Cost Estimate Summary for Willson Park/Rte 62 (Concord Road/North Road/Great Road)

10. Willson Park/Rte 62 (Concord Road/North Road/Great Road)	Recommendations	Estimate (in 2022 dollars)
Interim Improvements	None	
Interim Total	-	
Long-Term Improvements	Two new signals with coordination Geometrics (new southbound right turn lane, sidewalks and crossings)	$600,000 $300,000
Long-Term Total		*$900,000*

14. North Road/Rte 4 & Carlisle Road/Rte 225

14.1 Existing Conditions

There are sidewalk and crossing gaps at this location:

- Missing sidewalk on west side of North Road north of Bedford Motel (approximately 300 feet) and at the intersection (approximately 70 feet).
- There are no crossings.

The 2012 *Great Road Streetscape Master Plan* proposes a gateway and geometric changes (including removing the channelizing islands) to "better channelize Carlisle Road traffic so that it comes to a complete stop. A crosswalk is proposed, with Rectangular Rapid Flashing Beacons alerting drivers to the presence of a pedestrian in the crosswalk." The Master Plan also considered installing a traffic signal at this location, but that alternative was eliminated. As part of a gateway concept, that plan also recommends sidewalks and crossings.

The 2015 *Bedford Pedestrian + Bicycle Plan* recommends installing a modern roundabout at this intersection; however, our evaluation shows that only a single-lane roundabout fits at this intersection and does not provide enough capacity to provide adequate levels of service. Moreover, large truck turns would be restricted at a roundabout. For example, a WB-40 (a tractor trailer truck with a 40-foot wheelbase) travelling southbound on North Road/Route 4 and wanting to turn right onto Carlisle Road/Route 225 would need to travel all the way around the roundabout to make this maneuver. A WB-67 (truck with a 67-foot wheelbase) on southbound North Road/Route 4 would only be able to travel *through* the roundabout and would have to find an alternate route to get on Carlisle Road/Route 225. In addition, some of the driveways of the VW dealership would be closed and the private driveway on the west side would be restricted to right-in/right-out.

14.2 Safety

The Safety Analysis did not indicate any specific issues to be addressed.

14.3 Traffic Operational Analysis: 2022, 2029 and 2040

- The overall intersection operates at LOS A under existing conditions because traffic along the Route 4 approaches flows freely through the intersection and right turns from Route 225 are yield-controlled. This results in minimal delays for these movements. However, the current intersection control also results in significant delays for the stop-controlled left-turns on the eastbound Route 225 approach due to difficulty in finding gaps in the free-flowing traffic stream along Route 4. In addition, the current intersection geometry and yield control for the Route 225 right-turns allow for high travel speeds which could result in safety concerns for vehicular conflicts but also create concerns for connectivity and conflicts with respect to pedestrians and bicyclists. Converting the intersection control to a roundabout or signal will increase delays on the free-flowing/yield controlled approaches; however, it will eliminate the long delays and LOS F for eastbound left turns. These proposed alternatives will also increase safety at the intersection for all roadway users.
- A single lane roundabout alternative was evaluated with 2040 traffic volumes. Under this alternative the intersection operates at LOS E and LOS D during the weekday AM and PM peak hours, respectively. During the weekday AM peak hour, the Carlisle Road eastbound approach operates over

capacity at LOS F with the average control delay per vehicle exceeding 90 seconds and 95th percentile queues of 820 feet (approximately 33 vehicle lengths). During the weekday PM peak hour, the North Road northbound approach operates over capacity at LOS F with average delays of 45 seconds per vehicle and 95th percentile queue lengths of approximately 6,500 feet (approximately 260 vehicles).

- Signal warrant analyses were completed using unadjusted traffic volumes from the count data collected in October 2021. Under the proposed signal operations, the Route 225 approach would be realigned to form a more typical 'T' type intersection with Route 4 and the right turn movement would be signalized. Under this proposed geometry and signalized operations, traffic volumes at this intersection meet MUTCD Signal Warrant 1 (Eight Hour Vehicular Volume), Warrant 2 (Four Hour Vehicular Volume), and Warrant 3 (Peak Hour) as shown in Appendix F.
- A signal alternative was also evaluated under 2040 traffic volumes, and this alternative operates at LOS C and LOS B during the weekday AM and PM peak hours, respectively. During the weekday AM peak hour, all approaches operate at sufficient levels of service (LOS D or better). During the weekday PM peak hour, all approaches operate at sufficient levels of service (LOS C or better).

14.4 Recommendations

Interim (2029) Recommendations

- None.

Long-Term (2040+) Recommendations

Geometrics

- Install a fully-actuated, coordinated traffic signal at the intersection. There is no minimum distance that is required between signalized intersections. However, traffic signals at closely spaced intersections should operate under a coordinated system. The MUTCD lists numerous factors that should be used to determine whether coordination would be beneficial. These factors include when the intersections are in close proximity (for example, to Willson Park) and there is a large amount of traffic on the coordinated street (in this case, Great Road is the coordinated street). The MUTCD provides the guidance that traffic signals with 0.5 miles of each other along a corridor should be coordinated unless operating on different cycle lengths. The proposed coordination of the Great Road movements at the Carlisle/North Road and Willson Park intersections is set to provide efficient traffic flow along Great Road through the intersections.
- Install sidewalks and crossings to close the pedestrian gaps at this location.

Table 10 Cost Estimate Summary for North Road/Rte 4 & Carlisle Road/Rte 225

11. North Road/Rte 4 & Carlisle Road/Rte 225	Recommendations	Estimate (in 2022 dollars)
Interim Improvements	None	
Interim Total	-	
Long-Term Improvements	New signal with coordination	$300,000
	Geometrics (realignment, sidewalks and crossings)	$300,000
Long-Term Total		*$600,000*

15. Miscellaneous Recommendations

15.1 Mid-block Crash Clusters

Recommendations for addressing safety issues at intersections have been provided in the preceding sections. Safety issues at segments are discussed below.

Segment between Shawsheen Road and Stop&Shop Plaza and segment between Willson Park and the North Road/Route 4 & Carlisle Road/Route 225 intersection

These crashes are likely due to the density of driveways. These conflict areas typically involve drivers turning in and out of the adjacent properties (Figure 12, Figure 13, and Figure 14). Improving access management, that is, reducing the number of driveway openings and driveway widths should mitigate the issue. An alternative would be to restrict drivers to "Right-turn only" enters and exits for driveways, but this will only be considered if further intervention is required due to the crash rate.

Ten of the 214 crashes in the study area between 2017 and 2019 involved a vulnerable user (nine involving someone biking and one involving someone walking). Geographically, the majority of the bicycle crashes occurred at the west end of the study area, as discussed in Appendix B. The west end of the study corridor (between North Road/Rte 4 & Carlisle Road/Rte 225 and approximately Mudge Way) is an HSIP Bicycle Cluster based on 2010-2019 data.

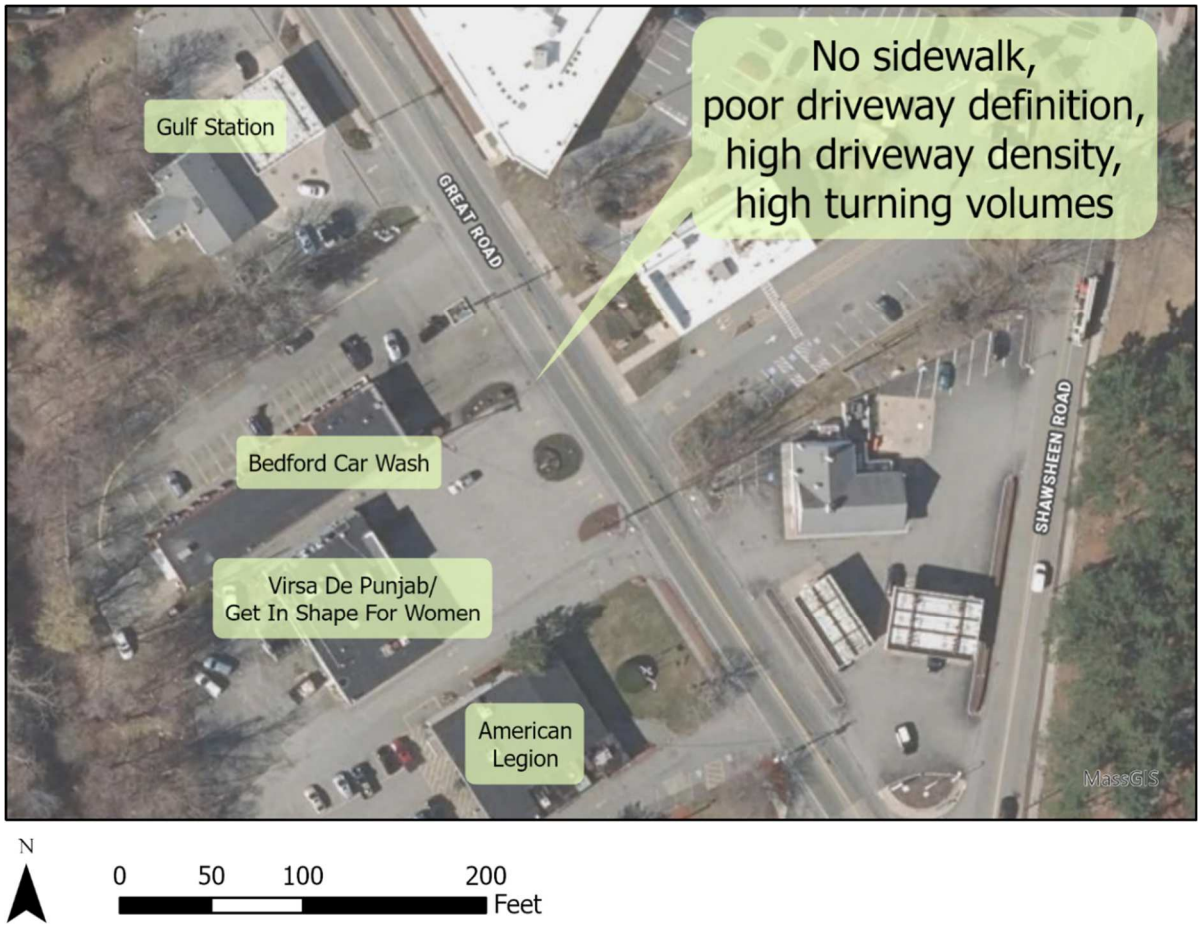

Figure 12 Segment by 345 Great Road (the Bedford Car Wash) and 353 Great Road (Virsa de Punjab)

Figure 13 Segment by 310 Great Road (former Papa Gino's)

Figure 14 Segment between North Road/Rte 4 & Carlisle Road/Rte 225 and Willson Park

Segment between Bedford Marketplace and Route 62/Brooksbie Road

West of the Brooksbie Road/Route 62 intersection (between Sunset Road and Orchard Road), there is a trend involving left-turns out of Ashby Road and failure to yield the right of way to eastbound drivers. This is likely due to difficulty finding a long enough gap in traffic on Great Road to exit out of Ashby. Coordinating signals in the corridor, as recommended throughout this memorandum, should help mitigate the issue. Additional recommendations for the intersections within this segment have been noted in preceding sections.

15.2 Walking Infrastructure

The Existing Conditions assessment indicated that:

- There are no crossings at Great Road and Shawsheen Avenue at the Bedford Plaza Hotel.
- The sidewalk on the north side of Great Road between Fletcher Road and Springs Road (between 88 and 90 Great Road) is blocked by a tree (Figure 15) and does not have an alternative route as the sidewalk closer to the buildings is blocked by outdoor café seating (Figure 16). Someone using a mobility assistance device would not be able to get through.

Figure 15 Sidewalk Gap by 88-90 Great Road

Figure 16 Sidewalk in front of 88 Great Road

Recommendations for improving walking include:

- As noted, the recommendations of the 2015 *Bedford Pedestrian + Bicycle Plan* should be implemented.
- Construct an ADA-accessible sidewalk to close the sidewalk gap (about 230 feet long) on the west side of Great Road between the Gulf Gas Station and the American Legion Post.
- Add crossings at Great Road and Shawsheen Avenue and simplify the intersection by making the Shawsheen Avenue approach more perpendicular to Great Road.
- Evaluate alternatives for making the sidewalk in front of 88 Great Road accessible.

- Install the midblock crossing at Bedford Farms as recommended in the *Great Road Streetscape Master Plan*. (The Town has already secured a MassDOT Shared Streets grant to complete this project in 2023.)

15.3 Bicycling Infrastructure

The 2015 *Bedford Pedestrian + Bicycle Plan* includes many worthwhile recommendations that should be implemented, such as installing green markings at intersections and driveways, protected intersection treatments at major side streets, and various types of bike lanes.

15.4 Network Connections

The 1967 report, *A Plan for Improvement and Development of the Central Business District of Bedford, Massachusetts*, includes several recommendations that are still relevant in 2022. Transportation networks with multiple connecting segments are inherently more efficient than funneling all traffic onto a single corridor (Figure 17). (This natural tendency towards equilibrium is reflected when cut-through traffic spills out from an overcapacity corridor into alternative connecting segments.)

The 1967 report recommends series of connectors that have pros and cons that would need to be carefully weighed and discussed with abutters:

- Extend Wiggins Ave to South Road
- Connector from the eastern end of Wiggins Ave to Great Road (location to be determined; potentially Bridge Street)
- Extend Middlesex Road to North Road
- Connector between Dunster Road and Great Road
- Connector between Alaska Ave and Page Rd
- Connector between the two Elmbrook Road neighborhoods via Jonathan Way

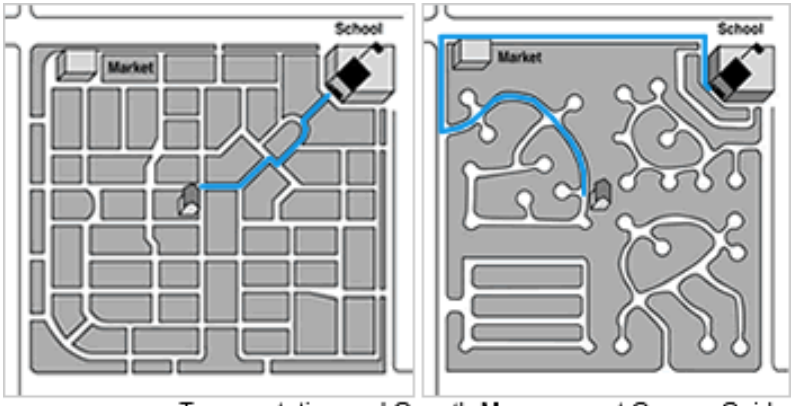

Figure 17 Network Connectivity Example (https://transportation.ky.gov/Congestion-Toolbox/Pages/Connectivity.aspx)

Connectivity

"Providing a strong connected network of roads and pedestrian facilities can help distribute traffic, reduce travel distances and times, improve routing for transit and reduce walking distances. Good connectivity also provides better routing opportunities for emergency and delivery (solid waste, recycling, mail) vehicles. All of these effects can play a positive role in reducing congestion on the street network."

-Team Kentucky Transportation Cabinet

16. Summary

Traffic signal coordination is a tool that is used to synchronize multiple intersections and enhance the operation of one or more directional movements in a corridor. The intent of coordinating traffic signals is to provide smooth flow of traffic and reduce congestion along heavily traveled roadways in order to reduce travel times, stops and delay. A well-timed, coordinated system along Great Road where the Great Road movements at each intersection are coordinated with one another would permit continuous movement through the project corridor and reduce congestion by minimizing stops and delays, which also reduces fuel consumption and improves air quality.

Note that while the recommendations do not include transit signal priority equipment, they do support transit operations by prioritizing the Great Road approaches at the signalized intersections and improve traffic flow along the corridor. Since the Route 62 bus route runs along Great Road within the project corridor between Loomis Street and Shawsheen Road, the recommendations will essentially implement *Passive Transit Signal Priority* which involves optimizing signal timing or coordinating successive signals to create a "green wave" for traffic along the transit line's route. This does not require any additional equipment.

If Active Transit Signal Priority[9] were added to the intersections at Loomis Street and South Road/Springs Road (where Bus Route 62 enters Great Road from the side streets) it would impact operations along Great Road by giving priority to the side street approaches. In addition, Active Transit Signal Priority would require additional equipment including loop detectors that can detect transit vehicles and upgrading the technology in the signal controller cabinet and potentially the technology on board transit vehicles. Close coordination with the MBTA would be needed prior to implementing Active Transit Signal Priority.

When the Town implements the Long-Term Improvements (specifically, installing new signals and replacing old equipment), Adaptive Signal Control Technology (ASCT) at the traffic signals along the project corridor could be an effective method to further improve traffic operations and increase efficiency. The signal equipment upgrades recommended in this Study will accommodate the future implementation of Adaptative Signal Control if there is a need to do so. Adaptive Signal Control works from a cloud-based management system for ease of management and maintenance. It adjusts signal timings in real time according to the volumes detected by the video system, rather than using signal timings based on a snapshot of volumes based on count data. Adaptive Signal Control and the additional data and analytics that are associated with it are typically provided by technology companies as an additional service that requires an annual subscription.

The following tables summarize Interim and Long-Term Improvements, as well as the overall cost estimates. The cost estimates are order-of-magnitude, planning level estimates.

These improvements would be eligible for the MassDOT Local Bottleneck Reduction Program, which "seeks to fund innovative solutions to address congestion bottlenecks on local roadways to improve traffic flow." Specifically, the program targets delays that are created from poor traffic signal timing, outdated equipment, lack of adequate vehicle detection, or geometric deficiencies, and can be used on individual intersections or on small corridors. The program provides $500,000 maximum for construction costs in a single fiscal year.

[9] Active Transit Signal Priority uses technology to indicate when a transit vehicle is approaching a signal to prioritize the movement of the transit vehicle. Specifically, equipment on a bus communicates to a signal to minimize delay for the bus and its passengers.

Interim Improvements	Signal phasing/timing updates* and equipment**	Signs/pavement markings	*Estimate (in 2022 dollars)*
1. Great Road & Shawsheen Road	X		*$30,000*
2. Great Road at Stop&Shop Plaza	X		*$35,000*
3. Great Road & Brooksbie Road/Route 62		X	*$10,000*
4. Great Road & Loomis Street	X	X	*$37,000*
5. Great Road at Bedford Marketplace Plaza	X		*$35,000*
6. Great Road & Hillside Avenue/Bacon Road		X	*$3,000*
7. Great Road & Springs Road/South Road	X		*$35,000*
8. Great Road & Fletcher Road/Elm Street	*None*		
9. Great Road & Mudge Way	X		*$35,000*
10. Willson Park/Rte 62 (Concord Road/North Road/Great Road)	*None*		
11. North Road/Rte 4 & Carlisle Road/Rte 225	*None*		
		TOTAL	***$220,000***

*Includes revising pedestrian phasing from exclusive to concurrent and programming LPIs.

**GPS time clocks for signal coordination and cameras for video detection. GPS time clocks provide the signals with a reliable time source, as opposed to an internal clock that may drift.

Long-Term Improvements	Full signal replacement and coordination	Signal coordination only	New signal with coordination	Geometrics	*Estimate (in 2022 dollars)*
1. Great Road & Shawsheen Road	X				*$300,000*
2. Great Road at Stop&Shop Plaza	X			Tighten corner radii, reconstruct median on Stop&Shop approach	*$600,000*
3. Great Road & Brooksbie Road/Route 62			X	Realign Brooksbie Road/Route 62 approach	*$600,000*
4. Great Road & Loomis Street	X			Reduce eastbound through lanes from two to one on both sides of intersection	*$1,000,000*
5. Great Road at Bedford Marketplace Plaza	X				*$300,000*
6. Great Road & Hillside Avenue/Bacon Road				Remove left turn lanes	*$10,000*
7. Great Road & Springs Road/South Road		X		Road widening to accommodate right-turn lane	*$330,000*
8. Great Road & Fletcher Road/Elm Street	*None*				
9. Great Road & Mudge Way		X			*$30,000*
10. Willson Park/Rte 62 (Concord Road/North Road/Great Road)			X	New southbound right turn lane, sidewalks and crossings	*$900,000*
11. North Road/Rte 4 & Carlisle Road/Rte 225			X	Realignment, sidewalks and crossings	*$600,000*
				TOTAL	***$4.7M***

16.1 Implementing Signal Recommendations

The Town's signal contractor can use the information in this report to implement the signal recommendations, including the timing and phasing updates (complete plans are in Appendix E) and the equipment recommendations. The tables below provide additional specifics on how to begin to implement this Study.

Implementing Interim Improvements	*Locations*
Contact MassDOT to share this plan and the recommendations for its intersections. Since MassDOT owns and maintains the signals at Shawsheen Road and at Stop&Shop Plaza, any changes at those intersections will need to be approved and/or implemented by the agency.	MassDOT signals at Shawsheen Road and at Stop&Shop Plaza
Install GPS time clocks to coordinate the four signals on the western end of the project corridor. Contact signal manufacturer to assess best installation approach.	1. Loomis Street 2. Marketplace 3. Springs/South Road 4. Mudge Way
Install video detection systems at all signalized intersections. (When new signal equipment is installed in the long-term, the video equipment can be removed and reinstalled on the new signal.)	All signalized intersections: 1. Shawsheen Road 2. Stop&Shop Plaza 3. Loomis Street 4. Marketplace 5. Springs/South Road 6. Mudge Way
Implement interim signal timing and phasing improvements (Appendix E) at all signalized intersections. Contact the Town's signal contractor and provide a copy of this report and its appendices.	

Implementing Long-Term Improvements	*Locations*
Design and construct geometric improvements, including new signals (locations in **bold**)	1. Stop&Shop Plaza **2. Brooksbie Road/Route 62** 3. Loomis Street 4. Hillside Avenue/Bacon Road 5. Springs/South Road **6. Willson Park/Rte 62 (Concord Road/North Road/Great Road)** **7. North Road/Rte 4 & Carlisle Road/Rte 225**
Replace existing signal equipment (except at Mudge Way and Springs Road/South Road)	1. Shawsheen Road 2. Stop&Shop Plaza 3. Loomis Street 4. Marketplace
Coordinate signals on entire corridor	All signalized intersections: 1. Shawsheen Road 2. Stop&Shop Plaza 3. Brooksbie Road/Route 62 4. Loomis Street 5. Marketplace 6. Springs/South Road 7. Mudge Way 8. Willson Park/Rte 62 (Concord Road/North Road/Great Road) 9. North Road/Rte 4 & Carlisle Road/Rte 225

Appendix A. Existing Conditions

Appendix B. Safety Analysis

Appendix C. Traffic Operational Analysis

Appendix D. Traffic Count Data

Turning Movement Counts (TMC) Data Sheets

Automatic Traffic Recorder (ATR) Data Sheets

Appendix E. Synchro Worksheets

Appendix F. Signal Warrant Analysis Worksheets