RSG INC.
RESOURCE SYSTEMS GROUP, INC.

TECHNICAL MEMORANDUM

To: Michael Behrendt, Town Planner, Durham, NH
Steve Pesci, Special Projects Director, University of New Hampshire
From: Dirk Grotenhuis PE; Ben Swanson; Austin Feula
Subject: Main Street/Pettee Brook Lane/Quad Way Roundabout Analysis
Date: 4 November 2013

The Town of Durham has asked RSG to evaluate the implications of converting the unsignalized Main Street/Pettee Brook Lane/Quad Way intersection into a single-lane roundabout. This memorandum presents projected vehicle path choice and transit route changes due to this conversion, along with overall vehicle miles travelled (VMT) and emissions projections.

Project Overview & Key Findings

The existing Main Street/Pettee Brook Lane/Quad Way intersection is unsignalized with stop control for the northbound, Quad Way, approach (which is a right-in-right-out only) and free movements on all other approaches. As seen in Figure 1, existing conditions prohibit the northbound left-turn movement from Quad Way onto Main Street and the southbound through movement from Pettee Brook Lane onto Quad Way. With the installation of a roundabout both of these movements will be possible. Additionally, U-turns will be possible along Main Street and Quad Way.

In addition to allowing new access routes to the UNH B Lot parking lot (a major commuter lot), this potential intersection change would also allow for a significant reduction in transit route length for several regular routes on the Campus Connector and Wildcat Transit systems.

The availability of these movements will allow drivers to seek shorter paths to/from the downtown Durham area, and results in a decrease of bi-direction volumes on several major roadways in downtown Durham, including Garrison Avenue, Edgewood Avenue, College Road, Main Street, Academic Way, McDaniel Drive, Faculty Drive, and Mill Road. Bi-direction traffic volumes on Pettee Brook Lane, Madbury Road, and Quad Way are expected to increase with this intersection change.

In the core downtown area (from Edgewood Road east to Madbury Road and including the UNH campus south to McDaniel Drive) we project construction of a roundabout at the Main Street/Pettee Brook Lane/Quad Way intersection will result in a net decrease of approximately 23 vehicle miles travelled (VMT) during the weekday AM peak hour. Using this peak hour projection, we estimate the proposed roundabout could result in an annual reduction of over 80,000 vehicle miles travelled in the core Durham downtown each year.

By applying Durham Traffic Model results to the EPA's MOVES air quality emissions model we also project construction of the proposed roundabout will result in a net decrease of approximately 70 grams of CO and approximately 68 grams of NOx during the AM peak hour in the core Durham downtown, which could translate to annual reductions of up to 250 kg of CO and NOx in the downtown each year.

Additionally, we note secondary benefits to pedestrian safety at the Main Street/Pettee Brook Lane/Quad Way intersection and on other downtown streets including Edgewood Road and Garrison Avenue.

Figure 1: Existing Roadway Configuration at the Main Street/Pettee Brook Lane/Quad Way Intersection

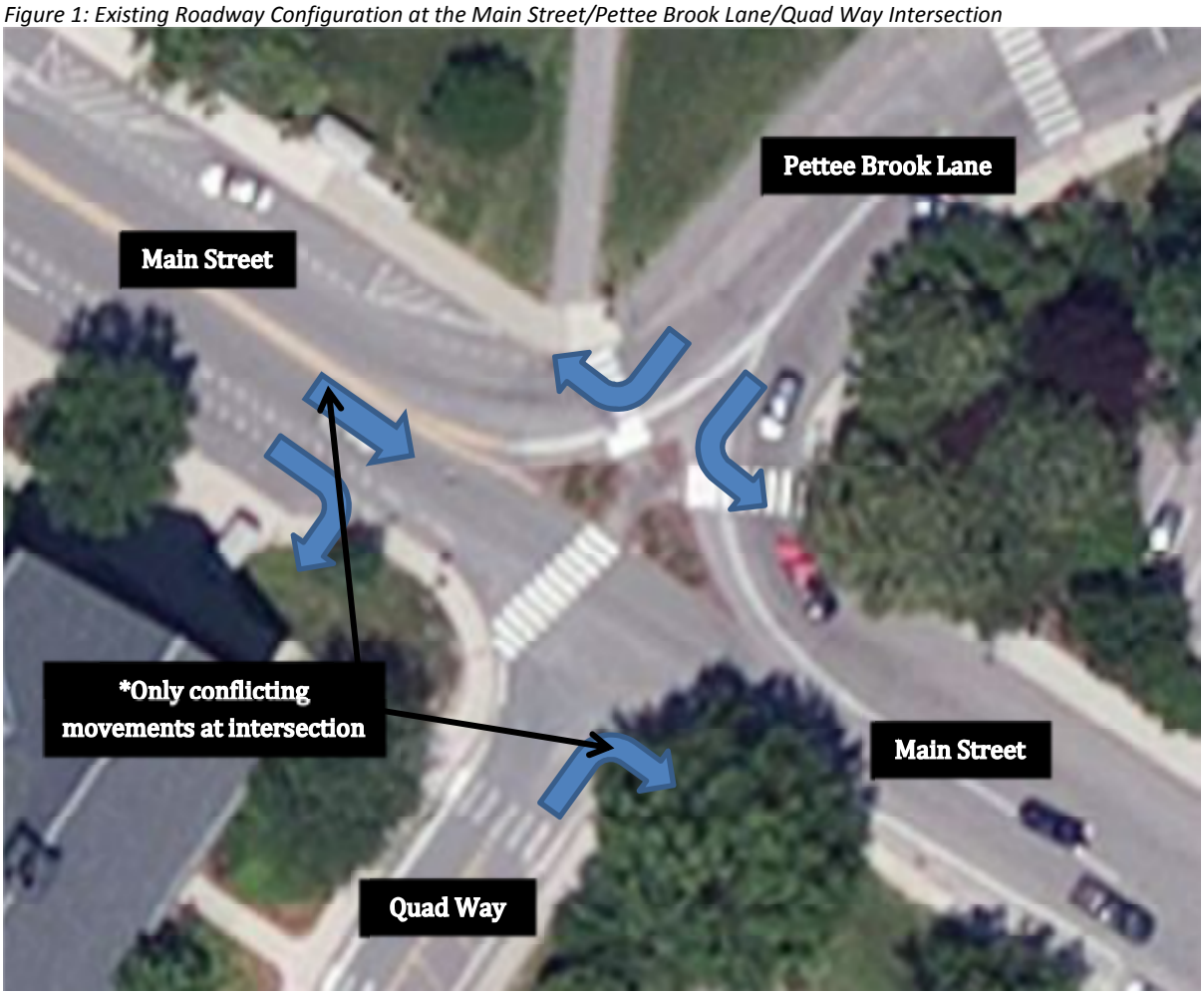
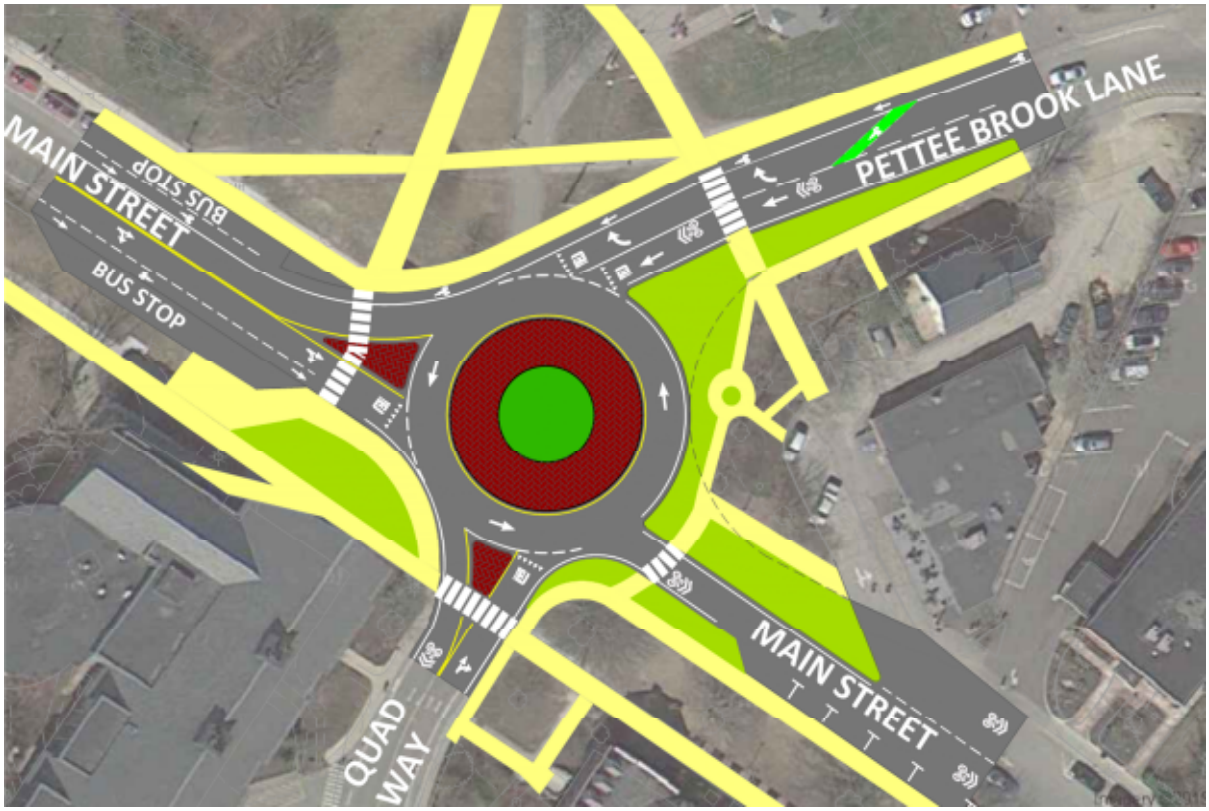


Figure 2: Proposed Roundabout Configuration at the Main Street/Pettee Brook Lane/Quad Way Intersection



Analysis – Scenario Volume Results

To provide an analysis of the impacts of the proposed circulation change on local traffic conditions, we ran the existing and roundabout scenarios described above using the Durham Traffic model. This detailed origin/destination based micro-simulation model has been jointly developed by the Town of Durham and the University of New Hampshire and is well-suited for assessing transportation network changes such as this. The model was initially constructed in 2009 and was calibrated to 2008 AM peak hour conditions. The model has since been recalibrated to 2013 AM peak hour conditions.

Existing traffic volumes in the downtown are presented in Figure 3. After modifying the existing model for a roundabout at the Main Street/Pettee Brook Lane/Quad Way intersection, we reran the model to obtain the projected scenario traffic volumes shown in Figure 4. Figure 5 presents the overall change in traffic volumes from the existing scenario to the roundabout scenario. A more detailed discussion of the observed changes is presented below in the next section.

Figure 3: 2013 AM Peak Hour Existing Traffic Volumes – Unsignalized at Main St / Pettee Brook Lane

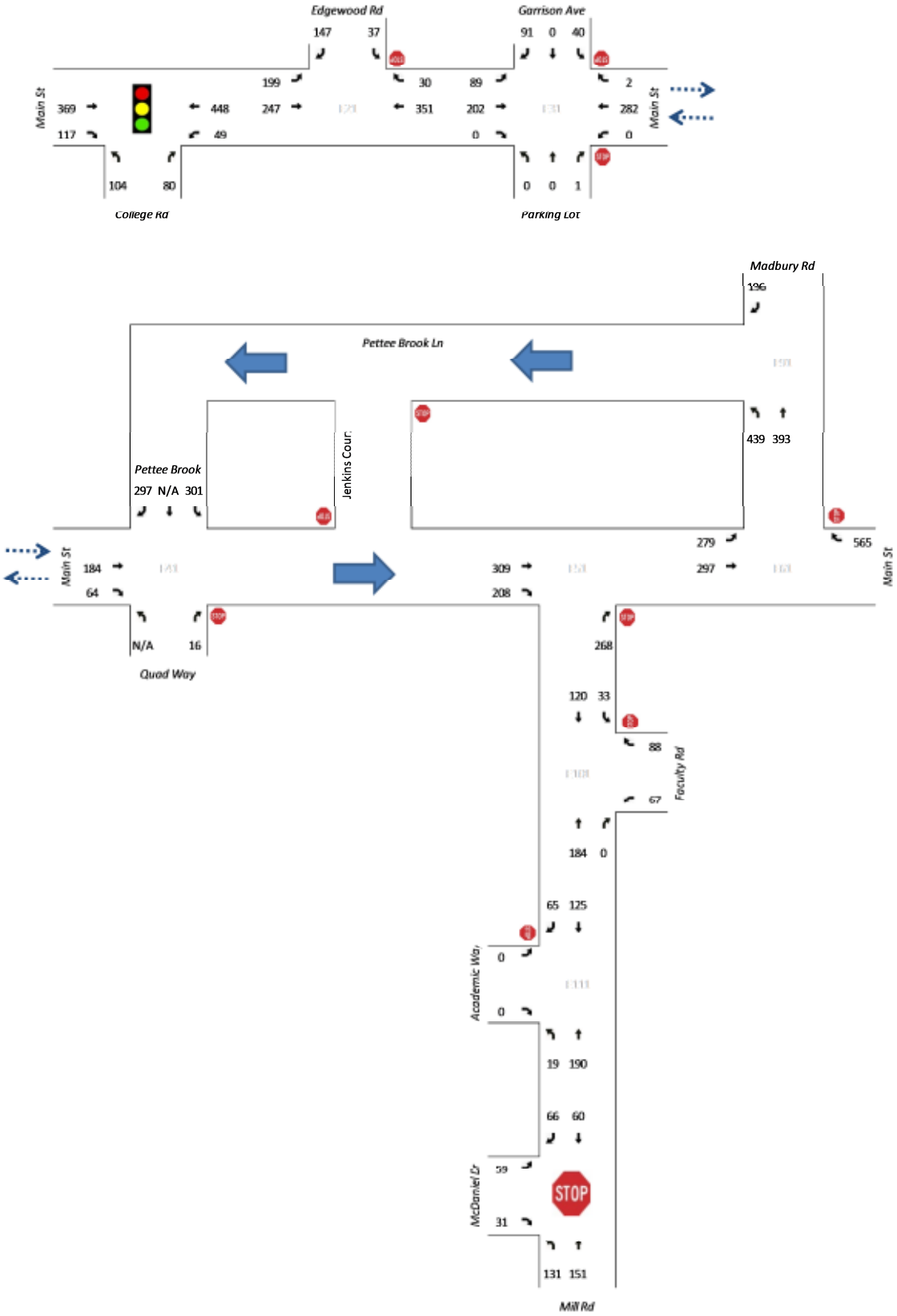


Figure 4: 2013 AM Peak Hour Build Traffic Volumes – Roundabout at Main Street/Pettee Brook Lane/Quad Way

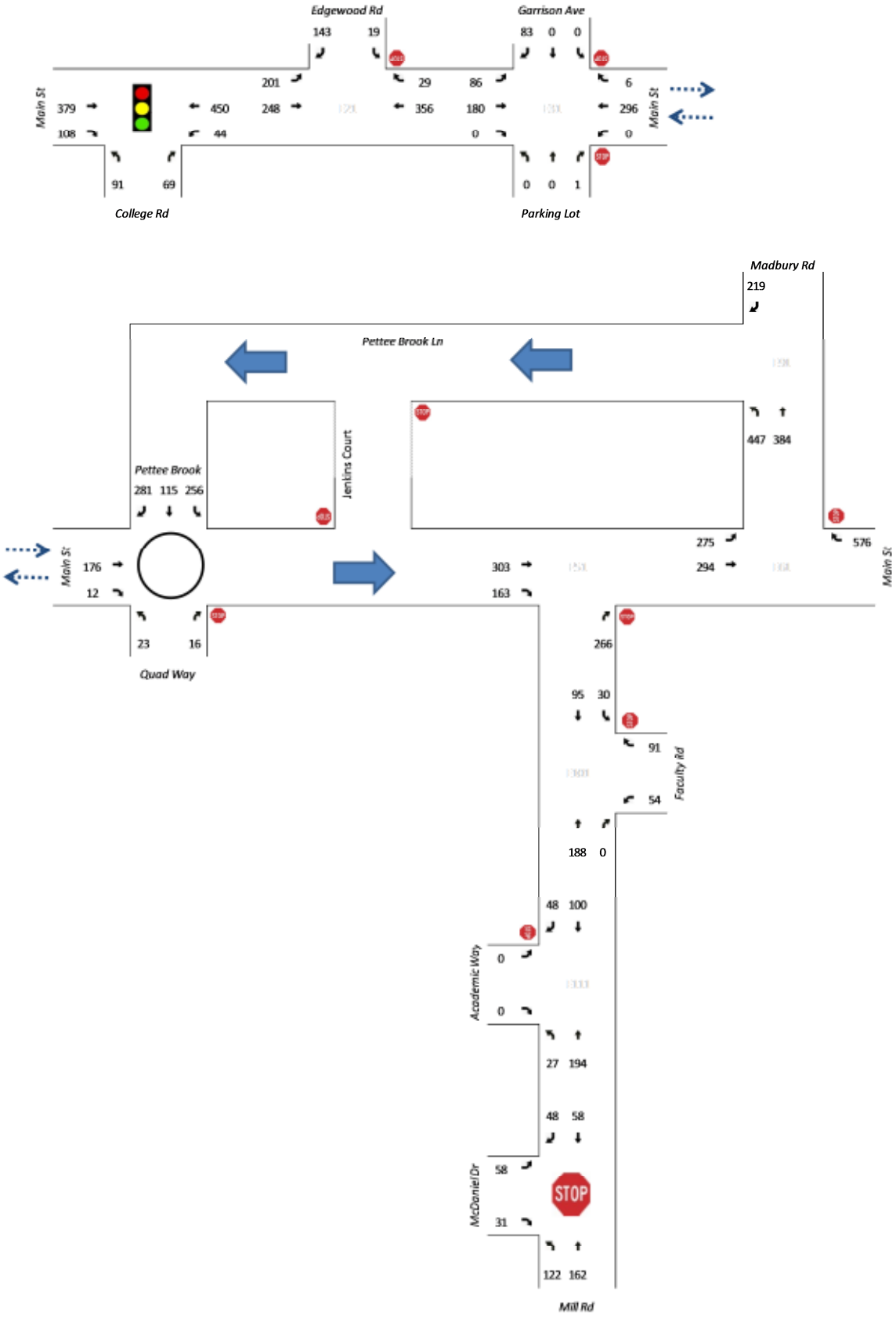
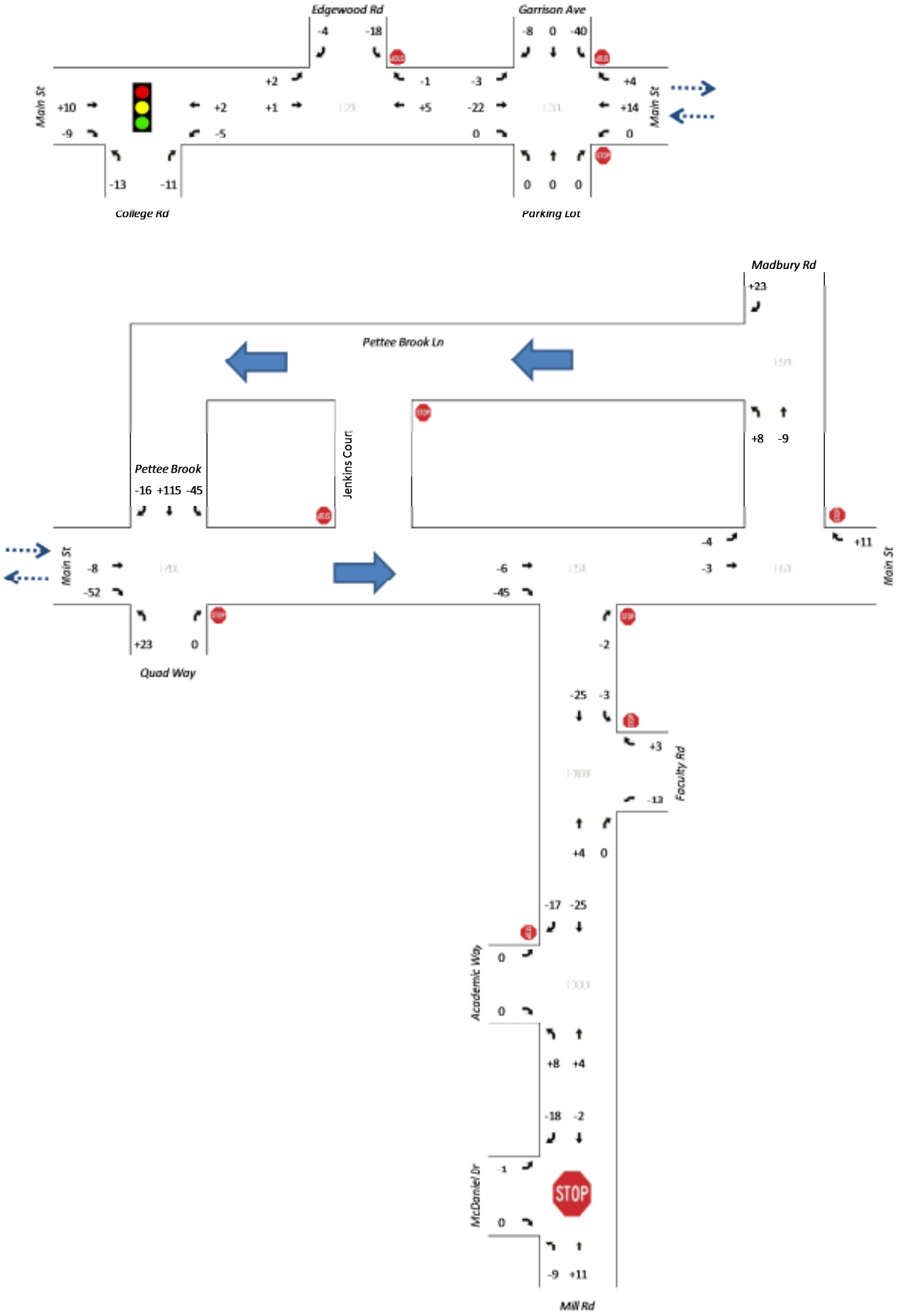


Figure 5: 2013 AM Peak Hour Change in Volumes – Existing to Roundabout at Main Street/Pettee Brook Lane/Quad Way



Alternate Route Analysis

The Durham traffic model contains a complete representation of every street, road, and highway within the Town's boundaries. As in the real world, motorists have multiple route choices for any specific trip. The model represents these route choices for each origin-destination pair and thus enables a measure of how traffic may change on alternative routes proximate to the downtown under the roundabout conversion.

As can be seen below in Figure 6, bi-directional volumes on College Road, Edgewood Road, and Garrison Avenue are reduced following the introduction of a roundabout at the Main Street/Pettee Brook Lane/Quad Way intersection, due to rerouting allowed by the introduction of the southbound through movement from Pettee Brook Lane to Quad Way and the northbound left-turn movement from Quad Way to Main Street. These movements allow more direct access to/from B-lot for vehicles travelling to/from locations north of Main Street. Volumes on Academic Way and McDaniel Drive are also reduced as more traffic shifts to Quad Way. Additionally, volumes on Faculty Road are projected to decrease as this cut-through route becomes less desirable when compared to the more direct route entering B-Lot by way of Quad Way.

At the same time, bi-directional volumes on Pettee Brook Lane, Madbury Road, and Quad Way increase following the introduction of the roundabout.

The reduction of trips along Main Street west of Pettee Brook Lane is mostly due to vehicles adjusting their path to make a southbound through from Pettee Brook Lane to Quad Way instead of the previous paths which included left-turns from Garrison Avenue and Edgewood to Main Street to Quad Way. Similarly, the reduction of trips along Main Street east of Pettee Brook Lane is mostly due to vehicles adjusting their path to make the new southbound through movement from Pettee Brook Lane to Quad Way, where they previously made a southbound left-turn from Pettee Brook Lane to Main Street to Mill Road.

No operational dynamics such as excessive queuing or delays were observed in the traffic simulation due to the installation of a roundabout at this intersection.

Figure 6: AM Peak Hour Link Volumes[1]

AM Peak Hour Link Volumes

	Existing	Roundabout	Change
College Rd	350	312	-11%
Edgewood Rd	413	392	-5%
Garrison Ave	222	175	-21%
Pettee Brook Ln	598	652	+9%
Madbury Rd	844	851	+1%
Mill Road	476	429	-10%
Quad Way	80	166	+108%
Main St (West of Pettee Brook Ln)	545	492	-10%
Main St (East of Pettee Brook Ln)	501	448	-11%
Faculty Rd	188	175	-7%
Academic Way	84	75	-11%
McDaniel Dr	287	259	-10%
Main St (West of College Rd)	1038	1028	-1%

[1] Locations that increase in volume are highlighted in red while locations that decrease in volume hare highlighted in green.

Vehicle Miles Travelled

The introduction of the roundabout at the Main Street/Pettee Brook Lane/Quad Way intersection will allow many vehicles to complete their trips in a shorter distance by allowing them to perform a left turn from Quad Way onto Main Street and a through movement from Pettee Brook Lane onto Quad Way. In the core downtown area (from Edgewood Avenue east to Madbury Avenue and including the UNH campus south to McDaniel Drive) we project construction of a roundabout at the Main Street/Pettee Brook Lane/Quad Way intersection will result in a net decrease of approximately 23 vehicle miles travelled (VMT) during the weekday AM peak hour. Translating this to annual VMT, we project an approximate decrease of over 80,000 vehicle miles travelled per year in the core Durham downtown associated with construction of the new roundabout. Conservatively assuming an average fleet fuel economy of 25 mpg[1], this translates to a savings of over 3,000 gallons of fuel per year. [2]

The proposed roundabout could greatly benefit existing and future transit service by allowing specific routes to be shortened significantly - not requiring transit vehicles to travel around the one-way circulator (Figure 7). No major Campus Connector stops currently exist on this one-way loop, and this change reduces travel distance by over ½ mile for all transit vehicles that previously had to travel around the one-way Pettee Brook Lane circulator. This affects the Campus Connector routes 'West Edge' and 'The Cottages'.[3] While directly benefiting transit vehicle miles travelled, transit emissions, and transit costs, the resulting shorter and faster routes may also in-turn lead to increased transit ridership, which would further decrease passenger vehicle traffic and emissions in town.

For fiscal year 2014, the Cottages – IOL route of the Campus Connector is expected to run 11,099 loops per year and the West Edge route is expected to run 11,573 loops per year. Removing over a half mile loop from each of these two routes would translate to a total reduction of over 12,000 transit vehicle miles travelled over the course of the year. Considering it costs approximately $4.25 per mile to run each of these two routes, we project that constructing a roundabout at the Main Street/Pettee Brook Lane/Quad Way intersection and allowing these routes to be shortened, could save the Campus Connector system over $50,000 per year in operating costs.

Additionally, since the southbound through movement from Pettee Brook Lane is permitted with the construction of the roundabout, additional Wildcat Transit routes could potentially be shortened by travelling along Pettee Brook Lane instead of Madbury Road and Garrison Avenue. Potential transit route alternatives associated with this new southbound through movement are presented in Figure 8 and could affect Wildcat Transit Routes 3B (UNH to Dover via Route 155 / to UNH via Route 108), 4B (UNH to Malls & Portsmouth Market Square) and 5 (UNH to Newmarket).[4] These routes currently have inbound stops on Madbury Road and Garrison Avenue and additional consideration will need to be given to secondary impacts before making these potential route changes. However, adding new movement options at the Main Street/Pettee Brook Lane/Quad-Way intersection, including the new U-Turn, northbound-left, and southbound-through, all create potential for additional route alterations, which could benefit transit service and reduce emissions.

[1] The average fuel economy of 2013 model year vehicles sold in the US is reported to be 24.7 mpg (http://www.autonews.com/article/20130806/RETAIL01/130809911/average-fuel-economy-of-13-models-tops-that-of-12s-study-says#axzz2cW4P9LLa)

[2] Assumes peak hour traffic volumes are approximately 10% of daily totals and expanded to 365 days per year.

[3] The Campus Connector route 'West Edge' operates at 10 minute headways 12 hours a day, 5 days a week while classes are in session. The Campus Connector route 'The Cottages' operates at 10 minutes headways during peak hours and 20 minute headways for 14 hours a day Monday-Thursday, 11 hours a day on Fridays, and 7 hours a day on weekends, while classes are in session.

[4] The Wildcat Transit routes provide regional service and operate on longer headways than the Campus Connector routes. While headways on these routes are often an hour or more, the potential for some air quality improvements still could be achieved with new movements made available at the Main Street/Pettee Brook Lane/Quad Way intersection.

Figure 7: Campus Connector Routes

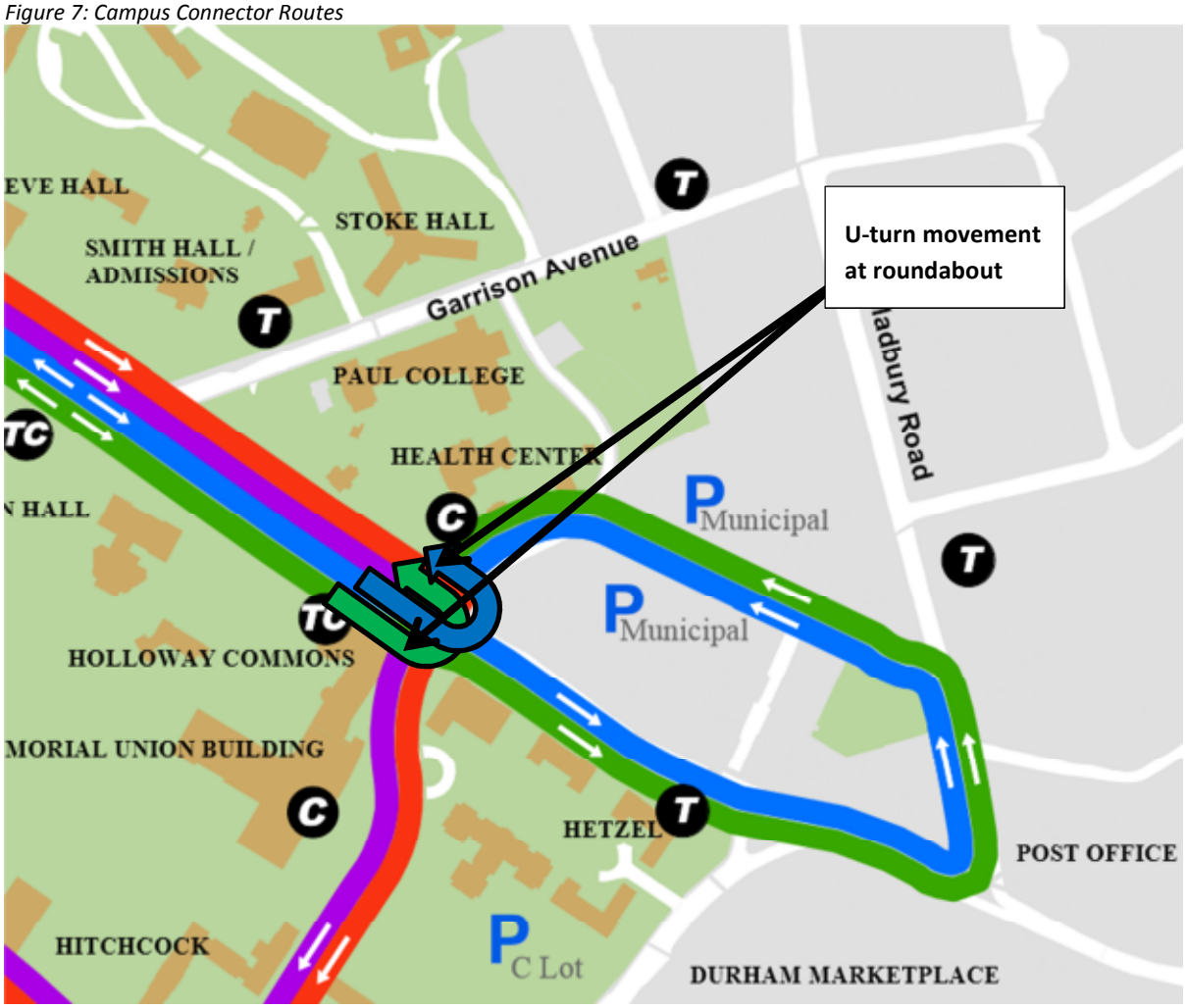
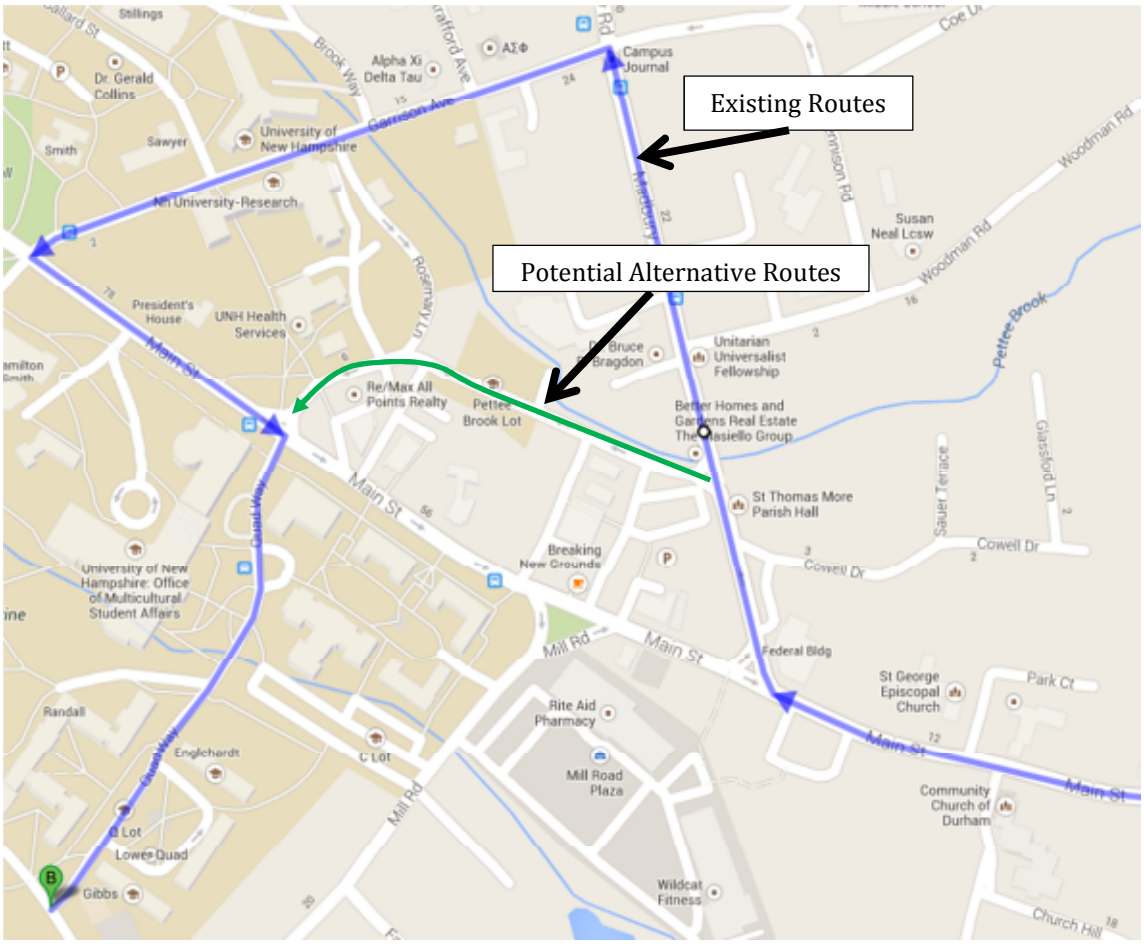


Figure 8: Potential Wildcat Transit Route Improvements



Air Quality Impacts

The relative air quality impacts of the Existing and Roundabout scenarios were examined using carbon monoxide (CO) and nitrogen oxides (NOx) as indicators.

Scenario vehicle emissions were estimated using EPA's emission modeling system, known as the Motor Vehicle Emission Simulator (MOVES). This new emission modeling system estimates emissions for mobile sources covering a broad range of pollutants.[1]

Because of Durham Traffic Model's highly detailed microsimulation modeling we were able to input the highest level of detail available into MOVES, and thus produce the most realistic output possible. The data produced from the Durham Traffic Model and entered into MOVES consists of vehicle location, speed, and acceleration for all vehicles, recorded every 1 second, for the entire midweek morning peak hour.

Within the core downtown area we project construction of a roundabout at the Main Street/Pettee Brook Lane/Quad Way intersection will result in a net decrease of approximately 70 grams of CO and approximately 68 grams of NOx during the AM peak hour. Again translating this to annual reductions, we project the proposed roundabout could reduce annual CO and NOx emissions up to approximately 250 kg per year each.[2]

[1] http://www.epa.gov/otaq/models/moves/index.htm

[2] Assumes peak hour traffic volumes are approximately 10% of daily totals and expanded to 365 days per year.

Highway Capacity Manual Delay Analysis

Using the Sidra Intersection 5.0 software package, we calculated peak hour delays and levels-of-service for the Main Street/Pettee Brook Lane/Quad Way roundabout. Level-of-service (LOS) is a qualitative measure describing the operating conditions as perceived by motorists driving in a traffic stream. LOS is estimated using the procedures outlined in the 2010 Highway Capacity Manual. Figure 9 shows the various LOS grades and descriptions for unsignalized intersections, including roundabouts.

Figure 9: Level-of-Service Criteria for Unsignalized Intersections

LOS	Characteristics	Unsignalized Total Delay (sec)
A	Little or no delay	≤ 10.0
B	Short delays	10.1-15.0
C	Average delays	15.1-25.0
D	Long delays	25.1-35.0
E	Very long delays	35.1-50.0
F	Extreme delays	> 50.0

Using Durham Traffic Model volumes for the weekday AM peak hour and adjusted count volumes for the weekday PM peak hour[1], we calculate that a roundabout here will operate at overall LOS A conditions during the weekday AM peak hour and overall LOS C conditions during the weekday PM peak hour. Typically LOS D or better conditions are considered acceptable while LOS A conditions are ideal.

Figure 10: HCM Delay and Level-of-Service Calculations

	AM Peak Hour				PM Peak Hour			
	LOS	Delay (sec)	v/c	95th % Queue (veh)	LOS	Delay (sec)	v/c	95th % Queue
EB, along Main Street	A	8.6	0.254	1.6	C	19.9	0.808	11.8
NB, exiting Quad Way	B	12.6	0.056	0.3	D	32.4	0.627	6.6
SB, exiting Pettee Brook Lane	A	9	0.27	1.9	B	11.3	0.463	4.3
Overall	A	9.1	0.27	1.9	C	17.2	0.808	11.8

Based on this analysis we project a roundabout will function well at this intersection in the near-term. Moderate eastbound queues exist during the PM peak hour (the 95th percentile queue is 11.8 vehicles in length) with 2013 volumes. If traffic volumes increase significantly in the future, additional capacity may be desired at this location or along alternate routes in the future.

Additionally, as noted above in the discussion of traffic volume changes expected with the roundabout construction, vehicle rerouting is expected to reduce traffic volumes on other downtown streets including College Road, Mill Road, Edgewood Road, and Garrison Avenue; and improvements in intersection operations are expected at the Main Street/College Road, Main Street/Mill Road, Main Street/Edgewood Road, and Main Street/Garrison Avenue intersections as a result of these reduced traffic volumes.

While volume rerouting is modeled explicitly for the AM peak hour, we expect similar, if not greater, benefits at these same intersections during the PM peak hour. In particular significant reductions in vehicle traffic are expected exiting College Road and Mill Road during the PM peak hour as traffic exiting the UNH B Lot parking area will reroute from these roads to join Main Street directly from Quad Way

[1] The PM peak hour traffic count conducted on Tuesday 4/16/2013. Data from this count are scaled to include new movements at the roundabout by pivoting based on AM peak hour count and model volumes.

with a roundabout in place. We anticipate this will directly reduce delays and queues on College Road and Mill Road.

Pedestrian Safety

Due to the large amount of pedestrian traffic around Durham, it essential to consider pedestrian safety when proposing any roadway improvements that alters vehicle flow and allowed movements.

The proposed roundabout is expected to improve pedestrian safety at the Main Street/Pettee Brook Lane/Quad Way intersection and on surroundings roadways. Currently only vehicles approaching this intersection from Quad Way have to yield to conflicting traffic. Vehicles travelling down Pettee Brook Lane and turning onto Main Street currently have no conflicting movements and thus are not required to slow down while travelling through the intersection. While vehicles are required to yield to pedestrians in crosswalks, the lack of an obligatory vehicular stop or yield increases the potential for conflicts with pedestrians crossing Pettee Brook Lane. With a roundabout in place all entering vehicles will have to contend with a conflicting vehicle flow and thus will need to slow down and yield to both vehicles and pedestrians. Additionally, a roundabout at this location will cause all traffic to slow somewhat to navigate the intersection, calming traffic entering the commercial section of Main Street to the east.

Additionally, as seen previously in Figure 6, bi-directional volumes on Edgewood Road, Garrison Avenue, and College Road are reduced with the installation of this roundabout. These three roads all have large amounts of pedestrian traffic due to their proximity to many of the campus halls. Reducing volumes on these roadways will help them become more pedestrian and bicycle friendly.

Please feel free to contact us with any questions.