COST-BENEFIT ANALYSIS OF BUILDING BICYCLE LANES IN TRURO, NOVA SCOTIA

by

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Abstract

With rising gas prices, the threat of climate change, and the growing problem of obesity, bikeway networks have become increasingly popular over the past few years as an infrastructure to encourage bicycling. This thesis examines the feasibility of building bicycle lanes in the town of Truro. The costs of building a bicycle lane network in Truro are compared with the benefits. The benefits of building bicycle lanes are the benefits of switching from car travel to bicycle travel. The internal and external costs and benefits are quantified following Litman (2009). To compute these benefits, it is necessary to estimate how many people would be likely to switch from using a motor vehicle to using a bicycle if indeed a bicycle lane was in place, and how many additional kilometres would be traveled by bicycle if there was a bike lane. These estimates are found using Statistics Canada census data on number of commuters on each mode of transportation, data on average commuting distance, and previous research on the impact of bicycle infrastructure on bicycle commuting. Once these estimates have been completed, the benefits of bicycling are compared with the costs of construction of the bicycle lane network to find the estimated net benefits. Results show that when only commuters are taken into account, costs of building a bicycle lane network exceed benefits.

1. Introduction

With rising gas prices, the threat of climate change, and the growing problem of obesity, bikeway networks have become increasingly popular over the past few years as an infrastructure to encourage bicycling. The health benefits to the individual cycling and environmental benefits of not driving a motor vehicle are examples of the advantages of choosing bicycling over driving. In many Canadian cities, such as Toronto and Calgary, bicycle lanes have been installed. In the province of Nova Scotia, however, there is a lack of infrastructure and related research.

This thesis attempts to address the research void by examining the feasibility of building bicycle lanes in the town of Truro. The benefits and costs are examined under a variety of scenarios related to increased use of bicycle commuting in Truro. The benefits of switching from automobile travel to bicycle travel are compared with the construction costs of building bicycle lanes to find the net benefits.

2. Background

Truro is the county seat of Colchester County, which was recently named by MacLean's to be the second most obese county in Canada. Over 70 percent of the population is overweight or obese (MacLean's 2012). As a result, there is clearly a need for public policy to address the adverse effects this puts on the provincial healthcare system and the wellbeing of residents. The population of the Truro Census Agglomeration, according to the 2011 Census, is 45,888 people. There is a population density of 16.8 persons per square kilometre (Statistics Canada 2011). This makes Truro a rural area. In comparison, the population density of Toronto is 945.4 persons per square kilometre, and Halifax is 71 persons per square kilometre.

In 2009 the Town of Truro, in conjunction with the County of Colchester and the Village of Bible Hill, funded a study to investigate the community's needs in terms of active transportation infrastructure and how to respond to these needs. This study includes a plan for a bicycle lane and trail network. The network maps are based on public consultation sessions, information and mapping provided by staff, and on researchers' experience with similar projects. The goals for this network were to safely connect communities within the County, to be designated for cyclists, to be a recreational facility and a transportation alternative, and to accommodate cyclists of all skill levels, from recreational to commuter (Colchester-Truro Bikeways Plan 2009, 12). As part of these plans, there are a proposed 31.11 kilometres of on-road bicycle lanes and 24.01 kilometres of signed-only routes, in addition to off-road trails. A bike lane is defined as a facility located in the traveled portion of the street or roadway and is designed for one-way cyclist traffic. Bike lanes are defined on the road through pavement markings and signage (Colchester-Truro Bikeways Plan 2010, 55). Signed-only cycling routes are bicycle routes designated by bicycle route signing along a street. On-road bicycle lanes have an estimated construction cost of $20,000 per kilometre, while signed-only routes have an estimated construction cost of $1,200 per kilometre (Colchester-Truro Bikeways Plan 2010, 72). For this thesis, only on-road and signed-only routes are included, because the off-road trails are more likely to be used for recreationally cycling, while this analysis aims to examine the impacts of cycling commuting only.

3. Literature Review

To investigate the feasibility of installing bicycle lanes in Truro, it is helpful to first look at the results of similar projects in other regions. From previous research, the advantages and limitations of certain methodologies can be learned, and assessing the results of these studies can aid the analysis of installing a bicycle lane in Truro.

3.1 Environmental and health benefits of bicycling

The literature often focuses on the health and environmental benefits of using a bicycle (Dill 2009; Grabow, Spak, Holloway, Stone, Mednick, and Patz 2012). One benefit of using a bicycle for transportation is the health benefit from increased physical activity, while there are also environmental benefits due to the decrease in greenhouse gas emissions from switching from driving in a car to bicycling.

A study done in the Midwestern United States (Grabow et al. 2012) considers both environmental and health benefits from replacing car travel with active transportation. This research looks at both health benefits from decreasing air pollution and from increased physical activity. In the study region of 11 metropolitan areas in the Midwestern United States, with a total population of 31.3 million, the researchers estimate that eliminating 50 percent of short car trips and replacing them with bicycle trips would result in mortality declines of approximately 1,295 deaths per year, including 608 fewer deaths due to improved air quality and 687 fewer deaths due to increased physical activity (Grabow et al. 2012, 73). This study also quantifies the related health impacts, estimating that the combined monetary benefit from improved air quality and physical fitness for the region would exceed $8.7 billion per year (Grabow et al. 2012, 73).

While this study does not examine trail or bikeway infrastructure, it does show the benefits from reduced car travel, which would be a corollary of increased use of bicycles for transportation. The fifty percent reduction in short car trips in this study is an ambitious estimate if there were no direct incentives to individuals to switch their mode of transportation. Also, this study is done in large urban areas; the study region has nearly the same population of Canada. This research concludes that one of the main benefits from increased bicycle use is decrease in air pollution due to motor vehicles. In a rural centre like Truro, the problems of motor vehicle pollution are less significant than in metropolitan areas.

3.2 Role of bicycle infrastructure

One of the few economic studies related to trail system development in Nova Scotia was completed by Janmaat and VanBlarcom (2009, 2013) on a proposed multiuse trail in King's County, Nova Scotia. This research shows that the building of the trail network increases demand for active transportation; that is, individuals indicate that they would walk or bicycle more if there were a trail. Noland and Kunreuther's study (1995) agrees with this, finding that people are willing to bicycle more when it is more convenient and safer to do so. Research by Teschke et al. (2012) on cycling risk in Toronto and Vancouver concludes that existence of bicycle infrastructure like bike lanes significantly decreases the risk of bicycling. Making bicycling safer by installing bicycle lanes may increase willingness to substitute car travel with bicycle travel.

Buehler and Pucher (2011), in their analysis of bikeway networks in 90 of the 100 largest U.S. cities, find that a 10% greater supply of bike lanes is associated with a 3.1% greater number of bike commuters per 10,000 people. This research shows that increased cycling facilities increase the number of bicycle commuters. In another study looking at major U.S. cities, Dill and Carr (2003) conclude that, for cities over 250,000 in population, each additional mile of bike lanes per square mile is associated with about one percent increase in the share of workers commuting by bicycle. However, correlation does not imply causation in either of these cases. People may be commuting by bicycle more because of increased cycling networks, or the cities may be building more cycling networks because people are commuting more by bicycle. Barnes, Thompson and Krizek (2005), who studied bicycle facilities and bicycle commuter shares in Minneapolis, conclude that the introduction of new bicycle facilities increased bicycle commuter share by 17.5%.

The concept of cycling as a primary use of trails is supported by research on trail use (Weigand 2008). Weigand cites studies that show the primary users of multi-use trails are cyclists. Thus, the installation of active transportation networks benefits cyclists more than any other group.

In terms of Canadian research on bike lane networks, Pucher and Buehler (2006) evaluate cycling trends in a variety of Canadian cities. These authors point out that in large cities, such as Toronto and Vancouver, there is an average of 19 kilometres of bicycle facilities for every 100,000 people, while in medium-sized cities, such as Calgary, Edmonton, or Quebec City, there is an average of 62.3 kilometres of cycling facilities for every 100,000 residents (Pucher and Buehler 2006, 106). In fact, all eight of the Canadian case study cities examined in Pucher and Buehler's study have bicycling shares of urban travel roughly three times as high as in U.S. cities of comparable size (Pucher and Buehler 2006, 116). Given the cold climate of Canada, this shows a comparatively high demand for bicycling facilities in this country. However, Pucher and Buehler also observe that the majority of bicycling is concentrated in the urban core. For this reason, in rural and suburban areas like Truro, increasing demand for bicycling could be more difficult than in metropolitan areas. In addition, Pucher and Buehler recommend that bicycling promotion should be combined with incentives to discourage vehicle use in order to effectively increase bicycling demand.

3.3 Cost-benefit analysis of bikeway networks

As far as can be determined, no cost-benefit analyses of bicycle facilities have been carried out for locations in Canada. Cost-benefit analyses of building bicycle lanes have been completed for three cities in Norway (Sælensminde 2004), finding that there are high benefit-cost ratios to building active transportation networks in these cities. Similarly, the City of Copenhagen (2009) carried out a study that estimates the costs (internal and external) of driving a kilometre on a bicycle and in a car, respectively, come to 0.60 and 3.74 Danish Krones.[1] This indicates the cost of driving a kilometre in an automobile is more than six times that of traveling via bicycle. Studies have also been completed in Portland, Oregon (Gotschi 2011), Lincoln, Nebraska (Wang, Macera, Scudder-Soucie, Scmid, Pratt and Buchner 2005) and in various areas of The Netherlands (de Hartog, Johan, Boogard, Nijland and Hoek 2010), and all of these studies

[1] In CAD: $0.11 and $0.67, respectively

observe a positive benefit-cost ratio to building bicycle lanes and/or trails. However, these studies all use different methodologies, so one must be careful when comparing their results.[2]

It cannot be assumed that what is true for European or U.S. cities is true for a rural town in Nova Scotia. Given the main focus of the aforementioned studies being urban centers with a high population density, the estimated impacts of constructing a bike lane as obtained in these studies may not translate directly to a rural town in Nova Scotia such as Truro. Cost-benefit analyses for bikeway networks have not been conducted in towns analogous to Truro. Using bicycles for travel in an urban area with more traffic and a shorter distance has different implications than using bicycles for travel in a small town with less traffic and less population density. With longer distances to travel, there may be more health benefits, but there also may be greater time costs because of a longer travel time. In urban areas, due to high traffic and shorter distances, it is possible that bicycling between two points may take the least time compared to any other mode of transportation. In a rural area, this is unlikely, and one must assume that there are significant time costs associated with bicycle transportation.

As for Canadian research, a study by Litman (2009) estimates per-vehicle mile costs of a variety of modes of transportation for commuting. The costs are

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[2] For example, these studies each had different time horizons for bicycle lane facilities, and intangible factors such as the value of life were valued differently in each study.

broken down into categories of impacts, and the costs of travel at peak and off-peak times are different in urban areas in comparison to the ones for rural areas. Litman shows that the greatest cost to travelling by bicycle is the time cost, while the greatest benefit is the health benefit. Litman estimates that a switch from car travel to bicycle travel will reduce external costs—those costs not borne by the user— by an average of $0.39 per vehicle-mile. At urban peak hours, external costs are reduced by as much as $0.69 per vehicle-mile, and for rural areas, this figure is $0.27. At a population density of 16.8 people per square kilometre (Statistics Canada 2011), the Census Agglomeration of Truro does not meet the 400 people per square kilometre criteria of being an urban area, and can be considered a rural area. Thus, using estimates from Litman (2009) as a reference, it is expected a switch from car travel to bicycle travel in Truro would reduce external costs by an average of $0.27 per each vehicle-mile. This thesis only looks at commuting travel. While other studies, such as Fix and Loomis (1997), have examined the economic impact of recreational cycling, the research that follows looks at the economic impact of cycling solely for commuting, due to data limitations.[3]

To the best of our knowledge, a cost-benefit analysis of cycling or of building bicycle lanes has never been conducted in a rural town like Truro in

[3] Data on mode of transportation for commuting is readily available from Statistics Canada, but there are no estimates for the number of recreational bicyclists.

Canada. The results of the analysis conducted in the thesis can be adopted to conduct an informed policy decision regarding active transportation in other parts of Nova Scotia and Canada.

4. Methods

4.1 Fundamentals of cost-benefit analysis

Cost-benefit analysis (CBA) is a technique often used in making policy decisions. It helps decision-makers choose whether or not to undertake a project by quantifying the costs and benefits in monetary terms. Using a cost-benefit analysis, policymakers can see how much a project will increase or decrease social welfare. It is important to note that a cost-benefit analysis takes into account all the relevant costs and benefits, including not only direct costs but also indirect costs and externalities. Costs that are not borne by the user are still costs and it is important to include them while analysing a proposed project. Another important thing to note about a CBA is that the analysis looks at the economic effects of a project over time. Because of inflation, the value of a cost or benefit now is greater than the value of a cost or benefit in the future. So, when doing a cost-benefit analysis, one must find the net present value of costs and benefits. The following steps for carrying out a cost-benefit analysis have been drawn from Boardman, Greenberg, Vining and Weimer (2011) and Townley (1998).

4.2 Specifying the set of alternative projects

Before finding the net benefits (benefits less costs) of installing bicycle lanes in Truro, it must be clear exactly what this project is comparing. In the case of Truro, the net benefits of installing a bicycle lane network are compared to the status quo. That is, the benefits of installing a bicycle lane are compared to the existing situation without a bicycle lane. Currently, 110 people commute by bicycle (Statistics Canada 2006) and the majority of people commute by motor vehicle. The share of the bicycle commuters in Truro is 0.55% of all commuters. Using this statistic, the incremental benefit of installing a bicycle lane network is calculated.

4.3 Identifying the impact categories and selecting measurement indicators

A number of average per-kilometre costs of commuting by car and by bicycle are examined. The methodology follows closely that of Litman (2009), where the costs per kilometre of commuting by motor vehicle and commuting by bicycle in a rural area are calculated. The difference between these costs represents the net benefit of bicycling. Costs are broken down into 20 relevant categories, which are detailed in Table 1. In addition to these costs, the construction cost of building the bicycle lanes, according to the Colchester-Truro Bikeways Plan (2010), is presented.

Table 1: Explanation of cost categories

Cost	Explanation
Vehicle Ownership	Includes fixed cost of vehicle purchase of lease, insurance and registration.
Vehicle Operation	Includes variable costs of maintenance and repair, fuel costs, and paid parking and tolls.
Travel Time	Places monetary value on the cost of time spent on transportation, including costs to individuals of unpaid time spent traveling, and cost to firms of paid employee time spent traveling.
Internal Crash	Includes costs of damages and risks to the individual traveling by a particular mode of transportation. These include property damages, lost income, emergency response services, medical treatment, and crash prevention expenditures.
External Crash	Includes uncompensated costs of damages and risks imposed by the individual traveling by a particular mode of transportation.
Internal Health Benefits	Represented as a negative cost; a monetized value of the health benefits enjoyed by an individual.
External Health Benefits	Represented as a negative cost; a monetized value of the benefits that a healthy individual has to society.
Internal Parking	Includes parking facility construction, land and operating costs.
External Parking	Includes environmental costs of parking facilities (decreased greenspace, stormwater management costs, and energy consumption of parking facility operation).
Road Facilities	Includes costs borne by the public to build and maintain road facilities.
Land Value	Includes the cost of land used for roadway facilities.
Traffic Services	Includes costs of traffic enforcement and courts, emergency response, driver's training and street lighting.
Transport Diversity	Includes the cost of having a transportation system that is not the most efficient, and the negative cost of having a variety of transport options.
Air Pollution	Includes costs of air pollutant (excluding greenhouse gas) emissions from a mode of transport, including costs to human health, the environment, and aesthetics.
GHG	Includes external costs of emissions of greenhouse gases from a mode of transportation.
Noise	Includes costs of the noise from transportation as reflected in the difference in property values between noisy and quiet areas.
Resource Externalities	Includes the external costs of the production and distribution of resources used in transportation (e.g. petroleum).
Barrier Effect	Includes the cost of delays and inconvenience that motorized modes of transport impose on non-motorized modes.
Land Use Impact	Includes the costs of the impacts of inefficient land use patterns due to use of a certain mode of transportation.
Water Pollution	Includes the external costs of impacts that modes of transport have on the water supply, such as water damage from road salt, and leakage of oil, antifreeze, or other hazardous fluids.

Source: Litman (2009)

4.4 Predicting the impacts quantitatively over the life of the project

The estimates for per-passenger-kilometre costs are taken from Litman (2009), and summed to find the average per-passenger-kilometre-traveled costs for a car and for a bicycle. The difference between these costs is assumed to be the benefit of switching from driving a car to using a bicycle for one kilometre of travel. Using results from Larsen, El-Geneidy, and Yasmin (2010), estimated average trip distance for commuting is 3.067 kilometres. According to Larsen et al. (2010), this is the median cycling distance for commuters in Montreal. While Montreal is different in size and population than Truro, this is the most relevant research completed on commuter trip distance, so it is assumed that the average cycling distance for commuters in Truro is the same as that of Montreal. Having established 3.067 kilometres as the average trip distance, and knowing the average per-kilometre-traveled costs, the cost per trip can be estimated. Because this study is focusing on commuters, two trips per day are assumed: one trip to work and one trip home.

However, it cannot be assumed that individuals are capable or willing to travel by bicycle every day of the year, especially in a climate zone like Truro with plenty of precipitation and a cold winter. According to Brandenburg, Matzarakis, and Arnberger (2007), who studied cycling patterns in Vienna in

2002, weather conditions play an important role in the decision to cycle. In particular, cycling was reduced when there was more than 1 millimetre of precipitation or when the temperature was less than 8° Celsius. So, for this analysis only days with less than 1 millimetre of precipitation and with temperatures of at least 8° C are considered to be cycling-friendly days. Using Environment Canada's historical weather data for 2012, it is estimated that there are 118 cycling-friendly days in a year.

Dill and Carr (2003) and Barnes et al. (2005) show that an increase in bicycle lanes is correlated with an increase in individuals who commute by bicycle. For this analysis, it is assumed that an increase in the number of kilometres of bicycle lanes will increase bicycle commuting. Dill and Carr (2003) estimate that for each additional mile of bike lanes per square mile, there is a 0.998 percent increase in the share of workers commuting by bicycle. Using this figure and the estimated additional miles of bicycle lanes per square mile in Truro from the Colchester-Truro Bikeways Plan (2010), the increase in the share of workers commuting by bicycle due to a bicycle lane can be estimated to be 0.77 percentage points. Out of 19,835 total commuters in Truro, this is about 153 people switching from car travel to bicycle travel. In this analysis, 153 people switching is the high case: the best-case scenario. Barnes et al. (2005), in their study of Minneapolis, estimate that the introduction of new cycling facilities increases commuter share in bicycling by 17.5%. An increase of 17.5% from the current number of bicycle commuters results in an additional 19 bicycle commuters. This is the low case in this analysis: the conservative scenario. It is assumed that the additional bicycle commuters are switching from motor vehicle travel rather than any other mode, because motor vehicle travel currently has the greatest share of commuters. These benefits from switching are compared with the construction costs of building a bikeway network.

Therefore, the equation for the annual benefit is as follows:

$$B_t = net\ benefit\ of\ kilometre\ traveled\ by\ bicycle\ rather\ than\ car\ \times\ average\ number\ of\ kilometres\ traveled\ by\ one\ commuter\ in\ a\ given\ year\ \times\ the\ number\ of\ people\ who\ will\ switch\ from\ car\ travel\ to\ bicycle\ travel$$

4.5 Monetizing all impacts

The monetization of the costs per commuting per kilometre by car and by bicycle is based on the estimates provided by Litman (2009). These estimates are adjusted[4] for inflation and exchange rate to calculate the costs in $2012 CAD.

[4] Litman (2009) estimates per-vehicle mile cost in 2007 USD

4.6 Discounting benefits and costs to obtain present values

The costs and benefits of installing a bicycle lane are computed for one year. However, a bicycle lane network would be in place for more than one year, and thus benefits and costs must be aggregated for all the years it is in use. It is assumed that the bicycle lanes will be in place for 20 years, based on the City of Copenhagen's CBA (2009). The future benefit and costs are discounted; that is, future generations are not given the same weight as users in the present. For this study, a discount rate of 3.5%, as recommended by Boardman, Moore and Vining (2010) is used to find the net present value of the increase in bicycle commuting over a 20 year period. For sensitivity analysis, 2.5% and 7% discount rates are used as well. The formula for the present value of benefits is

$$PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+i)^t}$$

where t is the number of years after the bicycle lane is installed, B represents the benefits in one year, and i is the social discount rate.

Then, total construction costs can be estimated, assuming that the cost for construction of the bicycle lane will be funded by borrowing and are paid back in equal installments. Construction costs, estimated from the Colchester-Truro Bikeways Plan (2010) are amortized over a 20-year period using a 3.5% interest rate (or 2.5% or 7%). Net present value of the construction costs are

$$PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+i)^t}$$

Subtracting these costs from the present value of the benefits of commuting with bicycle travel for the individuals that switch produces the net benefits of installing the proposed bicycle lanes in Truro.

$$NPV = PV(B) - PV(C)$$

<u>5. Results</u>

5.1 Benefits of switching from driving to cycling

In this section, estimates for the difference in costs between cycling and driving are shown, as are the benefits of switching from car to bicycle for a daily commute. Finally, the net benefits of building a bicycle lane network in Truro are presented.

Table 2 illustrates the estimated per-kilometre-traveled costs in 2012 Canadian dollars from Litman (2009) for the modes of transportation of bicycles and the average car. The average total cost, external and internal, of driving a car for one kilometre is $0.577, while this is just $0.228 on a bicycle. The greatest cost of driving a car is vehicle ownership, and the greatest cost of driving a bicycle is travel time. Driving a bicycle also incurs internal and external health benefits, which are represented in Table 2 as negative costs. The difference between the costs of driving a car and a bicycle can be interpreted as the benefits of commuting by bicycle rather than driving a car. Hence, the total net benefit of switching the mode of commute from a car to a bicycle is estimated to be $0.349 per kilometre for an individual.

Table 2: Costs per vehicle-kilometre traveled, car and bicycle, (2012 Canadian dollars)

Cost	Mode		
	Average car	Bicycle	Difference
Vehicle Ownership	0.167	0.041	0.126
Vehicle Operation	0.088	0.016	0.072
Travel Time	0.058	0.23	-0.172
Internal Crash	0.076	0.051	0.025
External Crash	0.034	0.002	0.032
Internal Health Ben.	0.000	-0.058	0.058
External Health Ben.	0.000	-0.058	0.058
Internal Parking	0.025	0.001	0.024
External Parking	0.015	0.001	0.014
Road Facilities	0.010	0.001	0.009
Land Value	0.021	0.001	0.020
Traffic Services	0.004	0	0.004
Transport Diversity	0.004	0	0.004
Air Pollution	0.002	0	0.002
GHG	0.009	0	0.009
Noise	0.004	0	0.004
Resource Externalities	0.021	0	0.021
Barrier Effect	0.005	0	0.005
Land Use Impacts	0.025	0	0.025
Water Pollution	0.009	0	0.009
Total per kilometre	**0.577**	**0.228**	**0.349**

Source: Litman (2009)

The average daily benefit of an individual's commute is estimated by multiplying the total per-kilometre net benefits by the average number of kilometres traveled each day (two trips of 3.067km each), as estimated by Larsen et al. (2010). The daily benefits from one person switching from car travel to bicycle travel for commuting are estimated to be $2.14. Using Environment Canada data and estimates from Brandenburg et al. (2007), the number of cycling-friendly days in 2012 is found to be 118 days. Therefore, it is estimated that the bicycle lanes will be in use for 118 days a year on average. By multiplying 118 days by average daily benefits of $2.14, the annual benefit per person of switching from car to bicycle is estimated to be $252.61.

To find the annual benefits from installing the bicycle lanes, it is assumed that the installation of bicycle lanes will increase bicycle commuting. As Table 3 shows, currently there are 15,465 residents of Truro whose primary mode of transportation to work is driving a motor vehicle, and 110 people use a bicycle for their daily commute.

Table 3: Truro residents' mode of transportation to work

Mode of transportation	Total
Car, truck, van as driver	15495
Car, truck, van as passenger	2115
Public transit	65
Walked	1585
Bicycle	110
Motorcycle	30
Taxicab	150
Other method	280
Total	19835

Source: Statistics Canada

In the high case, an additional 152.73 individuals move from auto commuting to bicycling in the presence of a bicycle lane, while in the low case, an additional 19.25 individuals move from auto commuting to bicycle commuting in the presence of bicycle lane facilities. The yearly benefits of motor vehicle commuters switching to bicycle can be seen in Table 4. If the low case occurs, there are annual benefits of $4,862.75. If the high case occurs, the annual benefits of building a bicycle lane network are $38,581.06.

Table 4: Annual benefits of installing bicycle lane network

	Annual Benefits
Low case	$4,862.75
High case	$38,581.06

Source: Author's calculations

Once these benefits have been found, the net present value of installing these bicycle lanes is found, assuming they can be used for 20 years. These benefits are seen in Table 5. At a discount rate of 3.5%, the net present value of benefits of building bicycle lanes is $73,974.11 in the low case and $586,910.62 in the high case. If future periods are valued more (2.5% discount rate), there is a greater net present value of benefits, and if future periods are valued less (7% discount rate), there is a smaller net present value of benefits.

Table 5: Net present value of benefits

	Benefits		
Discount rates	**2.5%**	**3.5%**	**7%**
Low case	$80,668.95	$73,974.11	$56,378.79
High case	$640,027.44	$586,910.62	$447,309.34

Source: Author's calculations

5.2 Costs of installing bicycle lanes

With a proposed 31.11km of on-road bicycle lanes and 24.02km of signed-only routes, the total construction cost in 2012 Canadian dollars is $696,417.55. (Colchester-Truro Bikeways Plan 2010). In the scenario where construction costs are paid up-front, the estimated net benefits of installing bicycle lanes can be seen in Table 6.

Table 6: Net present value of net benefits if construction costs are paid up-front

	Benefits		
Discount rates	**2.5%**	**3.5%**	**7%**
Low case	-$615,748.60	-$622,443.44	-$640,038.76
High case	-$56,390.11	-$109,506.93	-$249,108.21

Source: Author's calculations

When construction costs are paid up-front, at a 3.5% discount rate, installation of bicycle lanes has greater costs than benefits in both the low and the high cases. This holds true for 2.5% and 7% discount rates as well, with a range of net costs (negative net benefits) between $56,390.11 in the best-case scenario to $640,038.76 in the worst-case scenario.

If the construction costs are not paid up-front, it is assumed that the costs are repaid in annual installments over a 20-year time period. Table 7 shows the construction costs amortized over 20 years using the same interest rates as the proposed discount rates.

Table 7: Construction costs amortized over 20 years

Discount Rate	**2.5%**	**3.5%**	**7.0%**
Construction Costs	$893,463.72	$980,013.77	$1,314,737.80

Source: Author's calculations

To find the net benefits of building the bicycle lanes, the amortized construction costs are subtracted from the benefits. Results can be seen in Table 8.

Table 8: Net present value of net benefits if construction costs are borrowed

Discount rates	Benefits 2.5%	3.5%	7%
Low case	-$812,794.78	-$906,039.66	-$1,258,359.01
High case	-$253,436.29	-$393,103.16	-$867,428.46

Source: Author's calculation

If construction costs are borrowed, at the equivalent interest rate, in both the low and high scenarios, the costs of building a bicycle lane network are greater than the benefits. In every situation, there is an estimated net cost from building bicycle lane networks, ranging from $253,436.29 in the best-case scenario to $1,258,359.01 in the worst-case scenario.

The break-even point of benefits and cost is estimated. At a discount rate of 3.5%, and when costs are repaid over 20 years, costs and benefits are equal when 255 of auto commuters switch to bicycling. This is an increase in bicycling share of commuting of 1.28 percentage points, or a 131% increase in the current number of bicycling commuters. Therefore, if more than 255 individuals who currently commute by motor vehicle switch to commuting by bicycle as a result of bicycle lanes, there is a net benefit of building these bicycle lane facilities.

These results show that given the low number of commuters in Truro, the costs of building a bicycle lane network exceed the benefits. However, because the analysis examined only the benefits in terms of commuters, the net benefits may be understated compared to a scenario that includes recreational cyclists using the bike lanes.

6. Conclusion

As far as can be determined, this is the first cost-benefit analysis of building a bicycle lane network that has been carried out for a rural town in Nova Scotia. It is shown that due to the reduction in internal and external costs, there are significant benefits to an individual and society if a commuter switches their daily mode of transportation from automobile to bicycle. This indicates that it would be in society's best interest to encourage bicycle commuting.

Since increased bicycle lanes are associated with increased bicycle commuting, the construction costs of the proposed bicycle lane network in Truro were compared with the benefits of switching from car to bicycle for commuting. The net present value of the benefits of switching from car to bicycle was calculated and was compared with the total costs of construction of the bicycle lane network to determine the net benefits.

From the results of this study, it can be concluded that the proposed bicycle lanes in Truro, Nova Scotia cannot be justified on an economic basis. It is concluded that the existence of these bicycle lanes will not influence a sufficient number of people to change their commuting behaviour to cycling. If there is a greater than 131% increase in the current number of bicycle commuters due to bicycle lanes, it can be concluded that there is a net benefit of building these bicycle lanes. However, based on previous research, it is not likely that the construction of bicycle infrastructure will increase bicycle commuter traffic to this extent.

Before making policy recommendations, the limitations of this study must be discussed. This thesis only examines bicycling in terms of its use for commuting. However, this is not the only bicycle trip an individual may make. In fact, bicycles, and hence bicycle lanes, are used for other purposes as well, such as transportation to school, shopping, or other non-work destinations, and recreational and leisure use. Thus, the benefits of building a bicycle lane may be understated, as the benefits of the bikeway facilities have not been taken account for these other users. The data on commuting from Statistics Canada took into account only commuters over 15 years of age, not taking into account people younger than that who may commute to school each day on bicycle. The use of bicycles by children and for recreation and leisure use is not as easy to identify and measure, and because of this they are not included in this thesis.

In this analysis, the costs were calculated as total costs, while the benefits were calculated for only one segment of users of the bicycle lane, and hence understated. It is likely that if use of bicycle lanes for recreation and other uses taken into account, results would be considerably different. It is possible that when the benefits from these additional uses of the bicycle lanes are included in the analysis, the benefits of installing the bicycle lanes may exceed the costs.

In the future, further research should be completed to find the estimated increase in bicycle traffic (both commuters and recreational cyclists) in Truro if there were to be a bicycle lane. Should there be a sufficient number of cyclists using the bicycle lane, the project can be justified on economic grounds. Policymakers may also want to complete cost-benefit analyses on other initiatives that may increase cycling.

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