

TRAFFIC MODELING IN SUPPORT OF DARTMOUTH COLLEGE MASTER PLANNING

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1.0 INTRODUCTION

This report evaluates the traffic impacts associated with alternative parking scenarios that Dartmouth College is considering as part of its campus Master Planning efforts. The location and amount of parking are significant parameters in the fulfillment of the Master Plan. Parking – whether surface or structured -- is expensive to build, consumes valuable real estate, and directly impacts the levels of congestion experienced on the roadway network proximate to the college campus.

The tool used to evaluate the traffic impacts is a traffic simulation tool called CORSIM. CORSIM is a modeling platform based on a high amount of engineering detail, and calibrated to actual traffic counts and conditions. CORSIM simulates vehicle movement between pre-specified origins and destinations, and generates a significant number of performance measures. These performance measures enable us to compare different scenarios related to the provision of parking on campus.

This report has 3 parts, as follows:

- ◆ Description of Modeling Approach
- ◆ The Parking Alternatives Considered in the Analysis
- ◆ Analysis of Results

2.0 DESCRIPTION OF MODELING APPROACH

The modeling system employed for this project involves two stages. First, zone-to-zone¹ traffic flows are obtained from a regional transportation network model of the Upper Valley. Second, these traffic flows are reduced to a trip table², which becomes an input to the microsimulation model. The trip table represents traffic flow within the Town of Hanover. These steps are described in greater detail below.

2.1 UPPER VALLEY REGIONAL TRAFFIC MODEL

The regional traffic model of the Upper Valley generates peak hour³ estimates of traffic flow into and out of Hanover. This model is implemented with the Tmodel software, and involves the following steps:

¹ “Zone” in the modeling context refers to an area with associated land uses. A well-defined residential area can be modeled as one zone, as can a commercial section of a town. The Upper Valley regional model contains 100 internal zones, 25 of which are in the Town of Hanover.

² A trip table is an $n \times n$ matrix of zone-to-zone traffic flows.

³ Peak hour refers to the hour in a day with the highest amount of vehicular traffic. A peak hour is often defined for the morning (AM peak hour) and evening (PM peak hour). In some cases, the PM peak hour carries more traffic than the AM peak hour. For most of the intersections proximate to Dartmouth College, the AM peak hour carries more traffic than the PM peak hour.



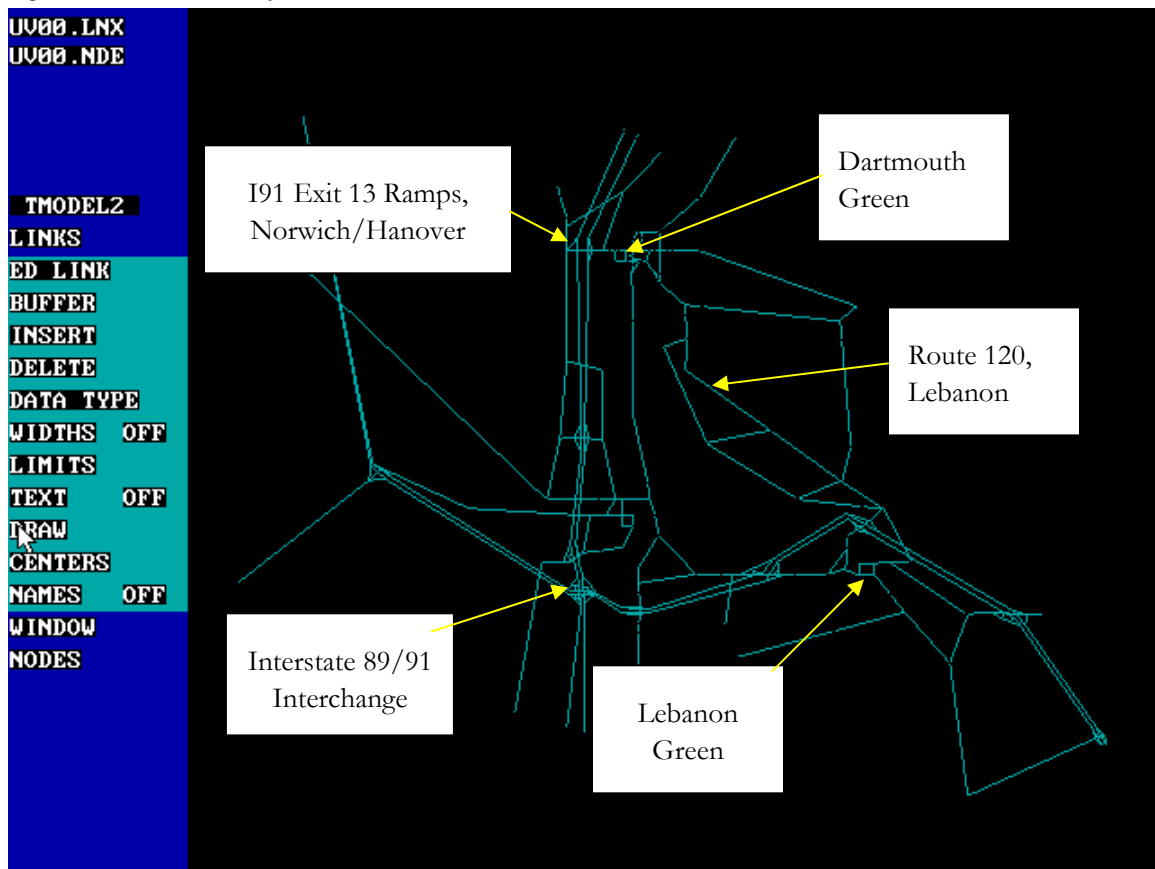
1. An estimate of the geographic distribution of households and jobs throughout the Upper Valley¹.
2. These geo-located households and jobs generate, in turn, vehicle trip origins and destinations.
3. Vehicle trips are assigned to a roadway network that represents all of the major and minor arterials in the region.
4. The model generates peak hour vehicle flows into and out from Hanover at the key points of access into the Town – Ledyard Bridge, Route 10 south toward Lebanon, Route 10 north toward Lyme, and Route 120 toward Lebanon. These vehicle flows – referred to as traffic screenlines -- are the main input into a traffic microsimulation model.

Figure 1 shows the regional Tmodel network, with labels indicating some major arterials of the region and other geographic milestones. The regional model has been calibrated for AM and PM peak hour traffic conditions. The model provides zone-to-zone traffic flow for these peak hours. To prepare this information for the next modeling stage, the 100-zone regional model must be reduced to represent the Hanover zones only.

¹ The core towns in the Upper Valley model are Hanover, Lebanon, Hartford, and Norwich. Towns on the periphery of the model, but which contribute traffic to regional arterials are: Lyme, Thetford, Grantham, Hartland, Plainfield, Enfield, Sharon, and Woodstock.



Figure 1: Tmodel Roadway Network



2.2 HANOVER TRAFFIC MICROSIMULATION MODEL

A detailed micro-simulation model is used to distribute the regional traffic flows into, out of, and within Hanover to most of the arterial, collector, and local roads/streets of Hanover. This portion of the modeling process is performed using the CORSIM simulation software, developed by the Oak Ridge National Laboratory for the Federal Highway Administration (FHWA).

The CORSIM model produces vehicles at each of the entry points into Hanover, as well as at several zones interior to Hanover. Interior zones represent clusters of land uses such as residential neighborhoods, commercial streets, or major parking facilities. For the purposes of this analysis, Dartmouth's parking facilities are major points of origin and destination for vehicles on the network. The major focus of this analysis is to understand the traffic implications of different parking supply scenarios as the College's parking inventory is augmented and shifted from place to place. The microsimulation model traces out the traffic implications of each parking regimen.

The CORSIM model contains a high degree of engineering detail related to the traffic network. Elements such as road grade, geometry, lane groupings, and intersection control are modeled in detail. Parking maneuvers and pedestrian activity can be introduced into the model as well to provide

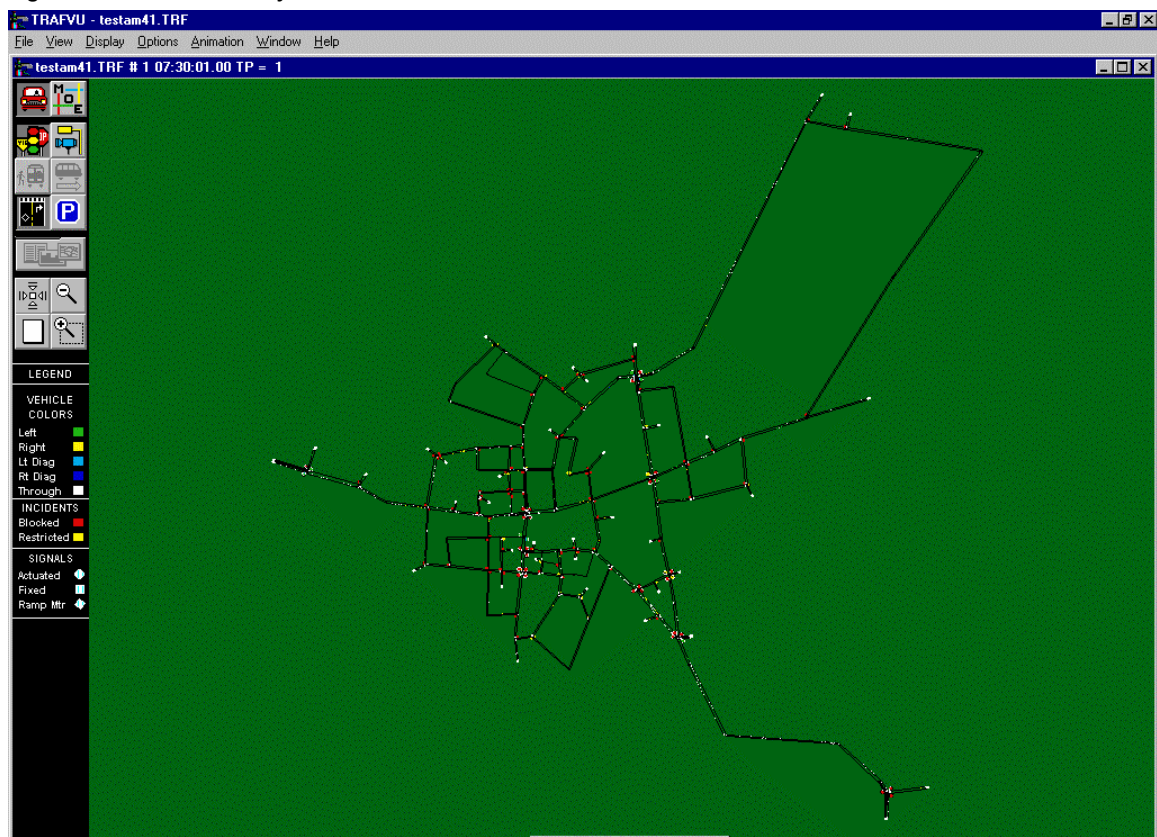


a high degree of similarity to actual operating conditions. Detailed signal plans, including vehicle detection and actuation, can also be modeled.

CORSIM contains a vehicle assignment algorithm¹ that designates a route for each origin-destination pair. With each parking scenario, different delays are experienced at different points in the network. The vehicle assignment algorithm accounts for these delays, and attempts to reduce them for the network as a whole. In this way, different traffic patterns will emerge, as driven by the locations of major parking facilities.

Figure 2 shows the CORSIM roadway network.

Figure 2: CORSIM Roadway Network



¹ Vehicle assignment refers to assigning a route to each vehicle between the vehicle's origin and destination. Vehicle assignment algorithms usually utilize some type of shortest path logic, which attempts to move vehicles between the origin and destination with as little delay as possible.



2.2.1 Model Calibration

The CORSIM model is calibrated to October 2000 conditions. This means that the model's output at key intersections in Hanover is compared with actual traffic data representing October, 2000 peak hour travel. Resource Systems Group collected AM and PM turning movement counts and observed signal operations at several intersections proximate to the campus.

In total, turning movements at 14 intersections and three roadway segments are compared with model output. The calibrated model output is provided, along with the turning movement data against which it was calibrated, in Appendix A.

The peak hour turning movement counts were adjusted to reflect the corresponding October 2000 weekday peak hour using continuous traffic data obtained from the New Hampshire Department of Transportation from a permanent counter on Route 120 in Lebanon. In total, the traffic count data were adjusted in two ways:

1. Annual Adjustment: Traffic counts obtained in 1998 and 1999 were adjusted upward 1% per year to scale to year 2000 conditions.
2. Monthly Adjustment: Traffic counts were adjusted to reflect October conditions using the ratio of average October peak counts to average peak counts for the month in which the traffic count was conducted.

To ensure calibration of on-campus traffic, specific link volumes were also checked against count data. Model-generated traffic using Tuck Drive, Maynard, and the interior street connecting Maynard with the Dewey Field parking lot have also been calibrated against field counts.

FHWA publishes standards for determining whether a travel demand model is calibrated. The Hanover CORSIM model is not technically a travel demand model. However, the entry and exit traffic volumes, which drive traffic flow into and out from the CORSIM model, are obtained from a travel demand model. Further, the calibration procedures of travel demand models are sound, and are considered relevant for this modeling approach. Two standards are used for evaluating the effectiveness of this model: root mean squared error and coefficient of correlation.

Root Mean Squared Error

The root mean squared error (RMSE) is an average link error that weights the larger volume errors in a network. It should be noted that the RMSE is always higher than the actual average network error because of the weighting scheme. RMSE should generally be less than 40%.

The following RMSE formulation is:

$$\text{RMSE} = \frac{\sqrt{\frac{\sum [(x - y)^2]}{n}}}{\frac{\sum x}{n}}$$



Where:

x = Ground count

y = Calibration volume

n = Number of observations

The RMSE of the Hanover CORSIM model is 30%.

Coefficient of Correlation

The coefficient of correlation, “r”, is commonly used to measure the strength and direction between two sets of variables. An r-value of 1.0 would indicate a perfect one to one correlation between the two variables. The r-value is estimated using the following formula.

$$r = \frac{\sum(x \cdot y) - n \cdot \bar{x} \cdot \bar{y}}{\sqrt{(\sum(x^2) - n \cdot \bar{x}^2)(\sum(y^2) - n \cdot \bar{y}^2)}}$$

FHWA recommends a minimum r-value of 0.88. The r-value of the Hanover CORSIM model is 0.95.

2.3 AM PEAK HOUR ANALYSIS

The analysis that follows has focused on the AM peak hour. The reason for this is that the AM peak hour (usually 7:30 – 8:30 AM) represents the heaviest traffic flow of any hour throughout the day within the area of greatest concern to Dartmouth College. During this time period the peak travel flow of three major generators converges – Dartmouth College, Dartmouth-Hitchcock Medical Center, and the Dresden/Hanover schools.

Figures 3 – 6 provide traffic count data for four locations in Hanover. All counts were conducted in the fall of 2000. The data show the average hourly traffic volumes traveling in both directions at the counter site. In all cases, data from at least 3 weekdays have been averaged in these figures.

The data show the “peakiness” of the AM peak hour versus the PM peak hour. There are 2 key reasons for these data trends. First, school drop-offs are concentrated during the AM peak hour. School-related traffic is minimal during the PM peak hour.¹ Second, arrivals and departures from workplaces also tend to mimic this trend. That is, arrivals tend to be more concentrated during the AM peak hour. Departures from work tend to occur over a 2-3 hour period.

The one exception to this is DHMC, which has a large staffing component that reports to work during specified shifts. Similar count data for Route 120, which is heavily influenced by DHMC,

¹ The PM peak hour in the Hanover area tends to be 4:30 – 5:30 PM.



show that traffic during the PM peak hour is approximately 8% heavier than during the AM peak hour.

For these reasons, the primary focus of the modeling effort has been in understanding the traffic impacts during the AM peak hour. The analysis that follows is based entirely on traffic dynamics during the AM peak hour.

Figure 3: Average Weekday Traffic Flow, Ledyard Bridge

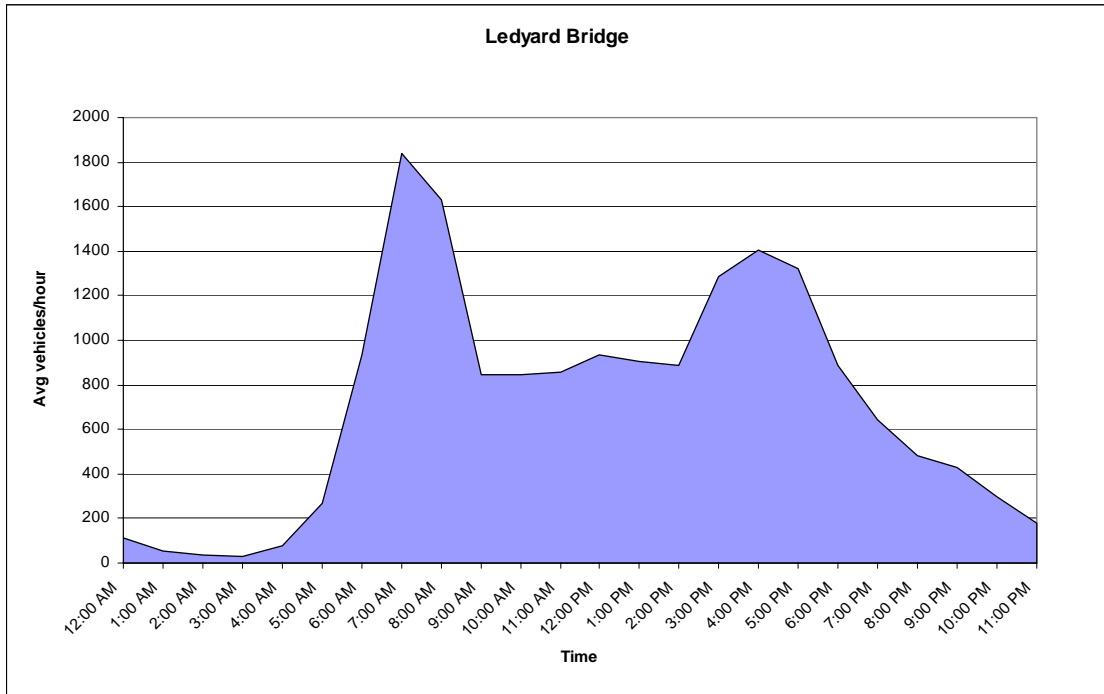


Figure 4: Average Weekday Traffic Flow, Trescott Road

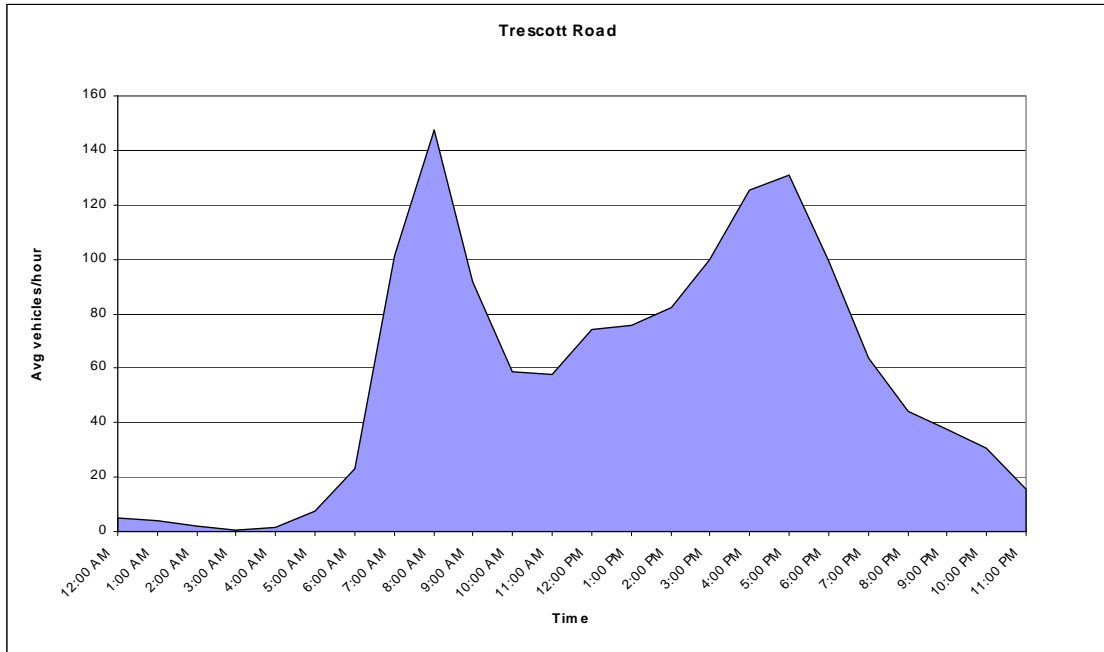


Figure 5: Average Weekday Traffic Flow, Tuck Drive

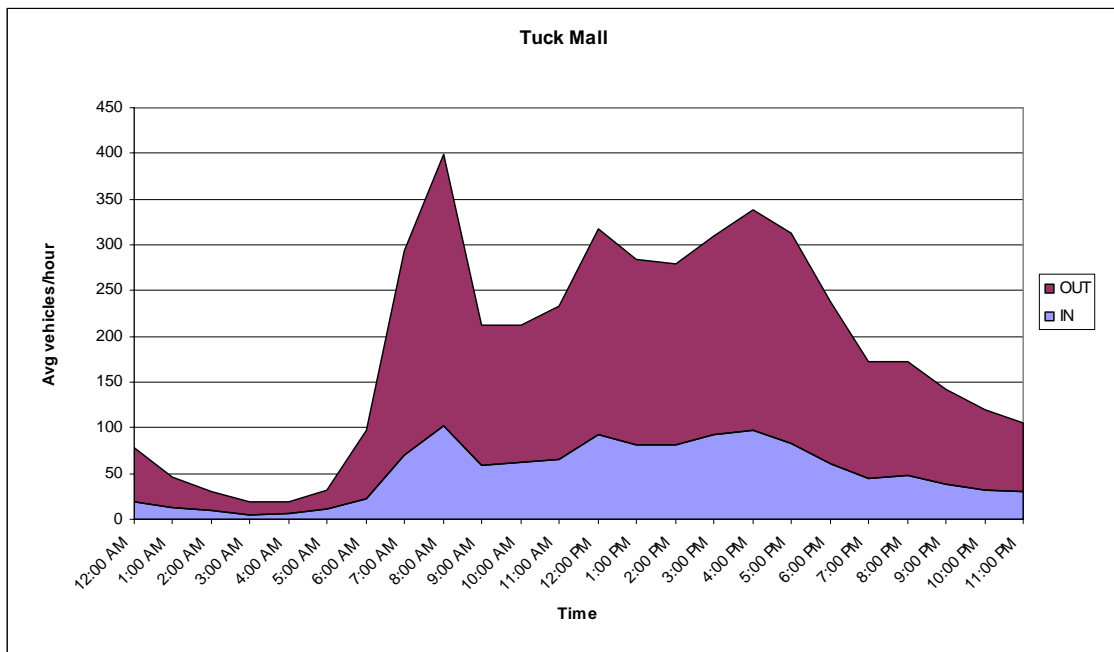


Figure 6: Average Weekday Traffic Flow, Route 10 at Reservoir Road

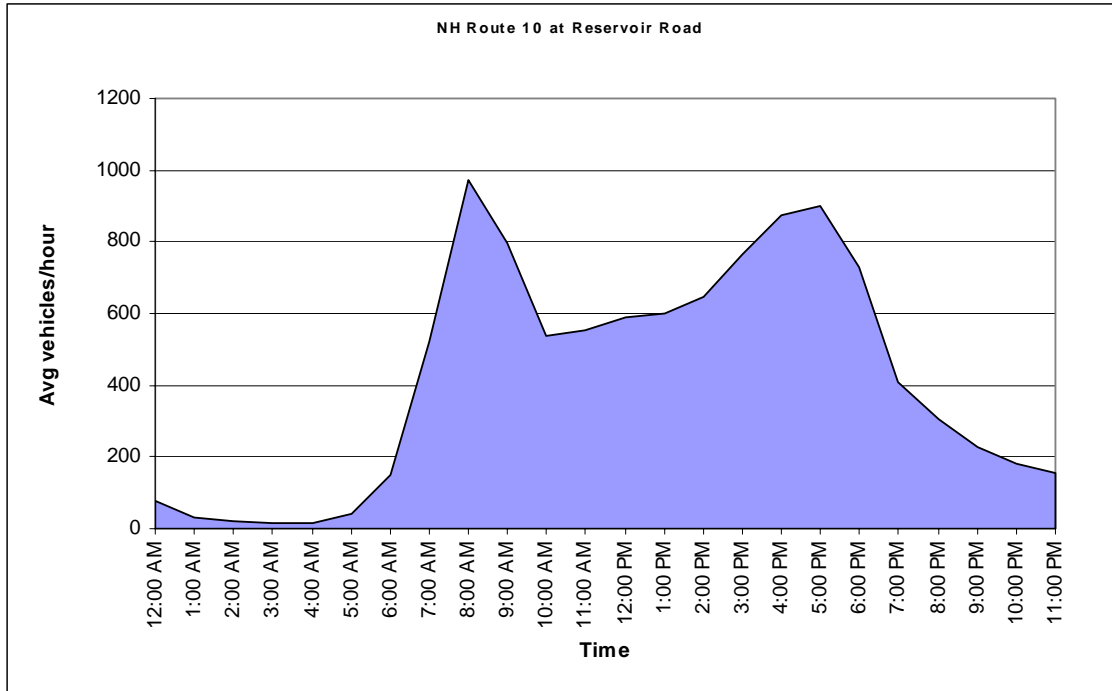


Table 1 shows overall AM peak hour traffic volumes at key intersections in Hanover, comparing the actual count data against the model-generated volumes.

Table 1: Total AM Peak Hour Traffic Volumes at Hanover Intersections, Count and Model-Generated

Intersection	2000 Count	2000 Model	Difference (Count - Model)
Main/South	775	795	-20
College/South	209	252	-43
Main/Wheelock	1693	1574	119
Park/Lebanon	1934	2070	-136
Med. School/Lyme/Park	1332	1371	-39
Park/Wheelock	1483	1488	-5
120/Greensboro	1935	2175	-240
Park/ Summer/Thompson Lot	1329	1400	-71
N.College/Wentworth	674	653	21
N. Main/ Tuck Mall	475	397	78
West/Wheelock	1695	1992	-297
Lebanon/Crosby	1054	1212	-158



3.0 PARKING ALTERNATIVES CONSIDERED IN THE ANALYSIS

The calibrated CORSIM model is used to evaluate future traffic and parking scenarios. The first step in the analysis is to define a future year (2005) scenario that represents a “No Build”. A “No Build” scenario is used to provide a basis for evaluating changes in traffic caused by a projected improvement or expansion (i.e. a Build scenario). For the purposes of this analysis, the “Build” scenarios refer to expansions related to the implementation of Dartmouth’s Master Plan.

Thus, a “No Build” scenario projected for the year 2005 does not include any specific elements of Dartmouth’s Master Plan. Instead, a 2005 No Build scenario represents general background growth in housing and jobs within the Upper Valley. This growth reflects historical growth rates¹. The 2005 No Build traffic scenario does not assume any changes to the supply or distribution of parking serving Dartmouth’s faculty, staff, or students. The No Build scenario also does not assume any changes to the local roadway network.

The Build scenarios represent implementation of some portion of the college’s Master Plan. The Master Plan is continually being updated to respond to the changing needs of the college’s students and the community. The current Master Plan foresees an annual growth of faculty and staff of 1.5-2.0%, but no increase in the number of students. The projected increases in staff are the drivers of parking demand, and of the related traffic impacts. Thus, the Build scenarios can be described by the supply and location of parking that is designed to meet the demand of varying levels of College employment. The employment levels, in turn, represent varying levels of Master Plan implementation.

Table 2 shows the parking inventories associated with the 2005 No Build scenario, along with the inventories assumed for 4 distinct 2005 Build scenarios². The parking configuration of the No Build scenario reflects existing parking inventory and location.

Table 2: Parking Inventories and Locations Associated with the No Build and Build Model Scenarios

Scenario	Core						H.H.S. Site	Dartmouth Total	Net Increase in Parking
	Campus	Maynard	Cummings	DMS/Dewey	Thompson	Ledyard			
2005 No Build	254	416	276	1007	342	225	-	2520	-
2005 Build Scenarios									
Scenario 1	254	208	645	1007	342	225	983	3664	1144
Scenario 2	254	208	276	2005	342	225	-	3310	790
Scenario 3	254	208	920	1007	342	225	-	2956	436
Scenario 4	254	208	276	1007	342	663	-	2750	230

As shown, each Build scenario reflects a varying level of Master Plan implementation, as reflected by the total parking inventory allocated to Dartmouth faculty and staff. All Build scenarios assume a

¹ Based on projections developed by the Upper Valley Lake Sunapee Regional Planning Commission, growth in Upper Valley household numbers is projected to increase 2.0% annually between 2000 and 2005.

² The parking inventories shown in Table 1 reflect parking allocated to faculty and staff.



reduction of half of the spaces currently situated in the Maynard lots. The expansion of a northern quadrangle north of the Berry-Baker complex would occur on the Maynard parking lots. A brief description of each Build scenario follows:

3.1 PARKING SCENARIO 1

This scenario represents the largest increase in parking tested by the traffic model. A net increase of 1,144 parking spaces is provided through expansions in two areas:

- 1) Hanover High School Acquisition: This scenario assumes that the College acquires the Hanover High School property and uses a portion of it for peripheral campus parking amounting to 983 spaces.
- 2) Cummings Lot expansion: an additional 369 parking spaces are constructed proximate to the Cummings Lot.

The parking supply in this scenario exceeds that needed to accommodate additional increases in faculty and staff. The parking inventory is more reflective of potential parking capacity at the Hanover High School and Cummings site, than it is of any projected needs.

3.2 PARKING SCENARIO 2

This scenario results in 790 new parking spaces provided on campus, on land associated with the Dartmouth Medical School and Dewey Field. This net increase in parking is also reflective of the potential parking capacity at this site, as opposed to a parking need driven by projected staff increases.

3.3 PARKING SCENARIO 3

This scenario results in a net addition of 436 spaces, all provided through an expansion at the Cummings lot. This new parking inventory would necessitate the construction of a parking garage on or proximate to the current Cummings parking lot.

Currently, Dartmouth College provides 0.80 parking spaces per FTE employee. Using this ratio, a net increase of 436 parking spaces could accommodate approximately 350 new FTE employees. This employment increment represents an 11% increase in College FTEs. As such, this scenario closely reflects the employment projections of the Master Plan.

3.4 PARKING SCENARIO 4

This scenario results in a net addition of 230 spaces, made possible through the construction of a parking structure on the Ledyard lot. This would expand the Ledyard inventory from 225 spaces to 663 spaces. To make this scenario practical, a shuttle bus system would need to be expanded to run between the Ledyard lot and the core campus.



3.5 OTHER SCENARIOS ANALYZED DURING MODEL DEVELOPMENT

During model development, several other parking supply scenarios were modeled, but are not analyzed in detail in this report. A brief description follows:

Route 120 Park and Shuttle: This scenario involved the development of a park and shuttle facility located along Route 120 in Lebanon. Such a facility would intercept incoming traffic before the intersection with Greensboro Road.

Staggering Shift Times: “Flex Time” is a Transportation Demand Management (TDM) technique designed to move some amount of commuting travel outside of the normal peak periods. The purpose of this scenario is to trace the traffic impacts of staggering the reporting times of Dartmouth employees.

Removal of Core Campus Parking: This scenario modeled the removal of parking from the core campus (254 spaces). This parking shortfall was made up in a variety of ways at different existing lots.

Scenarios Associated with Roadway Changes/Improvements: A variety of scenarios related to the 4 reported on in detail below were modeled with roadway changes or improvements. For example, Scenario 2 – the large parking expansion at DMS/Dewey – was modeled both with and without an access drive onto Route 10. The results described below do not include this access drive. Similarly, access through the Maynard lots to DMS/Dewey is currently permitted. However, it is a policy decision of the College to permit this traffic flow in the future or to cut it off. All scenarios reported on in detail in this report assume continuation of a roadway connection from Maynard to the DMS/Dewey parking lots.

3.6 MODELING CONSIDERATIONS ASSOCIATED WITH EACH PARKING SCENARIO

Each parking scenario results in “attracting” a net new number of vehicle trips into Hanover during the AM peak hour. The modeling system, beginning with the Upper Valley Regional Model, explicitly models the supply and location of parking for each scenario. Additional parking in a particular zone “attracts” vehicle trips, acting, in effect, as a proxy for new employment.

Ultimately, however, total regional traffic is related directly to the population and household growth projections. These projections are the foundation of all future scenarios. Regional projections supplied by the Upper Valley Lake Sunapee Regional Planning Commission estimate a 1.5 – 2.0% annual growth in the region’s households. All new households make vehicle trips, which increases the total regional travel, as estimated by the model. By increasing the supply of parking, Dartmouth attracts a greater or lesser share of these new vehicle trips. By changing the location of parking, these new vehicle trips are attracted to different commuting routes.

Table 3 shows the traffic volumes entering and exiting Hanover for each modeling scenario. These volumes are taken from Hanover’s four traffic screenlines – Ledyard Bridge, Route 120, Route 10 South (Lebanon), and Route 10 North (toward Lyme).



Table 3: Traffic Volumes Entering and Exiting Hanover, by Scenario

Scenario	Total AM Peak Hour Vehicle Trips	
	Entering Hanover	Exiting Hanover
Base Case	3712	1612
1	4212	1612
2	4028	1688
3	4008	1640
4	3892	1756



4.0 ANALYSIS OF RESULTS

The modeling system described in Section 2 is used to estimate the traffic impacts of each parking scenario. Zonal parking inventories are changed from scenario to scenario, and run through the modeling system to the microsimulation model.

There are several outputs of the microsimulation model. This analysis focuses on the following performance measures:

- ◆ Traffic volumes, congestion and delay – for intersections overall and for specific arterials
- ◆ Cut-through traffic in residential neighborhoods
- ◆ System-wide performance measures

4.1 AM PEAK HOUR TRAFFIC VOLUMES AND CONGESTION

Table 4 compares the AM peak hour traffic volumes at several key intersections in Hanover, by traffic scenario.

Table 4: AM Peak Hour Traffic Volumes for Traffic Scenarios

Intersection	2005 No Build	Scenario 1	Scenario 2	Scenario 3	Scenario 4	2000 Count	2000 Model
Main/South	850	1189	1023	922	860	775	795
Main/Wheelock	1631	1844	1827	1703	1742	1693	1574
West/Wheelock	1942	2322	2129	2287	2194	1695	1992
Med. School/Lyme/Park	1501	1692	1902	1597	1557	1332	1371
Park/Wheelock	1493	1739	1720	1588	1510	1483	1488
Park/ Summer/Thompson Lot	1454	1666	1547	1552	1485	1329	1400
Lebanon/Crosby	1297	1859	1396	1453	1360	1054	1212

Traffic engineers evaluate congestion with a measure called Level of Service (LOS). LOS is a qualitative measure describing the operating conditions as perceived by motorists driving in a traffic stream. The 2000 Highway Capacity Manual defines six qualitative grades to describe the Level-of-Service at an intersection (Table 5). Level-of-Service is based on the average control delay per vehicle.

Table 5: Level-of-Service Criteria for Signalized Intersections

LOS	CHARACTERISTICS	SIGNALIZED DELAY (sec)
A	Little or no delay	≤ 10.0
B	Short delays	10.1-20.0
C	Average delays	20.1-35.0
D	Long delays	35.1-55.0
E	Very long delays	55.1-80.0
F	Extreme delays	80.0 <



Three intersections are considered pivotal in metering overall traffic flow into and out of Hanover during peak periods – Main Street/Wheelock Street, Park Street/Lyme Road, and Park Street/Lebanon Street. For these intersections, overall Level of Service has been evaluated. These results are shown in Table 5.

Table 6: Overall Level of Service at Key Intersections, by Scenario

Scenario #	Main & Wheelock (Inn Corner)	Park & Lebanon (Co-op)	Park & Lyme Rd. (Med. School)
Base Case	C - 30 sec	C - 23 sec	B - 16 sec
1	D - 36 sec	C - 24 sec	B - 18 sec
2	D - 39 sec	C - 24 sec	E - 66 sec
3	C - 31 sec	C - 25 sec	B - 16 sec
4	C - 32 sec	C - 23 sec	B - 16 sec

The LOS results are based upon optimized signal timing and phasing subject to existing cycle lengths¹. Optimizing signal operation is a reasonable assumption because traffic demands from scenario to scenario can change significantly. Changing the allocation of green time from scenario to scenario enables the traffic signal to adapt to the varying traffic demands. Also, changing timing plans is a relatively inexpensive change to implement.

Discussion: Main & Wheelock and West Wheelock Street

For the Main & Wheelock intersection, overall LOS changes noticeably from scenario to scenario. Scenarios 2 and 3, which locate significant new parking inventory at Hanover High School and DMS/Dewey, respectively, bring significantly more traffic through this intersection than any of the other scenarios tested. Overall operations are compromised as a result, even after signal timings are optimized.

Scenarios 3 and 4 show only minor degradation at this intersection over the No Build case. Scenarios 3 and 4 both result in increased volume through the intersection. However, the largest increase in volume is estimated to be the northbound left turn (from Main Street onto West Wheelock westbound). This particular movement is given protected green time in the signal phasing, and is not capacity constrained. Thus, increasing traffic at this approach does not present a drag on intersection operations.

Scenarios 3 and 4 are based on increasing parking inventory on the west portion of campus at Cummings and Ledyard, respectively. Model runs show that an expansion at Cummings (Scenario 3) will result in heavier use of Tuck Drive to gain access to the Cummings lot. Approximately 110 – 140 new vehicle trips are estimated to use Tuck Drive to access the Cummings Lot from points north and east during the AM peak hour under Scenario 3. Because Tuck Drive provides an alternative route to the Cummings Lot, traffic at the Main/Wheelock intersection does not increase significantly in Scenario 3.

Scenario 4 – the more minor expansion of parking at Ledyard – does not show significant increases in the use of Tuck Drive to gain access to the Ledyard lot via Tuck Drive and West Wheelock. Model runs indicate that the increased flow of vehicles from points north and east will use the Main/West Wheelock

¹ Cycle length refers to the time it takes for a traffic signal to cycle through each green phase of the signal sequence, back to the beginning of the cycle.

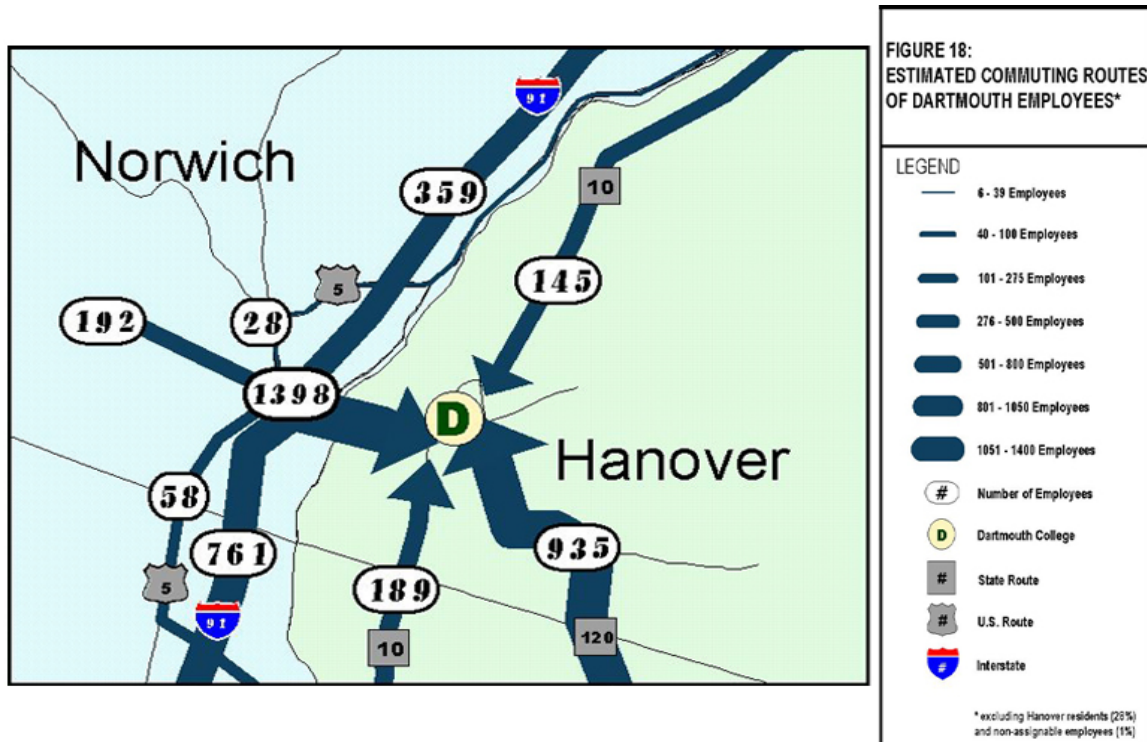


(Hanover Inn) intersection to gain access to the Ledyard lot. As indicated earlier, sufficient capacity is projected for this intersection such that the additional AM peak hour traffic continues to operate acceptably.

The congestion experienced at the Main & Wheelock intersection provides only a partial picture of congestion issues along Wheelock during the AM commuting period. The most commonly cited congestion problem in the morning is the extended moving queues traveling eastbound into Hanover on West Wheelock Street.

Figure 3 shows the estimated commuting routes of Dartmouth employees, and shows that over 50% of Dartmouth's employees cross Ledyard Bridge on the commute to Hanover. The majority of these – 80% -- use Interstate 91.

Figure 7: Commuting Patterns of Dartmouth Employees (Estimated Employees by Access Route)



Functionally, West Wheelock could be classified as a two-way urban arterial. During commuting periods, West Wheelock is primarily providing for through traffic, as opposed to providing access to adjacent uses. The one important exception to this is the access to Thayer Drive, where 15-20% of the incoming (eastbound) flow during the AM peak hour turns left.

Free flow speeds on West Wheelock are estimated to be 35 mph, and posted speeds are 30 mph. Arterial level of service is based upon the ratio of actual operating speeds versus free flow speeds.



Under existing conditions, West Wheelock in Hanover operates at LOS C conditions¹. Travel speeds vary over the segment between Ledyard Bridge and the Main/Wheelock intersection, but average 20 mph under projected 2005 traffic conditions. Table 7 shows the estimated average travel speeds along West Wheelock for each traffic scenario.

Table 7: Estimated Average Travel Speeds (mph) and Arterial LOS on West Wheelock Inbound, AM Peak Period²

Scenario	MPH	Arterial LOS
Base Case	19	C
1	15	D
2	16	D
3	11	E
4	19	C

All scenarios show degradation of traffic flow along West Wheelock, with the exception of Scenario 4, the minor parking expansion at the Ledyard Lot. West Wheelock includes an eastbound left turn lane at the driveway to Ledyard, and this provides sufficient capacity to maintain operating conditions similar to the No Build scenario.

Scenario 3, the major expansion of parking capacity at Cummings, shows the worst decline in arterial LOS. The main reason for this is the lack of a left turn bay on West Wheelock, causing delays, queue buildup, and overall reduction of travel speeds.

Scenarios 1 and 2 show degradation of operating conditions, which can be traced primarily to overall increased eastbound traffic.

Discussion: Park & Lebanon and Park Street

The LOS results for the Park & Lebanon intersection suggest that that the intersection will operate with reserve capacity during the AM peak hour for all scenarios tested. The analysis suggests that this entry point to Hanover will not encounter dramatically different operating conditions under any of the traffic/parking scenarios. A key reason for this is that the intersection tends to operate without significant traffic demand on the westbound leg (the Co-op driveway). Without regular calls for green time on this leg, the intersection can share green time among the other 3 legs, effectively converting it to a 3-approach intersection. Three-legged intersections can operate with high efficiency, especially when they include vehicle detection and signal actuation, which is the case at this intersection.

¹ Operating conditions further to the west, in the Town of Norwich, are estimated to be LOS E during AM commuting periods. All of the major commuting inflows to Hanover converge on the roadway segment along Main Street between the Route 5/I-91 Southbound Off ramp and the Ledyard Bridge. In addition, this segment reduces from two eastbound lanes to one eastbound lane at the approach to the Ledyard Bridge. This lane reduction is the main capacity reduction encountered along the entire roadway segment leading to the Main/Wheelock intersection.

² It is important to note that the travel speeds are averaged over approximately 1500 eastbound vehicles. Thus, a change of even 1 mph indicates a noticeable reduction of operating speeds.



Under existing conditions, congestion problems begin after the Park/Lebanon intersection on the commute into Hanover. Continuing down Lebanon Street, the commuter encounters the morning drop-off congestion associated with the high school and middle school. This congestion is greatest during a 15-minute period – 7:45 – 8:00 AM.

Continuing down Park Street, the commuter encounters two points of congestion. First, the commuter encounters the congestion associated with school drop-offs at the traffic signal at Summer Street. This intersection typically has a crossing guard to ensure safe pedestrian movement in the area, which further increases the delays of any through-vehicles. Second, Summer Street is the access to the Thompson Lot, which is the first major parking zone at the entrance to Hanover.

Continuing further up Park Street to its intersection with Wheelock Street, additional delays are encountered. Field observations at this intersection consistently show unmet demand¹ for at least one 15-minute period during the AM peak hour. Incoming demand from the east, north, and south tends to build up at this intersection. While the model is accurately calibrated to actual field counts at this intersection, it is not well calibrated to the operational delays at this intersection. This is an area of continued research for model improvement. The modeling system does not currently project appreciable change in operations at this intersection from scenario to scenario.

The Park & Lyme Road (DMS) intersection is the northerly terminus of Park Street. At this intersection, operations are projected to continue at relatively uncongested levels for all but Scenario 2. This scenario involves the major expansion of parking at DMS/Dewey, and generates a significant increase in left turns during the AM peak hour. The results shown in Table 6 assume the continuation of a roadway connection between Maynard and the DMS/Dewey lots. Despite this connection, the left turn demand at this intersection is heavy enough to upset overall operations. If the Maynard connector road were to be discontinued, the Park/Lyme intersection would approximately receive an additional 300 vehicle trips during the AM peak hour, and would fail.

Scenario 1 – involving the relocation of Dresden Schools to a site near Reservoir Road – does not result in significantly degrading operations at the Park/Lyme intersection. There are 3 reasons that this is the case. First, most of the new traffic demand using this intersection (approximately 200 new vehicle trips) moves through the intersection as through- and right turns. These movements tend not to be consumptive of capacity when traffic signals operate in actuated mode. Second, there continues to be significant reserve capacity at this intersection, due primarily to the lack of a high left turn demand on 3 out of the 4 legs. Third, as will be discussed below, the location of the Dresden schools by Reservoir Road creates significant shortcutting on Rip Road as an access route. The modeling system projects an additional 200 vehicle trips on Rip Road in Scenario 1, which is over a doubling of existing AM peak hour traffic flows.

¹ Unmet demand suggests overcapacity conditions. Unmet demand refers to the inability of the intersection to process all of the vehicles demanding to move through the intersection. Queues build up during periods of unmet demand, and many vehicles will need to wait for more than 1 signal cycle before moving through the intersection.



4.2 CUT THROUGH TRAFFIC

As traffic increases over time, there is greater use of neighborhood streets and other minor streets by drivers wishing to circumvent congested areas. Cut-through traffic has been evaluated for each scenario, focusing specifically on the following roads:

- ◆ West Street-School Street
- ◆ Buell Street
- ◆ Rip Road
- ◆ Tuck Drive

One way to evaluate cut through traffic is simply to compare it to some base condition. A certain amount of through traffic is currently experienced on residential streets in Hanover. This traffic will likely increase in the future with the increase of background traffic in general. The modeling system enables a projection of this cut through traffic under no build conditions, and all traffic/parking scenarios can be compared to this base case (Base Case = 1.0). This information is provided in Table 8.

Table 8: Index of Cut Through Traffic for Minor Roads and Neighborhood Streets

Scenario	Cut-Through Index
Base Case	1.00
1	1.45
2	1.08
3	1.04
4	1.03

The most notable result in Table 8 is the cut-through traffic estimated for Scenario 1. This increase is due primarily to the changes in traffic on Rip Road due to the school relocation.

Generally, changes in cut-through traffic can be expected to increase in proportion to parking and employment increases in Hanover and at Dartmouth College.

4.3 SYSTEM WIDE PERFORMANCE MEASURES

CORSIM generates a variety of system-wide performance measures. The ones compared in this evaluation are total vehicle miles traveled (VMT) and total vehicle hours of delay. To facilitate comparisons, the model outputs have been indexed against the 2005 No Build results. Table 9 displays the results.



Table 9: Index of Total Vehicle Miles Traveled and Total Vehicle Hours of Delay

Scenario	Vehicle Miles	Index of Total Delay
Base Case	1.00	1.00
1	1.09	1.45
2	1.07	1.26
3	1.00	1.27
4	0.99	1.05

The results in Table 9 give a more global sense of the impact of each parking scenario. Generally speaking, Scenarios 1 and 2 involve the greatest increases in vehicle trip generation, miles, and delay, with Scenario 1 showing the most far-reaching degradation of traffic operations. Generally speaking, Scenario 1 is attracting the greatest number of new vehicles into Hanover (see Table 3), pushing a greater amount of traffic onto local streets (Table 8), and increasing vehicle volumes at all key intersections (Table 4). These volume increases translate into performance degradation throughout the system. In many cases, the performance degradation is only equated to a few seconds per vehicle (Table 6). However, the degradation is spread over thousands of vehicles for an entire hour.

Scenarios 3 and 4 generate similar amounts of vehicle miles as the No Build. However, due to vehicle re-routing, there is more overall delay for both scenarios. The peripheral lots located at Cummings (Scenario 3) and Ledyard (Scenario 4) reduce travel for some commuters, but increase it for others. To the extent that Dartmouth College can direct use of its parking lots by certain user groups (i.e. employee commuters who use Ledyard Bridge), this impact can be minimized. This type of management policy has not been accounted for in the modeling analyzed herein.

The increase in delay is significantly greater for Scenario 3, which involves the expansion at the Cummings Lot. A portion of this delay is the aforementioned delays on West Wheelock associated with eastbound left turn movements. The existing modeling did not include a left turn bay to accommodate these additional left turns.

