Traffic Study and
Business Vitality Analysis
For Durham's Downtown One-Way Loop

Prepared for:
Durham, New Hampshire
University of New Hampshire
Strafford Regional Planning Commission
New Hampshire Department of Transportation

July 8, 2002

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Executive Summary

One-way and two-way traffic patterns were studied and compared for Durham's downtown one-way loop. Three scenarios were studied:

- The existing one-way traffic pattern
- The two-way traffic pattern with stop-controlled intersections
- The two-way traffic pattern with signal-controlled intersections

These three scenarios were analyzed using the following traffic periods:

- 2002 Weekday AM Peak Hour
- 2002 Weekday PM Peak Hour
- 2012 Weekday AM Peak Hour
- 2012 Weekday PM Peak Hour

The 2012 PM peak hour provided the highest volume and served as the design hour.

The traffic volumes were studied using Synchro and SimTraffic 5.0 traffic simulation software. Results varied slightly between the two software packages due to the different methodologies they use.

Traffic Pattern

The one-way traffic pattern clearly performed better than the two-way traffic pattern. Multiple measures of effectiveness (MOE's) such as vehicle delays, intersection capacity, queuing, and emissions indicate that the existing one-way system performs better than either of the two-way systems would. In fact, vehicle queues and delays for the two-way traffic pattern are generally at least 5 to 10 times that of the one-way system. The only way a two-way pattern would be able to accommodate the traffic demand is if all four of the major intersections around the loop were signalized and a center left-turn lane was provided so that left turning vehicles would not block other movements. This would be very expensive, and at certain intersections it would not be possible without impacting adjacent buildings. Therefore, it is the recommendation of this report for Durham to retain its one-way traffic pattern around the downtown loop.

Mill Rd. Approach

The existing one-way traffic pattern consistently performs well around the loop except for the Mill Rd. approach. During the current PM peak hour, queues back up past the adjacent driveway to the shopping center. Two possible improvement alternatives for this intersection are presented. These and other alternatives should be studied further and the best should be implemented when vehicle queues on the Mill Rd. approach reach an unacceptable level. This will likely occur before the design year of 2012.

Speeding on Pettee Brook Ln.

A speed study is recommended on Pettee Brook Lane in order to validate local concerns of speeding. If speeding is found to be a problem, some possible traffic calming solutions are presented. Accident rates around the loop are consistent with national average accident rates. The only area of accident concentration is the Mill/Main intersection. This further justifies redesign of the intersection.

Downtown Pedestrian Environment
Certain public infrastructure improvements are recommended, such as sidewalk improvements on Madbury Rd. and Pettee Brook Ln., handicap accessibility improvements, and signing improvements. These infrastructure improvements along with business redevelopment will serve to convert Pettee Brook Ln. from a "back alley" to a desirable business front, similar to Main St.

Business Vitality
Certain recommendations are made to improve business vitality in downtown Durham. Parking supply proves to be the biggest challenge to improving business in the downtown. Providing additional parking is important, especially as traffic grows over time. Also, due to the one-way traffic pattern, improved signing for businesses and public parking is recommended. Pedestrian improvements, such as connecting the Mill Road Plaza and the Main Street area, would also enhance the Durham's downtown.

Introduction

The Town of Durham has a long-standing one-way traffic pattern around their downtown. This one-way traffic pattern forms a loop around the central business district, adjacent to the University of New Hampshire. The one-way streets include portions of Main St, Madbury Rd, and Pettee Brook Ln. Figure 1 below shows the existing one-way configuration.

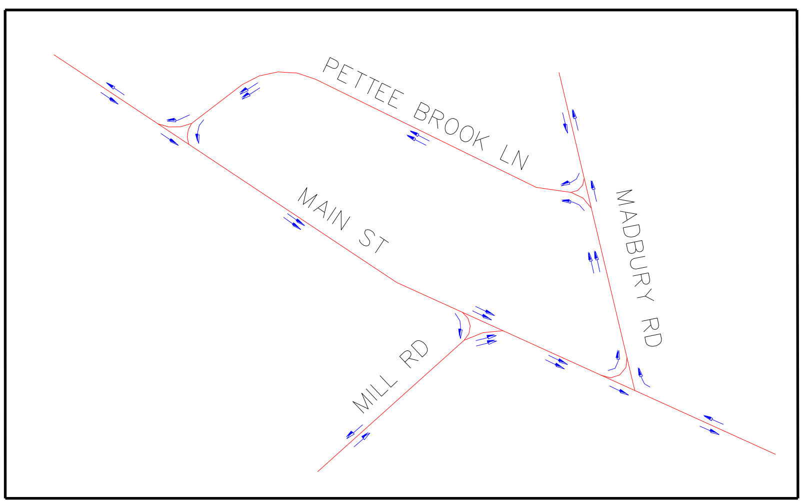

Figure 1: One-Way Traffic Pattern Around Downtown Durham

Figure 1 shows the number of lanes in each direction. Each of the four intersections shown has a central island that channelizes each movement. Almost all movements at all four intersections are free-flowing and need only to yield to pedestrians. The only exception is the Mill Rd. approach. This approach is stop-controlled.

Figure 2: Channelizing Island at Main and Madbury Intersection

One-way traffic patterns in downtown areas often serve to improve traffic flow and enhance pedestrian safety. However, drivers often must travel around the block to get to their destination, and in some cases, business vitality may be compromised. The purpose of this report is to examine the one-way traffic pattern in Durham's downtown area with the intent of improving traffic circulation, providing a safer environment for pedestrians and bicyclists, and creating an environment conducive to economic vitality and development. Some business owners may prefer a two-way traffic pattern; therefore the feasibility of a two-way pattern will be studied and compared to the existing one-way pattern. Current operational deficiencies will be addressed and possible solutions presented. Public infrastructure improvements will be addressed in order to promote safety and business enhancement along the entire one-way loop.

The purpose of this report is not to exhaustively study every traffic and business vitality issue in Durham, much like a Master Plan would. Rather, the purpose is to address important issues in the immediate downtown area, recommend certain improvements, and serve as a guide for further study.

One-Way vs. Two-Way Traffic Patterns
State-of-the-Practice Literature Review

Traffic Operations

One-way operations generally consist of two parallel roadways located close together, with adjacent roadways designated one-way in the opposite direction. Potential benefits of one-way streets on traffic operation include:

- Reducing intersection delays caused by vehicle turning movement conflicts and pedestrian-vehicle conflicts.
- Reducing travel time (increasing speeds).
- Simplifying traffic signal timing by a better progression of approaching traffic, and reducing signal phase requirements by eliminating left-turn conflicts.
- Improving public transit operation, and its impact on traffic.
- Redistributing traffic among adjacent arterial streets to relieve congestion.

One-way operation can also accommodate narrower lane widths than two-way operation, and thus has the potential for additional lanes or other uses of the pavement width.

Driver and Pedestrian Safety

An intersection of two two-way roads with no signal control has 32 potential vehicle conflict points, whereas an intersection of two one-way roads has only 5. Conflict points at intersections of one-way streets between pedestrians and vehicles are also reduced as compared to an intersection of two-way streets. One-way streets often improve drivers' fields of vision at the intersection approaches, thereby increasing the likelihood of drivers seeing pedestrians in adjacent crosswalks.

Accident data has shown that the proportion of pedestrian collisions associated with left-turning vehicles at intersections is nearly double that for right-turning vehicles. These left-turn collisions are partly caused by driver blind spots from the end of the front windshield/beginning of driver-side window. Another contributing factor is that drivers must shift attention at signalized intersections from the traffic light to the crosswalk as they approach the intersection. As the driver gets closer to the location of the turn, the angle between these increases, resulting in less time to look at the crosswalk for pedestrians.

Drivers turning left from a one-way street onto another street do not need to cross an oncoming traffic stream, and therefore can focus solely on finding a gap in crossing pedestrians. On the other hand, drivers turning left from a two-way street onto another street have to find a gap in both oncoming vehicles and pedestrians. This increases the likelihood of pedestrian-vehicle conflicts and also vehicle-vehicle conflicts. In this way, one-way street intersections generally reduce the amount of driver decisions when making turning movements, thus increasing intersection safety for both drivers and pedestrians.

Mid block pedestrian crossings may be safer overall on a one-way street rather than a two-way. Although vehicle speeds may be higher, the pedestrian only needs to look one way before crossing, rather than both ways.

Left-turn access from two-way streets to driveways has been found to represent the greatest accident potential at commercial driveways along major streets. They also create the most congestion. One-way traffic operation greatly reduces this accident and congestion potential by eliminating a need to wait for a gap in oncoming traffic before making the necessary turn.

Community Impacts

The ITE Traffic Engineering Handbook[1] states:

> In many cases, improved traffic movement and increased safety can produce economic benefits both to adjacent land users and to the general public. Nevertheless, when implementing a one-way street system, especially one involving commercial streets, traffic engineers should expect property and business owners to express concern about such circumstances as circuitous travel patterns and confusing traffic operations near business entrances and exits. (p. 227)

Business owners all want easy access to their businesses. Two-way traffic operation would better meet this desire than one-way. One-way traffic operation may require shoppers to take a longer and more inconvenient route to their destination.

Business owners prefer slow vehicle speeds in order to be more noticeable to the traffic stream. They also value adequate and convenient parking near their businesses. In fact, a national survey of municipal officials shows that the perceived lack of parking is the number one issue related to downtown business failure.[2] On-street parking may prove to be a useful way of both providing necessary parking and calming traffic if speeds are too high.

Overall, a one-way traffic operation restricts access, but increases mobility, capacity, and intersection safety. There is a controversial trade-off between meeting business owners' desires for low speeds, easy access, and sufficient parking versus providing a smooth and efficient traffic flow. The community officials must ultimately decide the purpose of the roadway under consideration: whether the higher priority is traffic operations or economic vitality. However, as alluded to by the above statement by ITE, there should be a balance point where all priorities are adequately met. For example, although many business owners desire slow vehicle speeds near their businesses, vehicle congestion may cause potential shoppers to avoid the area altogether. As stated above, "improved traffic movement and increased safety can produce economic benefits both to adjacent land users and to the general public." Congestion also has adverse economic and emotional impacts for drivers using the road system.

Table 1 below summarizes the comparison between one-way versus two-way traffic operations.

Table 1: Comparison Summary of One-Way vs. Two-Way Traffic Operation

Issue	One-Way Traffic Operation	Two-Way Traffic Operation
Traffic Operations: Capacity/Delays/ Vehicle Travel Time/ Signal Operation	Superior	Inferior
Intersection Vehicle Safety	Superior	Inferior
Intersection Pedestrian Safety	Superior	Inferior
Public Transit Operation	Superior	Inferior
Vehicle Access	Inferior	Superior

Methodology of Traffic Analysis

Existing One-Way Traffic Network

In analyzing Durham's existing downtown one-way traffic loop, the general procedure used to qualify the performance of traffic operations around the loop included the following.

- Data collection of existing conditions, including origin-destination data
- Generating a balanced traffic network using acquired data
- Forecasting traffic to the design year
- Analyzing existing and forecasted volumes to quantify traffic performance results

Data Collection

The Strafford Regional Planning Commission (SRPC) along with the Town of Durham provided the consultant with most of the necessary data for the analysis. Such data included the following.

- Traffic volumes were provided by SRPC at count stations along the loop and outside the loop, both during University of NH "in session" and "out of session" periods. Count 1 was taken for a one-week period beginning 8/20/01 (see Appendix K). Count 2 was taken for a one-week period starting on 9/24/01. Certain count stations for count 2 were taken the following week, starting on 10/1/01 (see Appendix L).
- Origin-Destination data for each approach was provided by SRPC, in which they recorded entering and exiting vehicles during a two-hour PM peak period on Wednesday April 10, 2002 at 4 - 6pm. This corresponds to the UNH "in session" PM Peak hour, which was the design hour. They recorded the last 3 digits of each license plate both entering and exiting the loop. Then license plate numbers

where matched and corresponding percentages were produced showing where vehicles from a certain approach exited the loop (see Appendix B).

- SRPC provided available electronic mapping of Durham.
- SRPC provided a traffic study[5] conducted in 1997 for UNH and Durham (see references). This report was used for regional annual traffic growth rates.
- The Town provided accident data for the last five years, and the Master Plan of Durham.

Generating a Balanced Traffic Network
Traffic count data was provided for several count stations for the two count periods. In order to analyze the existing traffic operations, the raw traffic volumes had to be converted into a balanced traffic network. The network would then be analyzed to determine the quality of traffic operations around the one-way loop. The steps that were taken to reduce the raw volumes into a balanced traffic network are listed below.

1. The AM peak hour and the PM peak hour for each weekday were separately averaged. Each count was kept separately, yielding average AM and PM peak hour volumes for both UNH “in session” and “out of session” periods. (See Appendix D.)
2. Each of the average weekday peak hour volumes for each counting station were recorded on the same diagram that corresponded with either the AM or PM period of that particular count. The average AM peak hour counts for all count stations during count 1 were recorded on a single diagram. Then the average AM peak hour counts for count 2 were recorded on a separate diagram. The same was done for the PM peak periods. These diagrams are shown in Appendix D.
3. The higher of the two average weekday AM peak hour volumes between the two counts were recorded on the same diagram (see Appendix D). These AM peak hour volumes were then balanced to produce the AM 2001 balanced traffic network (Appendix D). The same was done for the PM period volumes.

The counts taken while UNH was in session yielded the higher volumes. Also, the PM peak hour volumes were generally higher than the AM at most count stations.

Forecasting Traffic
The 2001 AM and PM balanced traffic networks were then forecasted 1 year ahead to produce the 2002 AM and PM peak hour volumes shown in Appendix A. The 2001 volumes were also forecasted 11 years ahead to the design year of 2012, also in Appendix A. The 1997 UNH / Durham Traffic Study[5] states that Durham’s traffic is growing at an average rate of 1 to 2% per year. A traffic growth rate of 1.5% per year was used to forecast traffic to the design year. The 1-year growth factor was 1.015 and the 11-year growth factor was 1.17795.

Analyzing the Existing and Forecasted Traffic Networks
Synchro plus SimTraffic Version 5.0 traffic simulation software was used to simulate and analyze the traffic network. Synchro uses the Highway Capacity Manual 2000[3] (HCM) method to analyze signalized and unsignalized intersections. It reports both approach delays and queues as well as other Measures of Effectiveness (MOE’s). SimTraffic is a

separate software package that animates and simulates the traffic network built using Synchro. Synchro is a macroscopic analysis tool that does the HCM calculations, whereas SimTraffic is a microscopic analysis tool that calculates the performance of each individual vehicle "based on lane changing and car following logic."[7] SimTraffic uses the vehicle and driver performance characteristics developed over the last 20 years by the Federal Highway Administration to model each individual vehicle.[8] *It is important to note that Sychro and SimTraffic both do separate average delay calculations per vehicle.* Since they use separate analysis methods, the results may be slightly different.

The traffic volumes in Appendix A were analyzed, and Synchro output reports for the existing one-way pattern are included in Appendix F. The analysis periods included:

- 2002 Weekday AM Peak Hour
- 2012 Weekday AM Peak Hour
- 2002 Weekday PM Peak Hour
- 2012 Weekday PM Peak Hour

Certain assumptions were made in analyzing the one-way pattern. These assumptions and pertinent example calculations are shown on the first part of Appendix F in the Synchro output reports. Such assumptions include the following.

Conflicting pedestrians

- For the mid-block pedestrian crossings across Main St, 80 peds/hr was assumed across all crossing during peak hour.
- For Mill and Main intersection, 40 peds/hr across each crosswalk was assumed.
- For Main and Madbury intersection, 20 peds/hr across each crosswalk was assumed.
- For Madbury and Pettee Brook intersection, 20 peds/hr across each crosswalk was assumed.
- For Pettee Brook and Main intersection, 40 peds/hr across each vehicle movement was assumed.

Other assumptions

- For conflicting parking maneuvers per hour, an occupancy rate of 80% was assumed.
- Mid-block traffic was assumed to generate 5 to 10% of traffic along each link, accounting for driveways and mid-block parking locations.

Two-Way Traffic Network

In analyzing Durham's downtown loop as a two-way street system, the general procedures used to qualify the performance of traffic operations in a two-way street system included the following.

- Distributing existing one-way traffic across the two-way system using the origin-destination data.
- Forecasting traffic to the design year
- Analyzing present year and design year volumes for the two-way system to quantify traffic performance results

Distributing One-Way Traffic across a Two-Way Traffic Network

The results of the origin-destination (O-D) study conducted by SRPC in Appendix B were used to distribute one-way traffic across a two-way traffic network. The results show the distribution of where vehicles from each approach leave the one-way loop. Since the O-D study was conducted during the PM peak period, the corrected percentages were used to distribute traffic for the PM peak hour. The percentages were slightly modified to distribute AM peak hour traffic, as shown in Appendix B. The AM percentages were modified based on differences between the AM and PM traffic count data.

A certain percentage of vehicles that entered the one-way loop also exited at the same street during the 2-hour O-D study. These drivers may have done errands in the downtown area, or other possible functions. For the two-way traffic distribution, half of these vehicles were modeled as going around the loop in one direction, and half as going around in the other direction. For distributing other destinations, the traffic was distributed across the shortest path, in a logical "gravity" method.

Distributing the 2002 one-way AM and PM peak hour traffic volumes produced the two-way traffic networks shown in Appendix C. These volumes were then forecasted to the year 2012 using the same method as the one-way traffic forecasting. The resulting 2012 traffic volumes are also found in Appendix C.

Analyzing the Two-Way Traffic Network

Synchro and SimTraffic were used to analyze the two-way traffic networks shown in Appendix C. The two-way traffic networks were analyzed in two ways: stop-controlled and signal-controlled. First, the intersections were modeled as all-way stop-controlled, where every approach has a stop sign. We checked if it was possible to model the intersections as two-way stop controlled intersection, where only the minor street approaches have stop signs and the major street approaches are free. The results quickly showed excessive delays and queues, much higher than those for an all-way stop controlled intersection.

Next, the intersections were modeled as fully actuated signalized intersections with optimized cycle lengths and intersection splits. The reported differences in delays and queues between coordinated and uncoordinated signals were negligible.

Modeling the two-way intersections as both stop and signal-controlled brings up the question, "Are signals warranted at these intersections?" The answer is yes. All four of the major intersections in all four of the two-way analysis periods meet the MUTCD[9] peak hour signal warrant.

The same assumptions as for the one-way analysis were made regarding conflicting pedestrians, adjacent parking, and so on. The two-way analyses for both stop and signal-controlled intersections assumed one lane in each direction, with all movements being made from a single lane. The existing geometry of the Durham's roads and intersections supports this assumption. Roadway and intersection widening would be required if a left turn lane was provided for each approach and on-street parking was retained.

Results of Traffic Analysis

Intersection Delay

The Highway Capacity Manual does not define overall intersection Level of Service (LOS) for unsignalized intersections that are not stop-controlled on all approaches. In this case, such as two-way stop-controlled intersection, LOS is defined separately for each approach. Therefore, overall intersection LOS is not defined for the existing one-way Durham intersections since they have free-flowing channelized turns. For these intersections, Sychro reports average delays for both individual approaches and the entire intersection. However, it only reports LOS for each approach rather than for the entire intersection. In the following tables, the average intersection delay is reported with the corresponding LOS from HCM Exhibit 17-2 (see Appendix F) for means of comparison with the other two columns. HCM Exhibit 17-2 is the LOS criteria for 2-way stop-controlled intersections. It also applies to all-way stop-controlled intersections. It is intended to be used for each individual approach, but in this case we are applying it to the overall average intersection delay and using it as a means of comparison.

It is also important to note that the LOS delay criteria for stop-controlled intersections "have different threshold values than do those for signalized intersections primarily because drivers expect different levels of performance from distinct types of transportation facilities. The expectation is that a signalized intersection is designed to carry higher traffic volumes than an all-way stop controlled intersection. Thus a higher level of control delay is acceptable at a signalized intersection for the same LOS." (HCM p. 17-32). For example, an average delay of 60 seconds would result in an LOS of F at a stop-controlled intersection, but an LOS of E at a signalized intersection. See Appendix F for LOS criteria of signalized and unsignalized intersections.

The following tabulated results are from the Synchro output reports in Appendices F, G, and H.

Table 2: 2002 AM Peak Hour Delays and Levels of Service

Intersection	Existing 1-way traffic pattern: Average Delay (sec) & Corresponding LOS	2-way traffic pattern with stop-controlled intersections: Average Delay (sec) & LOS	2-way traffic pattern with signal-controlled intersections: Average Delay (sec) & LOS
Mill & Main	5.2 A	53.8 F	15.0 B
Main & Madbury	1.7 A	136.1 F	97.3 F
Madbury & Pettee Brook	3.8 A	32.7 D	10.8 B
Pettee Brook & Main	3.8 A	32.7 D	12.0 B

Table 3: 2012 AM Peak Hour Delays and Levels of Service

Intersection	Existing 1-way traffic pattern: Average Delay (sec) & Corresponding LOS	2-way traffic pattern with stop-controlled intersections: Average Delay (sec) & LOS	2-way traffic pattern with signal-controlled intersections: Average Delay (sec) & LOS
Mill & Main	6.6 A	104.1 F	28.4 C
Main & Madbury	1.7 A	212.1 F	149.2 F
Madbury & Pettee Brook	4.0 A	76.1 F	36.8 D
Pettee Brook & Main	4.0 A	73.0 F	20.5 C

Table 4: 2002 PM Peak Hour Delays and Levels of Service

Intersection	Existing 1-way traffic pattern: Average Delay (sec) & Corresponding LOS	2-way traffic pattern with stop-controlled intersections: Average Delay (sec) & LOS	2-way traffic pattern with signal-controlled intersections: Average Delay (sec) & LOS
Mill & Main	18.6 B	167.8 F	86.3 F
Main & Madbury	1.7 A	296.7 F	193.6 F
Madbury & Pettee Brook	3.4 A	104.7 F	49.8 D
Pettee Brook & Main	3.8 A	44.5 E	16.9 B

Table 5: 2012 PM Peak Hour Delays and Levels of Service

Intersection	Existing 1-way traffic pattern: Average Delay (sec) & Corresponding LOS	2-way traffic pattern with stop-controlled intersections: Average Delay (sec) & LOS	2-way traffic pattern with signal-controlled intersections: Average Delay (sec) & LOS
Mill & Main	46.9 D	251.2 F	177.7 F
Main & Madbury	1.7 A	409.1 F	230.8 F
Madbury & Pettee Brook	3.6 A	188.4 F	106.0 F
Pettee Brook & Main	4.1 A	98.2 F	42.5 D

It is clear from the tabulated results that the existing one-way loop performs much better than the two-way traffic pattern in regard to vehicle delays. In fact, the two-way intersection delays are generally at least 5 to 10 times that of the one-way traffic pattern. Durham could not reasonably justify changing intersections that are performing at LOS A to the two-way configuration where they would perform at LOS D or F, especially since all intersections would need to be signalized and reconstructed, which would be very expensive.

For the two-way traffic pattern, signal-controlled intersections consistently performed better than stop-controlled, experiencing roughly half the delay of stop-controlled intersections. However, the two-way signal controlled intersections performed much worse than the existing one-way pattern.

Using the 2012 PM peak hour as an example (since this is technically our design period), two-way signal controlled intersections experienced over 10 times the delay of one-way intersections on average. Vehicle emissions also increase with the increased starts and stops of a 2-way system.

Some of the delays listed for the two-way system may seem too large to be accurate. However, the primary reason for excessive delays at two-way intersections is the fact that there is only one lane in each direction. When a driver wishes to turn left at an intersection, they must wait for an adequate gap in opposing traffic. When the opposing volume is high, these adequate gaps may be sparse. Thus the driver turning left must wait, and in doing so they block the entire queue of vehicles behind them.

The only way of improving traffic performance of the two-way system is to provide a center left-turning lane. This would involve road widening if on-street parking was retained.

According to the HCM unsignalized analysis in Appendix F, the northbound approach to the Mill & Main intersection currently experiences 51 seconds of average delay during the PM peak hour. This will increase to 127 seconds by 2012. Long vehicle queues accompany these delays. This stop-controlled approach proves to be the greatest problem of the existing one-way traffic network.

Intersection Capacity

One of Synchro's outputs for both signalized and unsignalized intersections is Intersection Capacity Utilization (ICU) Level of Service. The ICU is a percentage with a corresponding LOS. The ICU percentage can be thought of as an intersection-wide volume to capacity (v/c) ratio. Its calculation does not use the existing signal timings or sign controls. It calculates the intersection's ultimate capacity based on a fully protected, optimized signalized timing plan at a cycle length of 120 seconds. The ICU does not provide a complete picture of the intersection performance, but it does provide a clear view of the intersection's volume related to its capacity. The intersection ICU Levels of Service are defined from A through H. See Appendix E for the ICU LOS definitions. In Durham's one-way analysis case, where no signalized intersections exist in the analysis network, the ICU can be applied to an unsignalized intersection and give information about the ultimate capacity of the intersection if it were signalized. "For signalized intersections, a delay-based LOS can use an optimal timing plan to mask a capacity deficiency. It is quite possible to get an HCM LOS D with an intersection v/c ratio of 1.1."[4] In this case, an ICU LOS would give a more complete picture of intersection performance.

The ICU Levels of Service are tabulated below for the 2012 PM design hour to show how a 2-way intersection compares to a 1-way intersection. The lower the ICU, the greater the intersection capacity and the better it performs in regard to delays and queues. Since intersections of one-way and two-way streets have different capacities and will perform much differently, the ICU is a good means of comparison. The ICU for a 2-way intersection is the same regardless of whether it is signalized or unsignalized. The following data is found in the Synchro outputs of Appendices F, G, & H.

Table 6: 2012 PM Peak Hour Intersection Capacity Utilization for 1-way vs. 2-way networks

Intersection	ICU (%) and Corresponding LOS for Intersection of One-Way Network	ICU (%) and Corresponding LOS for Intersection of Two-Way Network
Mill & Main	99.1 % E	143.9 % H
Main & Madbury	101.7 % F	183.2 % H
Madbury & Pettee Brook	105.6 % F	132.2 % H
Pettee Brook & Main	86.0 % D	116.2 % G

Table 6 shows that intersections are more efficient with the one-way traffic pattern. The one-way intersections utilized a smaller percentage of the intersections' total capacity, and therefore are more efficient.

Table 7 below shows the hourly exit rate of vehicles through each intersection for the 2012 PM design hour. The number of vehicles that move through the intersection in one hour shows the capacity of each intersection type compared to one another. The following data is found in the SimTraffic design hour summaries in Appendix I.

Table 7: 2012 PM Peak Hour Total Hourly Exit Rate of Vehicles

Intersection	**Existing 1-way traffic pattern: Hourly Exit Rate (veh)**	**2-way traffic pattern with stop-controlled intersections: Hourly Exit Rate (veh)**	**2-way traffic pattern with signal-controlled intersections: Hourly Exit Rate (veh)**
Mill & Main	1902	1344	1350
Main & Madbury	2280	1494	1770
Madbury & Pettee Brook	2166	1266	1410
Pettee Brook & Main	2046	1128	1278

Table 7 shows that the capacity of the one-way intersections is much greater than two-way intersections. Again, signal-controlled intersections perform better than stop-controlled for the two-way system. It should be noted that even though the 2-way intersections have a lower exit rate, they are functioning at a higher ICU, and a worse Level of Service. Even though the one-way intersections have a higher vehicle exit rate, they still have more available capacity than the two-way.

Other Measures of Effectiveness (MOE's)

Vehicle queuing

Vehicle queuing is an important MOE in considering the geometry of the intersection and approaches. Sometimes intersections can function at reasonable delays while the queues exceed the provided storage space for that movement. When volume-to-capacity (v/c) ratios for each turning movement exceed 1.0, queues generally become excessive. Table 8 below shows the maximum queues at each intersection during the 2012 PM design hour. The maximum queues for the one-way intersections were taken from the HCM analysis in Appendix F. The 95^{th} percentile queues for the two-way intersections were taken from the SimTraffic design hour summaries in Appendix I.

Table 8: 2012 PM Peak Hour Maximum Queue Lengths at Each Intersection

Intersection	Existing 1-way traffic pattern: Maximum Queue Length (ft)	2-way traffic pattern with stop-controlled intersections: Maximum Queue Length (ft)	2-way traffic pattern with signal-controlled intersections: Maximum Queue Length (ft)
Mill & Main	378	1165	1331
Main & Madbury	35	696	815
Madbury & Pettee Brook	80	1209	910
Pettee Brook & Main	62	757	238

Table 8 shows that again, the existing one-way traffic pattern performs better than the two-way. Queues for one-way intersections are substantially less and do not impact adjacent intersections. Queues at three of the four two-way intersections reach an adjacent intersection. These queues block the adjacent intersection and do not allow it to perform properly. A SimTraffic animation will demonstrate this.

According to the HCM unsignalized analysis in Appendix F, the northbound approach to the Mill & Main intersection currently experiences a queue of 204 feet during the PM peak hour. This will increase to 378 feet by 2012. This stop-controlled approach proves to be the greatest problem of the existing one-way traffic network.

Environmental Considerations & Other MOE's

More communities are making a higher priority of assessing the environmental impacts of their transportation facilities, such as vehicle emissions and fuel consumption. Vehicle emissions and fuel consumption are greatly increased by starts and stops associated with intersection delays. Smoother traffic flow, where drivers are not stopping as frequently, generates less emissions and reduces fuel consumption. Table 9 below shows multiple network performance MOE's corresponding to a 10 minute period during the 2012 PM design hour. The following data is found in the SimTraffic design hour summaries of Appendix I.

Table 9: 2012 PM Peak Hour Network Performance MOE's for a 10-minute period

MOE	Existing 1-way traffic pattern	2-way traffic pattern with stop-controlled intersections	2-way traffic pattern with signal-controlled intersections
HC Emissions (g)	50	81	67
Total Fuel Used (gal)	19	31	27
Average Speed (mph)	20	6	7
Total Stops	237	1152	1566
Delay / Vehicle (sec)	17	299	219

Accident Analysis

Table 10 below shows the number of accidents inside of the study area or within 250 feet of the one-way loop from the 1997 through 2001. The following data was obtained from statistical accident summaries provided to the consultant by the Town of Durham.

Table 10: Number of Accidents In or Near the Project Area

Location	Year	1997	1998	1999	2000	2001	Average	Rate/Million Vehicle-Miles*
Streets:	Madbury Rd	3	1	7	3	3	**3.4**	6.6
	Main St	8	3	10	9	10	**8.0**	6.3
	Mill Rd near loop			2		1	**0.6**	3.3
	Pettee Brook Ln	6	5	6	7	4	**5.6**	6.5
	Jenkins Ct		1			1	**0.4**	N/A
Intersections:								**Rate/Million Entering Vehicles***
	Madbury/Main	1	1	4	3	2	**2.2**	0.33
	Madbury/Pettee Brook	1				1	**0.4**	0.06
	Pettee Brook/Main	2	1	2	1	3	**1.8**	0.29
	Main/Mill	4	4	11	8	6	**6.6**	1.15
Total Accidents within Study Area		25	16	42	31	31	**29**	
Total Town-wide accidents		251	213	304	268	268	**261**	

* = Approximate values

The New Hampshire average accident rate is currently 3.12 accidents per million vehicle-miles. This rate includes interstate freeways and high-volume highways, which typically have lower accident rates than downtown streets, such as the Durham study area. The accident rates as shown in Table 10 are consistent with national averages for similar local street facilities.[10] All legs of the loop have approximately equal accident rates, showing that none of the legs is significantly more dangerous than the others. There were no fatalities within the study area in the past 5 years.

National averages for accidents at unsignalized intersections range from 0.5 to 0.9 accidents per million entering vehicles.[10] New Hampshire intersection values were unavailable. Massachusetts official statewide average is currently 0.66. Table 10 shows that there is an accident concentration at the Mill/Main intersection, while the other intersections have accident rates well below average rates. The finding that there is a higher accident rate at the Mill/Main intersection is consistent with the other findings of this report. This intersection, particularly the Mill Rd. approach, experiences delays and queues much greater than any other place around the one-way loop. It is reasonable that a higher accident rate would be expected at this intersection, since drivers tend to take more risks when subjected to long delays.

Main St/Pettee Brook Ln/Quad Way Intersection

The Main St/Pettee Brook Ln intersection is analyzed in this report as a three-legged intersection. However, there is a forth leg of this intersection called Quad Way into the UNH campus, which presently serves as a driveway for delivery vehicles servicing an adjacent cafeteria. Quad Way also services very few passenger cars. The current traffic impacts of this two-way approach to the intersection are negligible.

UNH is currently constructing a new dormitory hall and expanding the existing cafeteria adjacent to the Main St/Pettee Brook Ln/Quad Way intersection. These improvements will be completed in 2003 and will generate more traffic to Quad Way. The following data summarizes traffic generation from the expanded cafeteria and new dorm hall, as forecasted by UNH.

- Residence Hall facility will generate a total of 2000 person trips per day.
  5% of those will be vehicular trips.
  50% of those will be accessing the hall by Main St.
- Dining Hall facility will generate 1500 a total of person trips per day.
  5% of those will be vehicular trips.
  50% of those will be accessing the hall by Main St.
- Delivery Service trips will generate a total of 40 trips per day on Quad Way.
- Campus Parking Lot C will be expanded by 44 parking spaces to provide a total of 150 spaces.
  50% of vehicles will access the lot from Mill Rd, and 50% from Quad Way.
  50% of the Quad Way trips will continue to Main St. and 50% will go south to College Rd.

The resulting traffic into and out of Quad Way by means of the Main St/Pettee Brook Ln intersection during the 2012 PM peak analysis hour consists of the following.

- 29 right turns from Main St. onto Quad Way.
- 34 right turns from Quad Way onto Main St.

These volumes were added to the Synchro and SimTraffic models for the intersection. Table 11 below summarizes the performance of the intersection during the 2012 PM peak hour both with and without the Quad Way forecasted traffic volumes. This reasonably models the "before completion" and "after completion" traffic scenarios. See Appendix N for the Quad Way Analysis and calculations.

Table 11: Performance of the Main St/Pettee Brook Ln/Quad Way intersection

Intersection Approach	Without Quad Way Approach forecasted volumes		With Quad Way Approach forecasted volumes	
	Average delay/vehicle (sec)	95th percentile queue (ft)	Average delay/vehicle (sec)	95th percentile queue (ft)
Main St. EB through	4.8	38	7.0	81
Pettee Brook Ln. SB left	3.1	27	4.8	249
Pettee Brook Ln. SB right		113		204
Quad Way NB right	N/A	N/A	55.4	60

As Table 11 shows, the increased usage of Quad Way has minimal traffic impacts on the other major approaches to the intersection. Delays remain well below the "LOS A" threshold of 10 seconds. The maximum queues increase, but remain within an acceptable range that can easily be handled by the existing infrastructure. According to the above results, the increased usage of Quad Way, as forecasted by UNH, will be able to be accommodated by the Main St/Pettee Brook Ln/Quad Way intersection. Traffic impacts to other intersection around the one-way loop are negligible.

Traffic Conclusions and Recommendations

Traffic Issues

The one-way traffic pattern is clearly superior to the two-way traffic pattern. Multiple MOE's such as vehicle delays, intersection capacity, queuing, and emissions indicate that the existing one-way system performs better than a two-way system would. In fact, the two-way intersection delays and queues are unbearable. Vehicle queues and delays for the two-way traffic pattern are generally at least 5 to 10 times that of the one-way system. There is no way that Durham can justify changing the existing intersections that are performing at LOS A to the two-way configuration where they would perform at LOS D or F, especially since all intersections would need to be signalized and reconstructed, which would be very expensive. Signalizing each intersection would cost roughly $100,000 per intersection, not including any geometric changes to the intersection.

The only way a two-way pattern would be able to accommodate the traffic demand is if all four of the major intersections around the loop were signalized and a center left-turn lane was provided so that left turning vehicles would not block other movements. Providing an exclusive left-turn lane would require road widening. Widening around the loop is not feasible in certain locations, and would harm the positive pedestrian environment that Durham currently has. In addition to being very expensive and greatly increasing vehicle queues and delays, it would also decrease the safety for motorists, bicycles, and pedestrians. Therefore, it is the recommendation of this report that Durham retain its one-way traffic pattern around the downtown loop.

Mill Road Approach

Figure 3: Mill Road Stop-Controlled Approach

The existing one-way traffic pattern consistently performs well around the loop except for the Mill Rd. approach. During the current PM peak hour, queues back up past the adjacent driveway to the shopping center. These queues will continue to grow, and will continue to block the shopping center entrance. Figure 4 below shows the existing stop-controlled Mill Rd. approach, as it appears in the SimTraffic model used for this study.

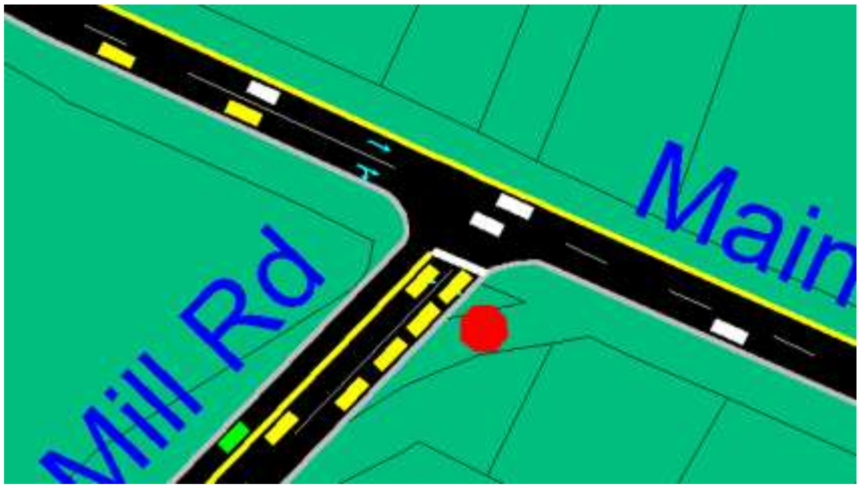

Figure 4: Existing stop-controlled Mill Rd. Approach

Two alternatives were generated in addition to the "no-build" alternative to improve traffic performance at the Mill Rd. approach. The first "build" alternative includes channelizing each movement, removing the stop sign on the Mill Rd. approach, and allowing all movements to be free-flowing. This is similar to the configuration of the other 3 intersections. Placing a channelizing island in the center of the intersection ensures that all movements are protected from the impedance of a conflicting movement. This provides for a more continuous, smoother flow of traffic through the intersection. Figure 5 below shows Alternative 1 for Mill and Main intersection, as it appears in the SimTraffic model.

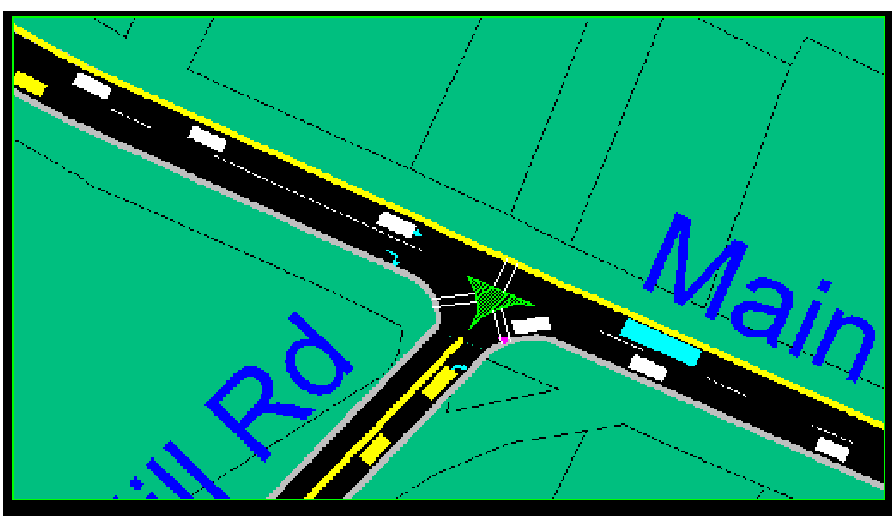

Figure 5: Alternative 1 for Mill and Main intersection

Alternative 1 would require the following:

- Reduce Mill Rd. approach from two lanes to one
- Channelize the eastbound right turn
- Channelize the eastbound through movement
- Channelize the northbound right turn.

It may seem counter-intuitive to reduce Mill Rd. approach from 2 lanes to one. However, this would converge vehicles into one smooth-flowing right turn lane, which would be channelized at the intersection with an exclusive receiving lane on Main St.

Alternative 2 for this intersection would include keeping the existing geometry of the intersection and signalizing it. The existing PM peak hour does meet the MUTCD[9] peak hour signal warrant. Figure 6 below shows the signalized alternative, as it appears in the SimTraffic model.

Figure 6: Alternative 2 for Mill and Main intersection

Further study should be done to determine exactly the right alternative for the Mill and Main intersection. For example, shifting all eastbound traffic to the left lane may impede access/egress from the adjacent on-street parking and it may tax the weaving capacity of Main St. between Mill Rd. and Madbury Rd. To come to a final conclusion is beyond the scope of this report. However, Table 12 below shows multiple MOE's of the different alternatives, as studied in Appendices F and J.

Table 12: MOE's for Mill & Main Intersection Alternatives performing in the 2012 PM Peak Hour for a 10-minute period

MOE	"No-Build" Alternative	Alternative 1: Channelized Movements	Alternative 2: Signalized Intersection
Delay / Vehicle (sec)	46.9	3.7	56.5
Total Stops	128	25	233
Average Speed (mph)	16	19	13
Total Fuel Used (gal)	1.7	1.6	2.4
Max 95th Percentile Queue (ft)	378	153	343

Based on this preliminary study of the Mill and Main intersection, it appears that Alternative 1 is superior to the others and should be implemented. However, the final decision of what intersection improvements should be made warrants further study with cost estimates for each alternative. It is the recommendation of this report that Durham study this intersection with more detail. Additional intersection traffic counts are warranted, especially during the weekday PM peak hour. A traffic count on Friday from noon to 5 pm will likely capture saturated traffic conditions at the Mill Rd. approach.

Timeline of Mill & Main Street Study and Improvements
Current delays and queues for the Mill Rd. approach warrant an in-depth intersection study. Durham should address the operational deficiencies of the Mill Rd. approach and implement an intersection improvement when queues and delays reach an unacceptable level. The Town must decide the timeline of this. It is the recommendation of this report that an intersection improvement be implemented before the design year of 2012.

Public Infrastructure Improvements

Certain improvements can be made to the existing infrastructure around the one-way loop in regard to safety and business vitality. Most of these improvements apply to Pettee Brook Lane and seek to change it from a "back alley" to a desirable business front, much like the existing Main St.

Figure 7: Main Street Sidewalk

As Figure 7 shows, a good sidewalk and streetscape environment can greatly improve business vitality. In order to develop the business potential of Pettee Brook Lane, sidewalk and streetscape improvements similar to those on Main Street should be considered by Durham. The following recommended improvements are a start for this process, and will enhance pedestrian, bicycle, and vehicle safety.

Traffic Calming on Pettee Brook Lane

Some Durham locals express concern of a speeding problem on Pettee Brook Lane, although no formal speed studies have been conducted. Although the accident rate for Pettee Brook Ln. is consistent with the other legs of the loop, conducting a speed study on Pettee Brook Ln. is recommended. If it finds that speeding is a problem, measures should be taken to slow vehicular speeds and provide safer, more visible pedestrian crossings. This can be accomplished by changing the existing pedestrian crossings into elevated and "Street-Print" patterned crossings. This will enhance pedestrian visibility, and will require vehicles to slow down over the elevated crosswalks. The pedestrian crossings on Main St. have brick-looking "Street-Print". This provides a visual distinction between the pavement and the crosswalk, having a traffic-calming effect. A potential problem with "Street-Print" is that it wears away over time, and must be regularly reapplied.

Madbury Rd. and Pettee Brook Ln. Sidewalk improvements

The following are recommended improvements to the Madbury Rd. and Pettee Brook Ln. sidewalks.

- The existing sidewalks are made of bituminous concrete. Some of the cross sections of the sidewalks are humped on Pettee Brook Ln., while some curbs are 2 to 3 inches high in places rather than the 6-inch standard. Replacing the existing sidewalks with cement concrete sidewalks and new curbs is recommended.
- The back of the sidewalk in front of the Don Thompson Real Estate office on Pettee Brook Ln. has a drop-off greater than 1.5 feet. Hand railing for pedestrian safety should be considered.

- Certain crosswalks on Pettee Brook Ln. end in driveways. This is unsafe, especially for handicap pedestrians who need a safe and level landing area at the end of each crossing. These crosswalks should begin and end in the sidewalk with standard wheelchair ramps.

Figure 8: Sidewalk on Pettee Brook Lane

Figure 8 above shows a couple of features that should be improved. It shows the deteriorating bituminous concrete sidewalks, the drop-off on the back of the sidewalk, the low curb height, and a crosswalk ending in a driveway.

Other recommendations include the following:

- Non-standard handicap accessibility is currently provided at the intersection of Pettee Brook Ln. and Main St. Wheel chair ramps should be provided at all crosswalks.
- The sidewalk on the north side of Pettee Brook Ln. is discontinued, ironically, in front of the University Safety Building. Sidewalk should be provided continuously along both sides of the street.

Figure 9: Discontinuous Sidewalk on Pettee Brook Lane