Costs and Benefits of a Road Diet for Livingston Avenue in New Brunswick, New Jersey

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Executive Summary

New Jersey has enacted a Complete Streets policy which encourages the retrofit of roads to accommodate all travelers. This policy is consistent with reducing roads with excess capacity via road diets; often this involves conversion of a 4-lane road to 2-lanes with a center turning lane, as well as the introduction of bicycle lanes on both sides of the road.

The analysis presented here is of a candidate road diet conversion site, Livingston Avenue in New Brunswick, New Jersey, an oversized arterial corridor accessing the center of the city. The VISSIM micro-simulation model is used to analyze current conditions and a number of road diet scenarios. The key measures analyzed are changes in average vehicle travel time and travel delay, as well as delays at signalized intersections. For this specific case of Livingston Avenue in New Brunswick, we find that the road diet may increase average travel delay, but has little impact on level of service at signalized intersections.

Safety impacts of road diets are one of the main reasons that these are pursued. Evidence on the safety effect suggests that road diet conversions of arterial streets in urban areas will achieve about a 19% reduction in crashes. Livingston Avenue currently has about 38 crashes per year, thus we would expect a reduction of about seven crashes per year, on average. Given the high number of pedestrians that cross the street, some of these would likely be fairly severe pedestrian-related crashes.

A benefit/cost analysis was conducted to evaluate the trade-offs between increases in travel time associated with the road diet conversion versus the benefits of crash reduction. The value of time was estimated using the median household income of New Brunswick residents, US median household income (as recommended by US DOT guidance), and higher value based on median household income for Middlesex County. The range of valuation of crashes was based on US DOT estimates of the value of a statistical life. Results show that there is a large positive net present value associated with a road diet conversion in all the scenarios analyzed, for all values of a statistical life (as recommended by US DOT), and for all estimates of travel time costs. These range up to a net present value over a 20 year life time of $60 million. Positive benefits are achieved even if there is only a 10% reduction in crashes or if the cost of the road diet conversion is as high as $10 million (we would expect the cost to be substantially less than this, and our base estimates assume a $60,000 cost).

Based on this analysis, our recommendation is that the City of New Brunswick and Middlesex County would achieve substantial benefits from a road diet conversion of Livingston Avenue.

Introduction

Complete Streets policies are aimed at balancing the needs of all roadway users, encouraging and allowing safe travel by bicyclists, pedestrians, transit users, and freight, in addition to existing car traffic. This is made possible through the transformation of the built environment and may include the installation of bicycle lanes, crosswalks, sidewalks, pedestrian signals, and transit stops. It may also include the addition of median islands, curb extensions, or the occasional road diet. The latter is the focus of this analysis for Livingston Avenue in New Brunswick, New Jersey, a major arterial road feeding the center of the city.

A Complete Streets policy institutionalizes the commitment of regional and local governments to safely accommodate all roadway users.*(1)* An ideal Complete Streets policy will contain ten key elements: vision and purpose; identification and specificity of all users; a balanced and comprehensive transportation network approach; all agencies and all roads; all projects; plausible exemptions; design criteria; performance measures; and implementation plans.*(2)* Complete Streets policies may be adopted via laws and ordinances, resolutions, tax ordinances, internal policies or executive orders, plans, design manuals and guides, or elected boards.*(3)* Once policies are adopted, the "National Complete Streets Coalition has identified four key steps for successful implementation: 1) Restructure procedures to accommodate all users on every project; 2) Develop new design policies and guides; 3) Offer workshops and other training opportunities to planners and engineers; and 4) Institute better ways to measure performance and collect data on how well the streets are serving all users."*(2)*

Nationally, 490 regional and local jurisdictions have adopted or committed to adopting Complete Streets policies. The list includes 28 states, the Commonwealth of Puerto Rico, and the District of Columbia.*(3)* As of January 2014, the states with the most Complete Streets policies adopted include New Jersey (94), Michigan (66), Florida (39), New York (34), and Minnesota (31). *(4)*

New Jersey has emerged as a nationally-recognized leader in the number of complete streets policies adopted. There are eighty-eight municipalities and six counties with complete streets policies in the state. This list includes some of the state's largest cities (i.e., Newark, Jersey City, Trenton and Camden) and counties (i.e., Essex, Hudson, Middlesex and Monmouth). Of the state's 8,791,898 residents, twenty-nine percent (2,590,031) reside in municipalities with complete streets policies and forty-two percent (3,738,643) reside in counties with complete streets policies.*(4)*

New Jersey has also been recognized for the strength of its complete streets policies, specifically the New Jersey Department of Transportation and the City of Trenton. NJDOT received the highest ranking for an internal Complete Streets policy in 2010, 2011 and 2012.*(5)* The policy highlights NJDOT's commitment to implement Complete Streets "through the planning, design, construction, maintenance and operation of new and retrofit transportation facilities, enabling safe access and mobility of pedestrians, bicyclists, and transit users of all ages and abilities." *(6)* Similarly, the City of Trenton's

Complete Streets policy was ranked number eight out of the country's top ten complete streets policies of 2012. Both agencies were recognized by the National Complete Streets Coalition.

The City of New Brunswick adopted its Complete Streets policy in May 2009. The policy reinforced the city's commitment to "creating a comprehensive, integrated, connected street network that safely accommodates all road users of all abilities and for all trips."*(7)* The city has since made plans to increase investment in bicycle and pedestrian infrastructure.*(8, 9)* The city has also passed legislation and increased enforcement in an attempt to eradicate preventable vehicular-pedestrian crashes. *(10, 11)*

A road diet generally consists of converting a four lane road to a three lane road where the middle lane is a two-way turning lane; Figure 1 displays a typical cross-section. Bicycle lanes (or wider shoulders) are also often part of the redesign of the road as there is now adequate space for them. Figure 2 and Figure 3 show before and after photos of a road diet on Livingston Avenue.

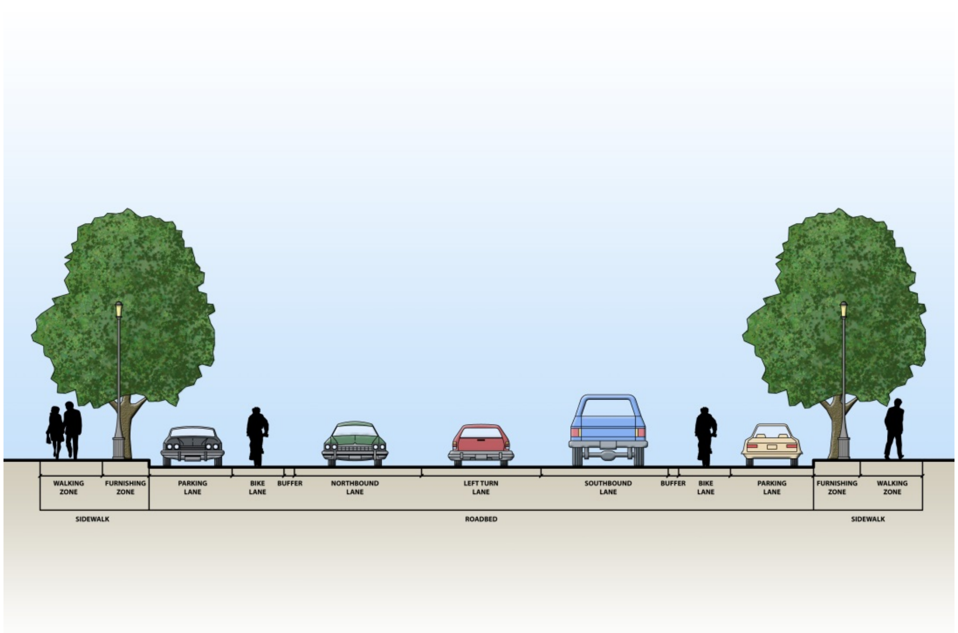

Figure 1: Road diet cross-section showing a typical configuration

Recent research has demonstrated that road diets can significantly reduce crashes *(12)*. A review commissioned by the FHWA synthesized the available research that has evaluated crash rates before and after implementation of a road diet. While not many projects have been evaluated, the results of this synthesis suggest that in large urban areas crashes can be reduced by about 19%. For rural highways that pass through smaller urban areas this can be as much as a 47% reduction in crashes. No studies have evaluated the impact on traffic fatalities and more severe injuries, but one would expect these to also be reduced.

Figure 2: Livingston Avenue as it is currently configured

Figure 3: A photo simulation of Livingston Avenue with a road diet

New Brunswick is located in central New Jersey and sits along the Raritan River. It is the county seat of Middlesex County. The population is about 50% Hispanic, 16% African-American and totals about 55,000 residents. Over one-third of the population is foreign born. About 25% of the population is below the poverty line and median household income is $40,280 based on the American Community Survey 5 year estimate, and average household income is $53,854. New Brunswick is home to the main campus of Rutgers University with an enrollment of over 40,000 students. The city is relatively densely populated at about 10,500 residents per square mile (4075 per sq. km) *(13, 14)*. Employment in the city has grown to about 27,000 jobs from 20,000 in 1990. Rutgers University and Johnson & Johnson are the two major employers in the city.

The northeast corridor offers direct train service to New York City, which has led to major redevelopment of the city as a transit-oriented development. About 10% of the population commutes to work by public transportation and slightly over 3% walk to work. Much of the city is very walkable, with adequate sidewalks along almost all major and minor streets *(13)*.

Livingston Avenue (also known as county route 691), the subject of this study, is a major local street corridor that connects downtown New Brunswick with US route 1 in the south. It stretches about 3.5 miles (5.6 km) and provides access to the many neighborhoods within the city. Livingston Avenue has four lanes with a 25 mph speed limit for its entire length in New Brunswick, except for the final block between New St. and George St. (the main downtown district of the city). The roadway has an AM peak volume of about 14,000 ADT and a PM peak volume of about 17,500-18,000 ADT. Most vehicles exceed the speed limit of 25 mph. Land uses along the street are a mix of residential, retail, and small offices. A number of uses fronting on Livingston Avenue attract vulnerable users, including three elementary schools, a rehabilitation center for the blind, the public library, a 50-unit senior citizen apartment building, multiple churches and a Rutgers University academic building Total pedestrian activity tabulated during this study amounted to over 9000 street crossings for both the morning and evening peak periods (over three hours), for counts at nine intersections along Livingston Avenue. The street was originally designed as a wide avenue as can be seen in the postcard image in Figure 4.

The street enters North Brunswick to the south where it reduces to three lanes, one of which is a central turn lane and has an increased speed limit (of 35 mph). Along this final stretch in North Brunswick the environment becomes more suburban in character and the sidewalks disappear.

Livingston Avenue has been identified as having on over-representation of pedestrian crashes among county roads in Middlesex county *(15)*. Livingston Avenue is classified as a four-lane urban minor arterial. Minor arterials are meant to interconnect with and augment the principal highway system. In urban areas they serve trips of moderate length at a somewhat lower level of travel mobility *(16)*. According to a road safety audit conducted in 2011 there were a total of 113 vehicle crashes between 2007 and 2009. Of these, 17% involved a pedestrian and 6% involved a bicyclist *(15)*. Over two-thirds of the pedestrian crashes occurred at night and most were at major intersections along Livingston Avenue. One issue noted in the audit is that the police department reported that many pedestrian crashes occur when vehicles that are stopped for the pedestrian block the view of other vehicles that are passing. This is a characteristic associated with this type of four-lane road. The road safety audit recommended consideration of a road diet as one way to mitigate these occurrences. This analysis is intended to evaluate the feasibility of a road diet on Livingston Avenue to understand how this may affect traffic flow and also to evaluate the benefits and costs of the conversion. Likewise, as most vehicles exceed the posted 25 mph speed limit, a road diet would be one way to increase compliance with the posted limits. There is evidence that road diets are effective at reducing crashes and reducing speeds *(12, 17, 18)* and some evidence that there is no effect *(19)*. A synthesis of the literature concluded that road diets are effective at reducing crashes *(12)*.

Livingston Avenue is signed as both a state and county route. This includes County Route 691 from Nassau St. to Suydam St., at which point it runs concurrent with state route 171 from Suydam St. to George St. The roadway is under the jurisdiction of both county and municipal authorities which can complicate any plans to implement a road diet.

The motivation for undertaking this study is that the roadway currently prioritizes vehicular traffic and does little to protect vulnerable road users. The City of New Brunswick seeks to investigate complete street alternative configurations that would accommodate all users safely. The goal of the study is to analyze the feasibility of implementing a road diet for the roadway and to determine the benefits and costs of a conversion.

The approach taken here is to investigate the feasibility of a road diet by analyzing the results of a micro-simulation of the traffic network using VISSIM software. VISSIM is a microscopic, time step and behavior-based simulation model developed to model urban traffic and public transport operations; a pedestrian module is also available but was not used for this project *(20)*. VISSIM is particularly useful for examining different scenarios with altered lane configurations and signal timings. The key output provided by the model is the total travel time within the network as well as the time each vehicle is delayed. This provides a means of assessing how the relative level of service of Livingston Avenue and the key intersections are affected by various road diet configurations.

The costs and benefits of the conversion are then estimated using standard approaches to evaluating the costs of travel delay and the costs of crashes. Construction cost estimates are included to assess the net present value over 20 years of a road diet conversion.

Figure 4: Livingston Avenue, postcard, date unknown. Source: New Brunswick Free Public Library, http://nbfpl.org/postcards/pc2.html

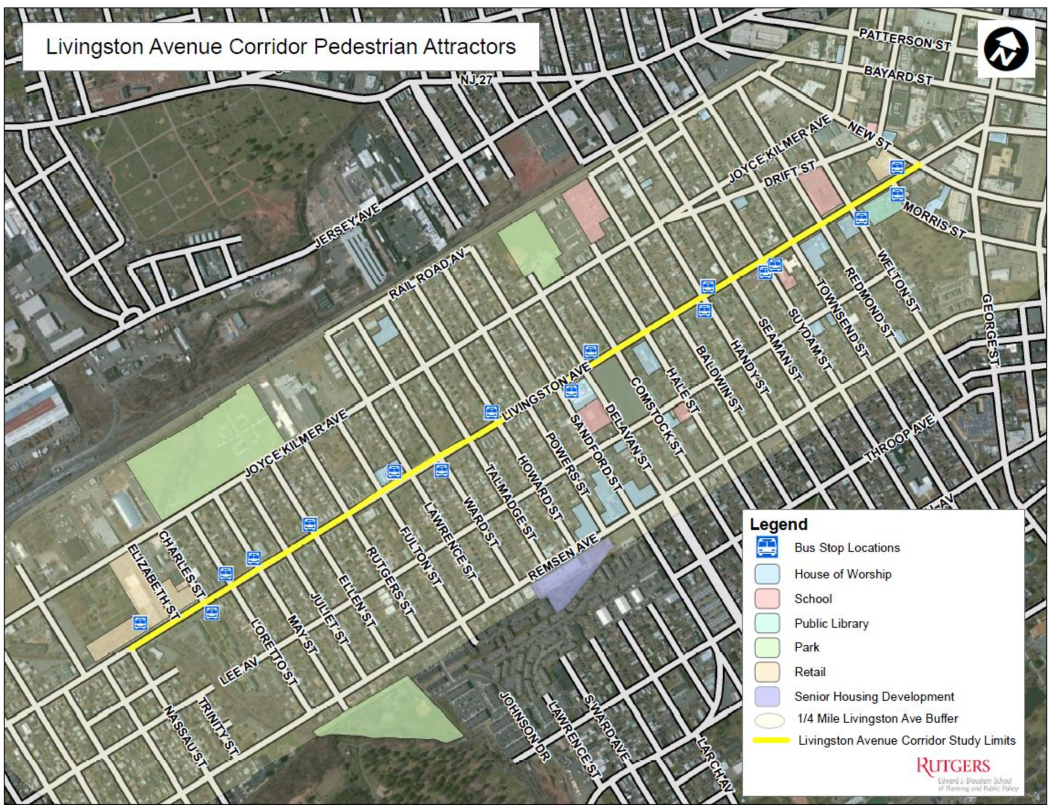

Figure 5: Livingston Avenue Study Area, with key pedestrian attractors

Data for Calibration

The study area for this project includes only the 1.5 mile segment of Livingston Avenue (shown in Figure 5) fully within the City of New Brunswick. There are a number of key pedestrian attractors shown in Figure 5, in addition to bus stops that line the street.

In order to calibrate the VISSIM model to actual traffic conditions, traffic counts are needed at various sites along the corridor. Physical turning movement counts at each of the five major signalized intersections were collected. These included: New Street, Suydam Street (SR 171), Handy Street, Sanford Street and Nassau Street (CR 620). Turning movement counts were also collected at one representative unsignalized intersection location, Lawrence Street. These data were collected on weekdays in November and December, 2012 for 3 hours duration for both AM peak hour (7AM~10AM) and PM peak hour (3PM~6PM). Two additional counts were performed during the AM and PM peak period to confirm the proportion of truck and bus traffic on Livingston Avenue.

In setting up the traffic assignment in VISSIM, we used the average counts for each signalized intersection. The traffic flow at each unsignalized intersection was scaled proportionally based on the counts from Lawrence Street. Thus, the turning movements for each unsignalized intersection were proportionally equivalent, but scaled up or down based on the Livingston Avenue traffic flow passing each unsignalized intersection.

Pedestrians were also counted. This was done at the same intersections plus three additional locations. These were the unsignalized intersections of Redmond Street and Welton Street, which serve as major crossings for an elementary school situated on Livingston Avenue (Roosevelt Elementary School). Counts were also conducted at the intersection of Elizabeth Street, which is adjacent to the Food Town Shopping Center. We do not analyze the VISSIM output associated with pedestrians. Pedestrians in the simulation interact with vehicles at the signalized crossings and can be seen in visualizations of the simulation.

A summary of all the pedestrian counts for those pedestrians who crossed Livingston Ave. (but not the side streets) at the intersections at which counts were made is provided in Table 1. The total number of pedestrians exposed to traffic on Livingston Avenue for the six hours in which counts were made is 3393 pedestrians, indicating a high degree of exposure and potential risk.

Table 1: Pedestrians crossing Livingston Ave.

Pedestrians Crossing Livingston Ave					
Street Name	Crosswalk 2		Crosswalk 4		**Total**
	AM(7:00-10:00)	PM (3:00-6:00)	AM(7:00-10:00)	PM (3:00-6:00)	
New Street	49	149	84	97	**379**
Suydam Street	88	242	74	197	**601**
Handy Street	63	136	76	144	**419**
Sanford Street	75	91	29	82	**277**
Nassau Street	19	25	3	42	**89**
Welton Street	57	102	148	192	**499**
Redmond Street	361	534	32	54	**981**
Elizabeth Street	12	46	5	46	**109**
Lawrence Lane	9	12	8	10	**39**
Total	**733**	**1337**	**459**	**864**	**3393**

Road Geometry

The road geometry data are derived from the 2012 New Jersey High Resolution Orthophotography, downloaded from the New Jersey Geographic Information Network *(21)*. The images were combined together in ArcGIS from which an image was exported to serve as the base map for the simulation. The map provides basic road geometry data, such as the edges of the roads, the centerline of the roads and other geometry. The basic road network was then plotted in VISSIM using this image as background.

Signal Timings

The existing traffic signals are timed with actuated signals at the intersections of Livingston Avenue with New Street, Suydam Street, Handy Street, Sandford Street, and Nassau. There are separate timing plans for the morning and evening. The signals operate on simple two- or three-phase plans allowing for extended green time when the pedestrian request is called in order to allow sufficient time for pedestrians to safely cross Livingston Avenue. The cycle length is fixed at 90 sec for New Street and Nassau Street. Variable cycle lengths are allowed at Suydam Street (52-80 sec), Handy Street (56-80 sec), and Sandford Street (54-80 sec).

For the study of the Livingston Avenue corridor, we did not collect sufficiently detailed data to record how often the signal is actuated for pedestrians or how often the vehicle extension was actuated. The analysis was conducted treating the signal timings as fixed as though there were high traffic and pedestrian demand in every cycle. The fixed timing plans used as the existing case for the study are summarized in Table 2. This is consistent with operation of the corridor at its capacity when all of the actuated phases would be at the maximum length anyway. In the interest of studying the performance of the corridor in the height of the AM and PM peaks, we are able to provide an estimate of the worst-case level of service for car traffic during the busiest time of the day. Therefore predictions of future performance are conservative and robust if pedestrian traffic in the corridor were to increase substantially in the future.

Table 2: Existing Timing Plan (sec)

Intersection	Green	Yellow	All Red	Phase Total
New Street (6AM – 9AM)				
Livingston Ave (All Movements)	38	3	3	44
New St (WB Lead)	10	3		13
New St (All Movements)	26	3	4	33
New Street (All Other Times)				
Livingston Ave (All Movements)	28	3	3	34
New Street (WB Lead)	10	3		13
New Street (All Movements)	36	3	4	43
Suydam Street				
Livingston Ave (All Movements)	34	4	2	40
Suydam St (All Movements)	34	4	2	40
Handy Street				
Livingston Ave (All Movements)	39	3	2	44
Handy St (All Movements)	30	4	2	36
Sandford Street				
Livingston Ave (All Movements)	36	4	2	42
Sandford St (All Movements)	32	4	2	38
Nassau Street				
Livingston Ave (All Movements)	36	4	2	42
Nassau St (All Movements)	32	4	2	38

The simulation model was calibrated to recreate existing traffic conditions with the current signal timings and traffic flows. The road diet on Livingston Avenue was then simulated with these existing signal timings to estimate the effect on intersection level of service from changing the street geometry without adjusting the traffic signals. The simulations resulted in excess congestion during the evening peak period. A set of re-optimized signal timings were developed specifically for the evening peak period to better reflect the changed traffic conditions (this is something that would need to be done if a road diet were adopted).

Synchro 8 was used to re-optimize the cycle length, phase lengths, and offsets in order to provide coordination for an efficient green wave for the peak travel direction (i.e., outbound from downtown New Bunswick), and minimize the effects of queue spillbacks blocking other intersections. Since the proposed road diet reduces the capacity at intersections, a longer cycle length is needed in order to reduce the effect of the lost time between phases on the intersection's capacity. The optimized signal timing plan for the evening peak, accounting for the changed geometry of the road diet, is summarized in Table 3.

Table 3. Re-optimized Timing Plan for PM Peak (sec)

Intersection	Green	Yellow	All Red	Phase Total
New Street (Offset = 0)				
Livingston Ave (All Movements)	32	3	3	38
New St (WB Lead)	10	3		13
New St (All Movements)	42	3	4	49
Suydam Street (Offset = 61)				
Livingston Ave (All Movements)	48	4	2	54
Suydam St (All Movements)	40	4	2	46
Handy Street (Offset = 52)				
Livingston Ave (NB Lead)	6	3		9
Livingston Ave (All Movements)	49	3	2	54
Handy St (All Movements)	31	4	2	37
Sandford Street (Offset = 98)				
Livingston Ave (All Movements)	51	4	2	57
Sandford St (All Movements)	37	4	2	43
Nassau Street (Offset = 0)				
Livingston Ave (All Movements)	51	4	2	62
Nassau St (All Movements)	32	4	2	38

Note: All offsets are for the beginning of the first listed phase relative to the intersection at New Street.

Features of this plan are that it requires no additional investment of signal controller infrastructure, because it is simply a new fixed timing plan that is optimized to the road diet. The cycle length is set to 100 sec at all intersections so that the signal phases are coordinated in every signal cycle. All phases are greater in length than the minimum time required for pedestrians to cross the intersection as estimated from existing pedestrian signal phases along Livingston Avenue.

Simulation Assumptions

Various assumptions and settings must be made in VISSIM prior to running a simulation. These include speed distribution assumptions, vehicle composition, and driver and pedestrian behavior.

For the speed distribution we use an "S" curve based on a speed limit of 30 mph, despite the posted limit being 25 mph. Observation of the street suggested that only a small fraction of vehicles observed the posted speed limit. Resource limitations prevented us from collecting actual speed data for Livingston Avenue. Average speed along Livingston Ave. within the simulation was 15.35 mph during the AM peak period and 14.71 mph during the PM peak period. This takes into account any vehicle stops at signalized intersections and due to other vehicles in the roadway.

Data on vehicle mix was collected. Buses and trucks are a very small proportion of the traffic flow during peak periods. We set both as Heavy Goods Vehicles (HGV) in

VISSIM. During the AM peak the percent HGV was 5%, while during the PM peak the percent HGV was 3%.

The settings for driver behavior were assumed to be the urban (motorized) environment default parameters as specified by VISSIM. These are based on Wiedeman's car following model *(20, 22)*. The driving behavior parameters as specified in VISSIM are as follows: look ahead distance, minimum: 0 ft, maximum: 820.21 ft; look back distance minimum: 0 ft, maximum: 492.13 ft.; average standstill distance: 6.56 ft, additive part of safety distance: 2.00 ft, and multiplicative part of safety distance: 3.00 ft.

The road diet was configured in VISSIM by realigning the lanes for vehicular traffic to fit within a narrower right of way that would allow for installation of bicycle lanes on both sides of Livingston Avenue. Since VISSIM does not have a straightforward way to model a shared left turn lane, the lane alignment at each intersection has been carefully constructed so that left turning vehicles from Livingston Avenue and from side streets interact in a realistic way. The simulated network with the road diet has been configured to recreate the vehicular interactions that would result from a shared left turn lane and, most importantly, to exhibit the expected capacity for vehicular traffic in the corridor.

For turning behavior we assume that if a vehicle is turning right from a side street to Livingston Ave, it will enter the right side lane of Livingston Ave. Left turning vehicles will enter the left side lane of Livingston Ave. Our road diet scenarios (discussed below) include a center lane that left turning vehicles will turn into from side streets.

Road Diet Scenarios

Our base case scenarios included both peak hours, AM and PM, based on our traffic counts. Signal timings for the AM and PM model varied slightly. The model was calibrated and adjusted as needed to match these counts and achieve a smooth flow without any major backups at intersections. Of particular note is the intersection with New Street at the northern end of Livingston Avenue. This is just prior to the core area of downtown New Brunswick. Most of the traffic turns right, flowing towards NJ state route 18, a controlled access road that parallels the Raritan River, both bypassing downtown New Brunswick to the north and headed towards US route 1 and the New Jersey Turnpike towards the south.

Our first road diet scenario included a center turning lane for the entire length of Livingston Avenue, from New Street to Nassau Street. The traffic lanes were reduced to one lane in each direction from two lanes in each direction in the base case. Bicycle lanes are also included, although we did not simulate bicycle traffic.

In our initial road diet simulations the PM peak hour model resulted in significant congestion and spillback at the northern end of Livingston Avenue. This resulted in blocking side street turns into Livingston Avenue. Given the PM peak hour situation above, we re-optimized the signal timing in an attempt to fix this problem. Unfortunately, these changes were insufficient to alleviate the spillback problem.

Given the problem with this simulation we tested what would happen by incrementally reducing the total traffic volume from 2% up to 10%, at intervals of 2%. The simulation performed adequately with the traffic volume reduced by 10% with the original signal timings. With modified signal timings (discussed previously) the simulation was adequate with an 8% reduction in traffic.

We feel that an 8-10% reduction in volume may be a realistic outcome when the road diet is implemented. First, if the road were to congest to the extent that our simulation suggested with a major spillback, then some drivers would opt to find different routes. In theory, the increase in congestion should lead to some suppression of demand. The opposite effect, induced demand, is a documented response to increased road capacity *(23)*. As we are reducing road capacity by up to 100% for the 1.5 mile stretch of Livingston Avenue, applying a lower bound lane-mile elasticity of 0.2 would result in a 20% reduction in vehicle-miles of travel along the road *(23)*. Thus, we feel an 8-10% reduction is at the low range of probable responses.

An alternative scenario was also tested that would not require any assumptions on reducing total traffic. Since most of the spillback problem is between New Street and Handy Street we tested alternative modifications to the road network between these streets.

One scenario involved not implementing the road diet between these two intersections. Thus, this part of Livingston Avenue would continue to be a four-lane road. This is not an optimal design from a walkability perspective as it is precisely this end of Livingston Avenue that is closest to downtown New Brunswick and has the most pedestrian traffic. However, this area could be made more bicycle- and pedestrian-friendly though the implementation of bicycle sharrows, enhanced crosswalks, signage, and pedestrian scaled lighting where necessary. In any case, this scenario worked well with the original signal timings, and if this scenario were not included as an option, then the analysis would not be able to provide any solution, due to the spillback between New Street and Handy Street.

Our other scenario to alleviate this problem was to keep two lanes for the southbound travel direction from New Street to Handy Street while the northbound flow would remain one lane. There were no spillback issues with the northbound flow, so this solution was aimed at allowing better flow for those vehicles turning into Livingston Avenue from New Street. This scenario works well with the re-optimized signal timing. This also allows the bicycle lane to be maintained.

Simulation Results

Results were run for seven different scenarios. These included AM and PM base case scenarios to establish a baseline for existing conditions; AM and PM road diet scenarios, with the latter having both an 8% and 10% traffic reduction, the former with the re-optimized signal plan; two additional PM peak road diet scenarios, but with no road diet from New St. to Handy St. in one case and two southbound lanes in the second case.

Each simulation was run for three hours of traffic, omitting the first and last five minutes of the simulation in calculating results. Details of each scenario are listed in Table 4.

Table 4. Scenarios Simulated with VISSIM

Scenario Number	Scenario	Scenario Description
1	Base case	AM
2		PM
3	Road Diet	AM
4		PM – 8% traffic reduction, re-optimized signal timings
5		PM – 10% traffic reduction, original signal timings
6		PM – 4 lanes maintained from New St. to Handy St.
7		PM – 2 southbound lanes maintained from New St. to Handy St., and 1 northbound lane

As VISSIM is a stochastic model, each simulation was run ten times and each measure of effectiveness was evaluated based on its mean and standard deviation. The standard deviations in all our simulations are small, thus we do not see major variations between each simulation due to random variation. The vehicles in the simulations were calibrated to actual traffic count data but vary slightly due to stochasticity. For the AM peak the simulation count is generally slightly less than 14,000 vehicles and for the PM peak about 18,500 to 19,000 vehicles (except for those scenarios where the vehicles are intentionally reduced). These results are shown in Table 5.

We measured the total travel time per vehicle along the corridor, the delay time per vehicle, and the delay time per vehicle for each of the signalized intersections, allowing the Level of Service (LOS) to be evaluated. Results for total travel along the corridor and corresponding delay times per vehicle are shown in Table 5. These are evaluated relative to the base case scenarios (1 and 2, for AM and PM respectively).

The base case scenarios (1 and 2) both have an average delay of slightly over 30 seconds. For our road diet simulations this increases to about 47 seconds for the AM period. Of the various PM road diet scenarios tested, the lowest delay occurs in scenario 6, when no road diet is implemented for the most northern blocks of Livingston Avenue, avoiding the spillbacks in the simulation. If we assume a 10% reduction in traffic (scenario 5), the average delay is similar. When only two southbound lanes are maintained (scenario 7) the increase in delay is worse than implementing the entire road diet. The last column shows the increase in total delay relative to the base case (AM and PM respectively). Using the road diet results with the lowest level of delay for both AM and PM periods we have a total increase calculated for all vehicles of 61.89 and 56.15 hours of delay per workday, respectively, or 118.04 hours. This does not account for any alternative routes that the 10% reduction in PM traffic may have taken to avoid the more congested road.

An alternative measure is to examine the change in travel times for those vehicles traversing the length of Livingston Avenue. These would likely be vehicles making non-local trips and commute trips. Table 5 also displays the result for both northbound and southbound average travel times and average delay as well as the increase in average delay time (relative to the base case AM and PM scenarios). Standard deviations are omitted for brevity, all were relatively low. VISSIM does not provide data on the number of vehicles traversing the length of Livingston Avenue, thus we cannot calculate a total aggregate delay.

Base case average travel times are about 300 seconds, for both the AM and PM peaks in both directions. The road diet increases these average travel times to no more than about 400 seconds, with most scenarios less than 400 seconds.

The final column summarizes the average increase in delay time for each scenario. This is the sum of the northbound and southbound increase in average delay. The road diet scenarios add about 120 seconds of additional delay; the lowest increase in average delay is when no road diet is implemented between Handy St. and New St. (scenario 6).

Delay at each signalized intersection is also analyzed. Results are shown in Table 6 for the five signalized intersections along Livingston Avenue that were simulated (standard deviations are omitted for brevity). Both average delay time for all vehicles entering each intersection as well as the Level of Service (LOS) are reported. For New Street and Nassau Street the LOS does not change for any of the scenarios, remaining at C for New Street and B for Nassau Street. The other three intersections are all at LOS B in the base case analysis; some deteriorate to LOS C, but this is still considered an adequate LOS. Those intersections that deteriorate from LOS B to LOS C show minor changes in total average delay.

Table 5. Performance measures for simulated results.

Scenario Number	Scenario	Average delay per vehicle (s)	Average speed (mph)	Average Number of vehicles	Total increase in delay (hrs)	Average travel time - New St. to Nassau (south-bound) (s)	Average travel time - Nassau St. to New St. (north-bound) (s)	Average delay time - New St. to Nassau (south-bound) (s)	Average delay time - Nassau St. to New St. (north-bound) (s)	Increase in average delay (south-bound) (s)	Increase in average delay (north-bound) (s)	Total increase in average delay, both directions (s)
1	Base case	31.10	15.35	13964	-	297.33	319.78	66.86	89.83	-	-	-
2		32.44	14.71	18963	-	316.98	304.56	85.21	74.48	-	-	-
3	Road Diet	47.03	13.32	13984	61.89	333.29	406.58	101.94	176.03	35.08	86.20	121.27
4		49.31	12.57	17798	83.36	385.64	368.59	153.75	138.72	68.53	64.24	132.77
5		44.00	13.11	17499	56.15	381.52	360.96	150.27	129.61	65.06	55.13	120.19
6		43.47	13.25	18975	58.14	375.45	348.08	143.41	119.30	58.20	44.82	103.02
7		52.66	12.30	18982	106.61	390.08	391.21	157.50	159.69	72.29	85.21	157.50

Table 6. Average delay and Level of Service (LOS) at each signalized intersection

Scenario Number	Scenario	New Street		Suydam Street		Handy Street		Sanford Street		Nassau Street	
		Average Delay Time	LOS	Average Delay Time	LOS	Average Delay Time	LOS	Average Delay Time	LOS	Average Delay Time	LOS
1	Base case	22.32	C	17.81	B	16.60	B	16.22	B	15.77	B
2		23.11	C	19.59	B	17.95	B	17.61	B	16.23	B
3	Road Diet	21.84	C	18.68	B	19.58	B	18.15	B	16.41	B
4		26.11	C	25.57	C	25.14	C	21.64	C	17.85	B
5		22.08	C	23.54	C	19.22	B	18.08	B	16.63	B
6		23.15	C	19.76	B	18.31	B	21.02	C	17.28	B
7		25.27	C	23.58	C	26.39	C	22.49	C	18.78	B

Benefit-Cost Analysis of Road Diet Implementation

Implementation of a road diet results in benefits to a community from the reduction of traffic crashes that would otherwise occur. The trade-off is that this also involves an increase in travel time for those using the road, as one objective of a road diet is to slow traffic down. The benefits and costs of implementation can be compared by conducting a benefit-cost analysis of the impacts of the road diet. This is based on analyzing the estimated dollar value of crash reduction and the dollar value of increases in travel time. The US Department of Transportation provides guidance on how to conduct this sort of analysis *(24, 25)*.

To analyze the benefits of crash reduction, US DOT guidance provides estimates of the value of a statistical life. This is defined as “the additional cost that individuals would be willing to bear for improvements in safety…that, in the aggregate, reduce the expected number of fatalities by one.” *(24)*. The value estimated for the year 2011 is $9.1 million with the recommendation that low and high values of $5.2 million to $12.9 million be evaluated. This value is indexed by 1.07% per year, under the assumption that increases in median real wages over time will result in higher valuations of statistical life. Therefore, for 2014 the value is $9,295,782 with the corresponding low and high values being $5,311,875 and $13,177,537, respectively.

While these values apply to fatal crashes, most crashes do not result in a fatality. Thus, guidance is also provided on crashes that result in a range of different levels of severity. These are valued as a fraction of the value of a statistical life as shown in Table 7.

Table 7. Relative Disutility Factors by Injury Severity Level (AIS) for Use with 3% or 7% Discount Rate

AIS Level	Severity	Fraction of VSL
AIS 1	Minor	0.003
AIS 2	Moderate	0.047
AIS 3	Serious	0.105
AIS 4	Severe	0.266
AIS 5	Critical	0.593
AIS 6	Unsurvivable	1.000

Source: *(24)*

Note: AIS is Abbreviated Injury Scale

As previously mentioned, the road audit of Livingston Avenue reported 113 crashes over 3 years, so this is slightly less than 38 crashes per year, on average. Some 17% involved pedestrians and 6% involved bicyclists *(15)*. An estimated reduction in crashes due to the road diet would be about 19%, or 7.16 crashes per year, on average.

The road safety audit of Livingston Avenue does not provide full information on the severity of crashes, but does provide a rough breakdown for a subset of 49 crashes. Of these, 12 (16%) involved pedestrians and bicyclists and all were classified as an injury crash. Of thirty-seven vehicle crashes, 29 were minor (property-damage only) and eight involved an injury. In addition, about 6-7% of all pedestrian casualties are fatal in the state of New Jersey, but we don't expect this high a fraction on roads in urban areas, so we assume 1% is not survivable. For vehicle only crashes we assume 0.01% are not survivable. Based on this information we assume the distribution of severity as displayed in Table 8.

Table 8. Assumptions on Severity of Crashes on Livingston Avenue

AIS Level	Severity	Distribution of crashes vehicle crashes	Distribution of non-motorized crashes
AIS 1	Minor	80.00%	20.00%
AIS 2	Moderate	10.00%	40.00%
AIS 3	Serious	6.99%	20.00%
AIS 4	Severe	2.00%	12.00%
AIS 5	Critical	1.00%	7.00%
AIS 6	Unsurvivable	0.01%	1.00%

The assumptions in Table 8 can be combined to develop a weighted value of statistical life based on this distribution of crashes and the split of vehicle versus non-motorized crashes on Livingston Ave. This is shown for low, mean, and high estimates of the value of a statistical life in Table 9 for annual crashes on Livingston Avenue.

Table 9. Cost of All Annual Crashes on Livingston Avenue Based on Statistical Value of Life and Weighted Severity Assumptions

AIS Level	Severity	Low valuation	Mean valuation	High valuation
AIS 1	Minor	$397,360	$695,380	$985,759
AIS 2	Moderate	$1,589,241	$2,781,171	$3,942,539
AIS 3	Serious	$2,097,128	$3,669,974	$5,202,491
AIS 4	Severe	$2,288,522	$4,004,914	$5,677,296
AIS 5	Critical	$2,823,818	$4,941,682	$7,005,241
AIS 6	Unsurvivable	$475,592	$832,285	$1,179,833
TOTAL		$9,671,661	$16,925,407	$23,993,159

Assuming the road diet results in a 19% reduction in crashes, and that the severity levels stay the same, the cost savings from the road diet in 2014 would be as shown in Table 10.

Table 10. Cost Savings based on Value of a Statistical Life and Severity Weighting Assumptions, for year 2014

AIS Level	Severity	Low valuation	Mean valuation	High valuation
AIS 1	Minor	$75,498	$132,122	$187,294
AIS 2	Moderate	$301,956	$528,422	$749,082
AIS 3	Serious	$398,454	$697,295	$988,473
AIS 4	Severe	$434,819	$760,934	$1,078,686
AIS 5	Critical	$536,525	$938,920	$1,330,996
AIS 6	Unsurvivable	$90,362	$158,134	$224,168
TOTAL		$1,837,616	$3,215,827	$4,558,700

The cost of the increase in travel time associated with the road diet can be estimated based on the value of travel time *(25)*. Guidance from the US DOT recommends that for personal travel this is 50% of the nationwide median household income, with plausible ranges varying from 35-60%. For business travel, the value of travel time is 100% of the nationwide median household income. Both are inflated by 1.6% per year, reflecting estimates of increases in the valuation of time. The nationwide median household income was $53,046 in 2012. New Jersey has a higher median household income of $71,637, while Middlesex County's median household income is even higher at $79,442. New Brunswick however has a median household income of only $40,280. This suggests a range of values to use for estimating travel time costs for this analysis; we analyze results assuming New Brunswick household income (low), Middlesex County household income (high), as well as US household income. Hourly value of time assumptions are shown in Table 11. These are applied for 260 work days per year based on US DOT guidance *(25)*.

Table 11. Value of travel time assumptions

	Value of time per hour	
	Personal travel (50%)	Business travel (100%)
New Brunswick	$9.68	$19.37
Nationwide	$12.75	$25.50
New Jersey	$17.22	$34.44
Middlesex County	$19.10	$38.19

Travel for business must also be taken into account. While our traffic counts could not discern all business travel, we did count heavy-goods vehicles and buses. These were 5% of the count during the PM peak and 3% during the AM peak. So these can be accounted for in our benefit-cost analysis.

We also assume that average occupancy of each vehicle is 1.2 people. We did not count occupancy rates, but this is a reasonable assumption as most vehicles are single-occupant.

Based on these assumptions, we can specify the cost of travel time increases in 2014 for each estimated scenario, including both AM and PM peak periods when delay occurs. Results for each scenario are presented, summing both the AM and PM analysis of delay. These are shown in Table 12.

The construction costs of converting the road must also be taken into account. While we don't have any specific values, these conversions are relatively cheap and mainly involve restriping of the road. Removal of existing stripes would also be necessary. Based on contractor estimates from New Jersey bid sheet data, we assume that the cost for both striping and restriping is about $2000 per mile. This would be done for a 1.5 mile length; four existing stripes would be removed while an additional eight new stripes would be painted. A bicycle lane would also be required for each side of the road; we assume the bicycle lanes cost as much as putting down eight stripes. This gives a cost estimate of $60,000.

Table 12. Estimated cost of delay for one year for different value of travel time assumptions (2012 valuations)

Scenario, combining AM and PM delay	Total cost of delay (New Brunswick household income)	Total cost of delay (US household income)	Total cost of delay (Middlesex County household income)
4	$396,001	$593,849	$883,474
5	$320,650	$481,987	$717,276
6	$326,161	$490,168	$729,431
7	$460,386	$689,431	$1,025,485

The total cost and benefits of the annual travel time costs and safety benefits are evaluated over a 20 year project lifetime. Construction costs occur in the first year and the stream of costs and benefits are discounted to the present. We assume a 4% discount rate. This provides a net present value for the project.

Results are presented for all combinations of estimates for each road diet scenario. These include assuming the value of travel time is based on a low (New Brunswick household income), national (US household income), and high (Middlesex County household income) as well as the low, middle, and high estimates of statistical life.

In Table 13 we present the results using US DOT recommended valuations of travel time (based on median US household income) and low, middle, and high valuations of statistical lives saved. All scenarios show a large positive net present value over 20 years.

Table 13. Net present value of road diet, assuming US median household income for estimates of travel time costs

Scenario, combining AM and PM delay	Low VSL	Middle VSL	High VSL
4	$17,473,429	$33,496,609	$58,009,043
5	$19,327,208	$35,350,388	$59,862,822
6	$19,191,632	$35,214,812	$59,727,246
7	$15,889,440	$31,912,619	$56,425,054

VSL = valuation of statistical life

Decision makers in New Brunswick may be more concerned with the travel time costs of New Brunswick residents. For this reason we also present results assuming a New Brunswick household income is used to estimate the valuation of travel time; these results are shown in Table 14. US DOT guidance suggests testing a lower range of travel time valuations down to 35% of median US household income; the New Brunswick household income at a 50% valuation is slightly above this lower level, so is a reasonable assumption. Net present value over 20 years is positive in all scenarios, and over $60 million when a high value of statistical life is assumed.

Table 14. Net present value of road diet, assuming New Brunswick median household income for estimates of travel time costs

Scenario, combining AM and PM delay	Low VSL	Middle VSL	High VSL
4	$20,752,166	$36,775,346	$61,287,780
5	$22,000,888	$38,024,068	$62,536,502
6	$21,909,563	$37,932,742	$62,445,177
7	$19,685,177	$35,708,356	$60,220,790

VSL = valuation of statistical life

Assuming the highest level of travel time costs, based on the median income of Middlesex County, we still find all scenarios have a positive net present value over 20 years. These are shown in Table 15.

Table 15. Net present value of road diet, assuming Middlesex County median household income for estimates of travel time costs

Scenario, combining AM and PM delay	Low VSL	Middle VSL	High VSL
4	$12,673,763	$28,696,943	$53,209,377
5	$15,427,997	$31,451,176	$55,963,610
6	$15,604,297	$31,627,476	$56,139,911
7	$10,320,367	$26,343,546	$50,855,980

VSL = valuation of statistical life

These results assume a 19% reduction in crashes and that the cost of restriping is $60,000. Both these assumptions could be off. If crash reductions are much lower, a relevant question is what percent reduction is needed to justify the road diet, based on the assumptions outlined above? If we assume only a 10% reduction in crashes, then most scenarios still show a substantial positive benefit. Two scenarios that assume Middlesex County travel time costs have a negative value, as shown in Table 16, but only when a low valuation of statistical life is assumed. Thus, we can assume that even with only a 10% reduction in crashes, the road diet is beneficial, and that this is still a conservative estimate.

Table 16. Net present value assuming 10% crash reduction from road diet conversion and Middlesex County travel time costs

Scenario, combining AM and PM delay	Low VSL	Middle VSL	High VSL
4	-$293,200	$8,140,052	$21,041,334
5	$2,461,033	$10,894,286	$23,795,567
6	$2,637,334	$11,070,586	$23,971,867
7	-$2,646,597	$5,786,656	$18,687,937

VSL = valuation of statistical life

Table 17 displays results assuming a $2 million and a $10 million cost of restriping. We present just those scenarios with high travel time costs and low valuation of statistical life, to emphasize the point that benefits are not very sensitive to initial construction costs. The $10 million cost comes close to zeroing out the net present value for one scenario.

Our analysis did not account for growth in traffic over time. While there is evidence of a saturation in growth of travel (otherwise known as “peak car”)*(26)*, we might still expect some growth in traffic associated with further development in New Brunswick. While we did not run a simulation model with additional traffic, we adjusted the travel cost for each scenario to assume a 5% annual growth in traffic over 20 years. This is probably unrealistic, but the bottom line is that it results in only one negative net present value over a 20 year lifetime (scenario 7 with a low valuation of statistical life). Thus, the results are very robust with respect to growth in traffic.

Table 17. Net present value assuming alternative costs for the road diet, assuming highest travel time costs and lowest valuation of statistical life

Scenario, combining AM and PM delay	$2 million cost	$10 million cost
4	$10,733,763	$2,733,763
5	$13,487,997	$5,487,997
6	$13,664,297	$5,664,297
7	$8,380,367	$380,367

Many other factors not accounted for in this analysis may affect both the benefits and costs of the road diet conversion. On the benefits side, we have not accounted for the benefits that pedestrians receive from less time crossing Livingston Avenue and how their travel time may be reduced. We have also not accounted for the benefits that bicyclists receive, such as health benefits, or the savings associated with using a lower cost mode of travel. On the cost side, we have not accounted for the costs associated with diverting some traffic or suppressing demand, as well as how travel time and crashes may change on parallel routes. Given the large magnitude of the benefits, we would not expect these to change the finding that the road diet provides a positive net present value.

Conclusions

Our results have shown that implementation of a road diet, consistent with a complete streets policy along Livingston Avenue will result is some extra delay to traffic both along and within the corridor. However, the costs of the delay to traffic are less than the large benefits associated with the reduction in traffic crashes, based on a cost/benefit analysis. Furthermore, the implementation of a road diet with modifications to the signal timing to improve traffic flow will result in no or little change in the Level of Service (LOS) along Livingston Avenue. Where the LOS is degraded, the new LOS is still within acceptable service levels. Additionally, as a large majority of vehicles on the roadway have been identified as traveling in excess of the speed limit, the minor increases in travel time on the road should result in lower overall speeds. Lower vehicle speeds correlate with reduced traffic crashes. Research suggests that road diets may decrease crashes by about 19% in urbanized areas such as Livingston Avenue.

The AM peak period is not affected as much as the PM peak period. Various adjustments to signal timings and reducing the flow of traffic provide some mitigation to the increase in delay; additional exploration of other mitigation options might be worth exploring, however one of the objectives of a road diet is to reduce speed, thus one would expect to see delay times increase.

The use of micro-simulation software is one approach to assessing changes in road configurations. This analysis is limited by any inherent assumptions embedded within the model, although our analysis was robust to multiple simulations for each scenario. The standard deviations in travel time and delay were minor for each scenario. Probably the main limitation is how travelers react to a new configuration. Some may divert to alternative routes, some may opt to bicycle along the corridor if it is safer; while we estimated results with up to a 10% reduction in traffic during the PM period, shifts in traffic behavior may be greater.

The decision to move forward with a road diet plan for Livingston Avenue depends on a balancing of the costs and benefits by the City of New Brunswick and Middlesex County. Our benefit/cost analysis that balances the costs of travel time delay with the benefit of reducing crashes, show overwhelmingly positive benefits outweighing the travel time costs associated with the road diet conversion. The net present value over 20 years is estimated to range from $10 million to over $60 million for the road diet conversion. This assumes a 19% crash reduction. All but two scenarios are still beneficial if only a 10% crash reduction is achieved. While we did not have cost estimates for the road diet conversion, costs as high as $10 million do not lead to any negative net present values for the range of scenarios examined.

Our conclusion is that a road diet conversion for Livingston Avenue would be overwhelmingly beneficial for the City of New Brunswick and Middlesex County.

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