

Uni-Cycle

The Influence of Barrier Perception on bicycle commuting behaviour at Dalhousie University

Prepared by Shawn Barry, Jennifer Kay, Shirley Lui, William Martin,
Anne Publicover and Jessica Wysmyk

Abstract

In Canada, 25% of national green house gas emissions come from transportation. For this reason, transportation is seen as an important area to examine as a Greening the Campus initiative at Dalhousie University. In order to further understand sustainability issues with transportation on campus, this project sought to determine the influence of barrier perception on the bicycle commuting behaviour amongst Dalhousie's student population. The research carried out was primarily for descriptive purposes and used a mix of inductive and deductive methods. The primary research tool was a survey of the student population that collected baseline data on commuting habitats and qualitative responses on questions specific to bicycle commuting. The data collected revealed that 87% of commuting by Dalhousie students is by sustainable modes, with walking accounting for the largest group (58%) and bicycling the smallest (7%). The research also showed that the five strongest barriers to bicycle commuting are: weather, travel time, wind, car traffic, and safety. When these results were analyzed however, it was shown that there were very weak relationships between barrier perceptions and the actual number of trips by bicycle. It was also discovered that 65% of students at Dalhousie live within 2 km of campus. With these two results it became clear that social factors and local environment are likely more significant determinants of travel behaviour than the perception of physical barriers. Based on this conclusion it was recommended that Dalhousie develop a comprehensive sustainable transportation plan that examines all modes of travel together. This plan should include provisions for transportation and demand management and mixed mode use. This recommendation also suggests that pedestrian facilities and environments are the most important area of focus for sustainable transportation on campus. Bicycles are still seen as an important mode for commuting and could possibly be provided for with the construction of pedestrian friendly infrastructure; but will not likely increase in use until more is known about the social influences in commuter decision making.

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1.0 Introduction

The 2006 report on Human Activity and the Environment, released by Statistics Canada, found that emissions generated by transportation activities account for one quarter of total national green house gas emissions. Results released by GPI Atlantic (2006) also showed that Halifax Regional Municipality (HRM) commuters drove close to three hundred million kilometers in their cars in 2001. Despite heightened awareness of the impacts of this travel behaviour, more Canadians are driving to work today than they ever have in the past (Statistics Canada, 2006). In an effort to encourage more sustainable commuting behaviour, HRM released a Bike Plan in 2002. The plan indicated that two-thirds (67%) of workers throughout the HRM rely on motor vehicles for commuting; however, on the Halifax Peninsula, less than 37% drive, more than 32% walk to work, 13.5% use public transit and nearly 3% cycle (HRM 2002). The extent to which travel patterns amongst students at Dalhousie University compare with these statistics was unknown prior to this study. It was understood, however, that transportation is an important factor when considering campus sustainability. Because it is widely recognized that bicycling offers a potentially more sustainable commuting option, it is key to understand how this mode of transportation could be encouraged amongst university commuters. This project sought to address this question by researching the main perceived barriers to cycling as a primary commute mode for Dalhousie Students.

By identifying the barriers to cycling, this project hopes to facilitate an increase in bicycle ridership. A 1995 study by Noland found that a decrease in risk barrier perception influenced modal shifts and that bicycling had a disproportionately higher shift than other

modes. Pertinent information at Dalhousie, derived from this study, could therefore be invaluable to transportation-related Greening the Campus initiatives.

2.0 Background

Several studies have investigated barriers to cycling and what motivating factors encourage this transportation mode. The following literature review will explore some of these topics to enhance the understanding of barriers perceptions and their relationships to bicycle commuting.

2.1 Physical Environment

The built environment heavily influences how people travel in the city (Handy et. al 2002). Much evidence suggests that pedestrian and bicycle-friendly urban design promotes active, healthier, and more livable communities. High population density, mixed land use, street connectivity, human scale design, and aesthetic qualities have all been shown to correlate strongly with decreased perception of barriers to walking and cycling (Handy 2002). The direct provision of bicycle facilities has also been seen to strongly influence barrier perception. In a 1993 study of bicycling to work around Seattle, Washington, Shafizadeh and Niemeier found that in general, cyclists would rather cycle longer distances on a bicycle path than cycle shorter distances on the street with vehicular traffic. Lack of paths created specifically for bicycling, then, is a specific barrier related to a planned environment.

A review of case studies by Pucher, Komanoff and Scimek found that, although the number of bicycle trips doubled in the United States in the 1980s and 1990s, structural changes in

policy are needed to make cycling a widespread mode of urban travel. US efforts to promote bicycling have generally focused on building bike paths and bike lanes. Although cycling facilities are necessary, they must be “complemented by a comprehensive program to make all roads bikeable, through both physical adaptations and enforcement of cyclists’ right to use the road” (Pucher 1999). For example, though New York City has flat terrain and is well lit, pavement is typically uneven, bike paths on bridges connecting boroughs are substandard and/or closed, and traffic is extremely heavy (Pucher 1999). The key to overcoming these barriers, the authors suggest, would be a series of bike lanes. Currently, only 1% of New York streets provide such lanes.

A barrier less often associated with the built environment is distance. Today’s sprawling development tends to place people farther from goods and services they need, and can be a deterrent to traveling by bicycle. According to a National Personal Transportation survey, distance is the most common barrier to both walking and biking (Pioneer Valley Regional Bicycle and Pedestrian Transportation Plan 2000).

2.2 Concern for Safety

Another barrier to bicycling is its perceived high-risk level, especially on streets where cars and bikes share the same road. Since driving an automobile is seen as a safer form of transportation, concern for safety is then a barrier to bicycling as a more sustainable commuting choice. According to Pucher (1999), walking and cycling are roughly three times as dangerous as riding in a car, on a per trip basis. Bicycle safety campaigns in North America have tended to focus only on promoting helmet use. Not only has this not addressed larger safety issues, and placed the safety burden solely on cyclists, it has also been

shown to have a very minimal reduction in hospitalizations due to head injury for cyclists (Pucher 1999). Interestingly, a study of 68 California cities in 2000 illustrated that, the greater the number of bicycle commuters, the lower the risk of injury (Noland, 1995). Work by the Bicycle Federation of Australia similarly found that cycling is safer in countries where more people cycle (Bicycle Federation of Australia).

2.3 Weather

Research on bicycle use suggests that weather may be one of the strongest barriers, and one that is perhaps the most difficult to address (Brandenburg, Matzarakis and Arnberger 2003). As one might expect, more people are willing to bicycle in fair weather conditions than in precipitation or the cold. In a study of 1000 commuters, a group of Swedish researchers determined that the number of car trips increased by 27% from summer to winter and bicycle trips declined by 47% (Bergstrom and Magnusson 2003). A 1990-1991 study of Seattle bicyclists indicated sharp declines in the number of bicyclists during the rainy season (US Department of Transportation). In a national bicycling and walking study, 86 percent of respondents from Boston and 90 percent from Gainesville, Florida listed Adverse Weather Conditions as an influential factor in deciding not to bicycle (US Department of Transportation).

2.4 Convenience

In the National Bicycling and Walking Study, the US Department of Transportation lists convenience as a primary factor in bicycle-use decisions. Surprisingly, studies indicate that bicycle commuting is considered more convenient than car commuting. In a 1989 “Go Boulder” program in Boulder, Colorado, efforts to reduce traffic congestion and air pollution introduced a series of programs to encourage use of alternate forms of

transportation. The “Non-Polluting Commuter Race” event matched bicyclists up against automobile drivers. Each was given a series of tasks to do around the town; the goal was to see which mode of transportation was actually faster. The cyclists won every year, and Boulder bicycle trips increased by 2.2% (GoBoulder).

Scottish cyclists claimed that a convenience-like motivation for them was being in more control of their time (Crawford). Without being subject to traffic jams, the responding cyclists did not feel at the mercy of such time wasting variables on the way to work.

2.5 Health Benefits

According to a survey of bicycle commuters, nearly 95 percent of those who commute by bicycle said that health and fitness were important motivations in bicycling to work (Moritz).

A Danish study in 2000 also provided evidence that cycling to work reduces causes of all mortality risks (Andersen et. al 2000). This study also showed a strong link between time spent driving in a car and obesity. In the study, every additional 30 minutes spent in a car each day increased a person’s chances of being obese by 3 percent.

2.6 Concern for the Environment

The desire for a cleaner environment is one of the biggest motivating factors for those who choose to bicycle. Moritz’ s survey indicates that concern for the environment was a motivating factor for 81.6 percent of respondents. Participants in the same Scottish study cited above also indicated environmental concerns when asked what motivated them to cycle to work (Crawford).

2.7 Monetary Incentives

Economists would argue that, if people acted in their own self-interest, more people would bicycle if it makes economic sense to do so. Bicycle advocates on the other hand, list both concern for the environment and cost savings as motivating factors for cyclists. The US Department of Transportation has calculated that the estimated cost for bicycling is \$0.05 per mile compared with \$0.35 to \$0.45 per mile to drive an automobile. This study suggests that because few people actually calculate the true costs of their transportation choice, they do not have the sufficient information to realize the significant savings bicycle commuting offers. Another US study also indicates that these costs are greatly influenced by demographics and social trends such as trip length and personal income (Everett; Shafizadeh et. al).

2.8 Conclusions

In general, it appears that there are several dimensions of barriers to cycling. Perhaps the most significant dimension, for development and policy, is the built environment. This level is mostly influenced through institutional and municipal level decisions. A second dimension is personal health and safety: namely the perceptions of physical injury risk versus actual long-term health benefits. This level is primarily influenced through public education. A third dimension includes the external influences of weather and social factors. Poor weather provides strong disincentives with few opportunities to create counter-balancing incentives for bicycle ridership. Social factors contain complex issues of individual habits, ethics, and economics, requiring deeper societal changes. All of the dimensions have numerous specific barriers as well as requirements for different levels of planning to address the final choice to commute by bicycle.

3.0 Research Process

It was important that the methods used in this project precisely reflected our research question and objectives. Group understandings of the goal, purpose, research question definitions, and project approach are delineated below.

3.1 Research Question and purpose

The research question was founded upon two primary Dalhousie campus objectives: a) to gather information on the perception of barriers to bicycle commuting, and b) to collect baseline data against which those perceptions could be compared. The first objective worked towards the goal of informing and facilitating the choice to commute by bicycle. The second was a longer-term approach that aimed to set a baseline for tracking trends over time in response to cycling promotion initiatives. This baseline data also allowed for direct correlations between barriers and actual bicycling behaviour to be analyzed.

3.2 Research Tools

The orientation of this project was primarily information gathering, and the project approach was primarily descriptive. Two distinct methods were employed, one more deductive in nature, the other more inductive. The project's central method was an information-gathering questionnaire of closed-ended questions (see appendix I). The questionnaire contained both quantitative questions such as age category and distance from school, as well as qualitative questions such as positive or negative reactions to given aspects of cycling. This was a deductive approach based on the theory that perceived barriers influence transportation choices. This component of the methods strived for breadth of information at the expense of deeper, explanatory understandings of the social psychology behind transportation

decisions. The questionnaire enabled correlation between amount of bicycle commuting, both in terms of trips taken and distance traveled, to the strength of perceived barriers. A secondary method of installing open-response poster-boards (with markers attached) in buildings around campus helped us to develop the surveys. Each board asked generally what students liked and disliked about cycling to campus, and invited them to make comments on the board. The posters were placed in high traffic student spaces and gathering spots on each campus. This method served several purposes. First, it built a list of locally relevant perceived barriers, which may not have been covered in the literature review or considered by the researchers (who all cycle). This improved the comprehensiveness and validity of the questionnaire. Second, this method was a more exploratory approach that did not assume “perceived barriers” are what limited cycling to and from campus (for example, perhaps the main impetus behind not cycling was a particular enjoyment of driving). This method complemented the deductive, theory-based method with an inductive method that questioned and informed the original theory.

3.3 Definitions

The relationship between the objectives and methods has been explained. However, in order for these methods to be valid and reliable, continuity between the specific research question and the methods must be ensured. This requires some defining. As previously mentioned, our researchable question is: What is the Influence of Barrier Perception on bicycle commuting behaviour at Dalhousie University.

3.3.1 Nominal definitions

“Perceived barrier”: any physical or conceptual deterrent, as viewed/understood by students

"Campus": Dalhousie University property composed of Sexton, Carlton, and Studley campuses

"Main": cited by a statistically significant number of respondents

"Commuting": traveling to and from Dalhousie University as a place of occupation

3.3.2 Operational definitions

- a) Measuring barriers in terms of student perception would more accurately indicate the reasons behind the choice not to cycle. Accordingly, “perceived barriers” will be measured through responses to pertinent, accurately worded survey questions, as well as through public communication forums (posters- see section 3.2).
- b) To standardize researcher and respondent understanding of “campus”, the specific region will be clearly indicated on a map by a colour zone.
- c) “Commuting” will refer to one-way trips between a student’s place of residence and Dalhousie, and will be specified as such on the questionnaire so measurements are consistent.
- d) Lastly, “main” barriers will be operationally defined as those cited by a statistically significant portion of the population at the defined orders of strength as measured by the survey (ratings of 1 for no barrier to 6 six for strongest barriers)

3.3.3 Methods Validity and Reliability

These operational definitions help secure the validity of the project methods. Additional means of validating the methods include the directness of the survey questions (directly and indirectly asking the research question) and the triangulation provided by the poster method. Possible lurking variables from the survey, such as influence of the researcher’s presence or wording that subtly encourages a particular answer, were removed in the poster forum.

3.3.4 Sampling Methods

The survey method took a representative sample from the population of both undergraduate and graduate Dalhousie students. Because this included all students, our population was a heterogeneous mixture of cyclists, non-cyclists, users of other forms of transportation and included differences in age, sex, and faculty enrolment. To better represent the diverse population, the sample was divided into the three main campuses: Studley, Carleton and Sexton. The total population of students (15,549) was proportioned by campus to set sample size, with results aggregated back to the full university scale. The number of students on each campus and the sample size needed for each is outlined in Table 1. The results from this sample were sought at a confidence level of 95% with a confidence interval of plus or minus 4% (CI = 95% +/- 4%) This required a total sample size of 578 students. See equation 1 for formula.

Equation 1: Determination of sample size for each campus.

$$\text{Campus sample size} = \frac{\text{Number of students on specific campus}}{\text{Total number of students}} \times \text{total sample size}$$

Surveys were distributed on each campus near the main entrances of several buildings at varying times of day. The first respondent was selected at random at the beginning of the session. From then on, in a systematic fashion, every third person was asked to participate. Quotas were set for each campus (see Table 1.) and sampling was continued until they were met. The complete survey has been included in Appendix I. For ethical reasons, the

voluntary nature of this survey required that each selected respondent be counted in the systematic process whether or not they agree to fill out the survey (see ethical form for further explanation).

Table 1: Number of students required from each campus

Campus	Studley	Carleton	Sexton	All
Sample size	336	169	73	578
Total # students	8829	4419	1912	15,549

3.4 Limitations

- 1) Due to time and sampling frame limitations, perfect probability-based sampling was not an option. Reliability was ensured through clearly explained methods and slightly altered probability-based sampling techniques (see above).
- 2) There was no exhaustive list from which to make a completely random start. In an attempt to remove researcher-biased selection, every third passing student was approached as a potential respondent.
- 3) The survey numbers in the end fell 6 surveys short of our quota (572 out of the required 578), which potentially affected our reliability.
- 4) Differing respondent reactions to various group members could have potentially affected our methods reliability as well as time of day and weather conditions during the survey, but this was unavoidable and likely insignificant. We precisely recorded all methods for future replication.

- 5) The survey mainly explored physical barriers and not social influences on commuter behaviour.
- 6) The survey was done in the winter; therefore, weather conditions at the time the surveys were being conducted could have influenced the answers of respondents (especially the rating of weather as a barrier).
- 7) There is a possibility that since the survey was given to students with varying experience commuting to the University (ex- first, second, third, etc year of study at Dalhousie) some respondents may have been better equipped to comment on barrier strength.
- 8) Some important barriers may not have been identified by the poster comments or researchers experience.

4.0 Results

4.1 Behaviour and Barrier Perception

Dalhousie student travel habits were broken down by number of trips into five categories, each representing a transportation mode. Figure 1 illustrates the percentage of trips undertaken in each category. The most popular mode of transportation was walking (58%). Public transit accounted for 22% of the total school trips, followed by motorized vehicles with 12%. Only 7% of the trips were taken by bicycle. Other forms of transportation, such as roller-blading and skateboarding, accounted for 1% of the total student trips. Notably, sustainable modes of transportation, such as walking, bicycles, and public transit, accounted for 87% of trips.

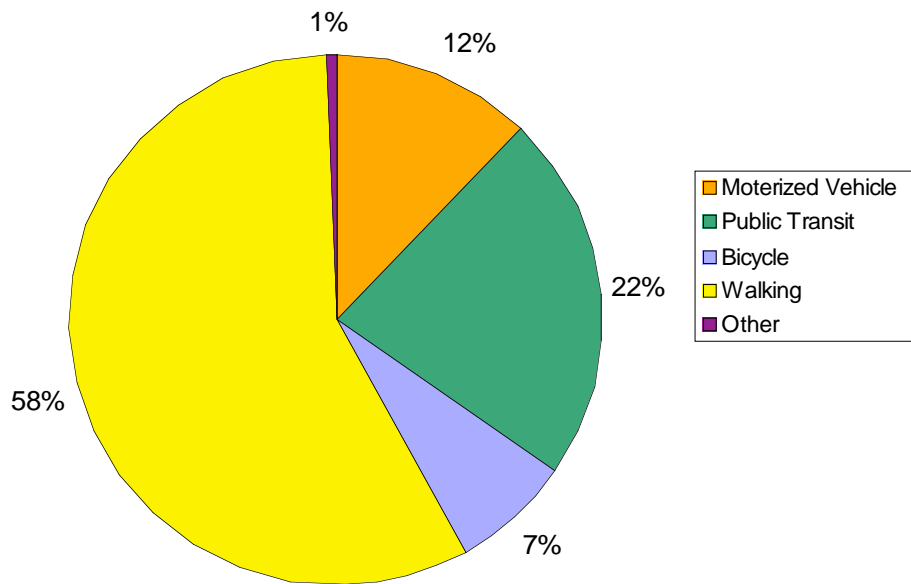


Figure 1 Percent trips by transportation mode.

Relative barrier strength was assessed by each individual using a ranking scale between 1 (not an impediment at all) and 6 (very strong impediment). Based on the total summed values for each barrier, the 5 strongest barriers were found to be poor weather, strong wind, travel time, automotive (car) traffic, and difficult/ awkward load (Figure 2). The weakest barriers to cycling were riding confidence/skill, unprofessional image, and health issues.

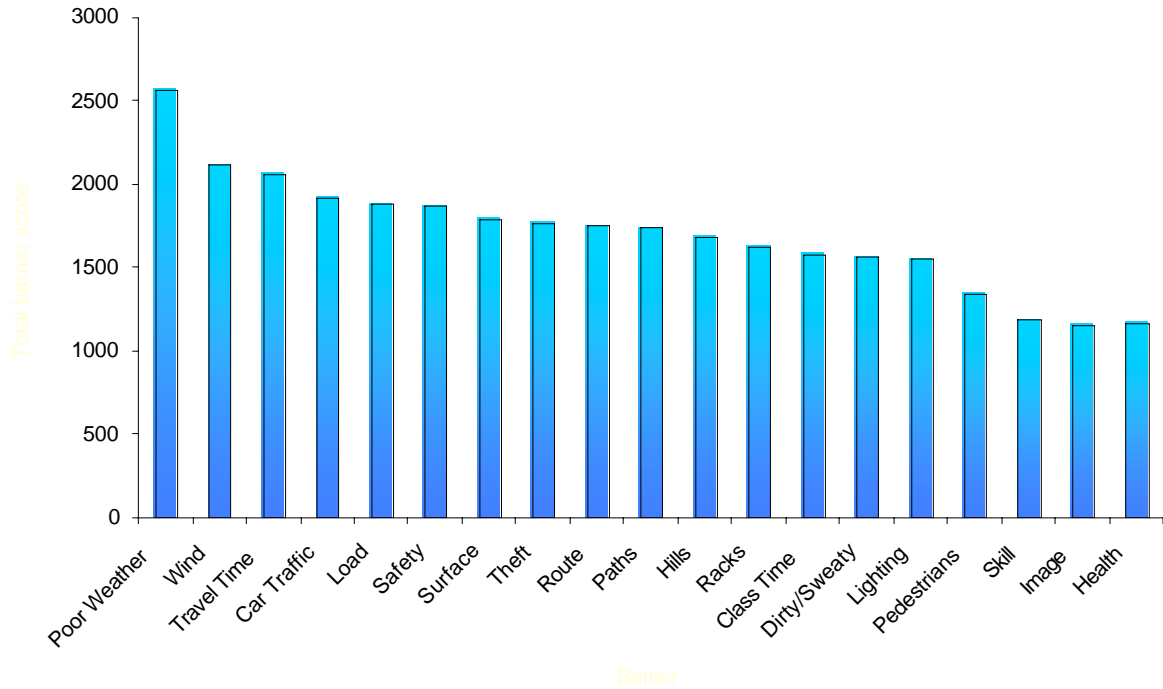


Figure 2: Total strength of barriers.

Figure 3 illustrates the sums of individual high-scores (strong [5] and very strong [6] impediments) in the ranking scale. This figure represents barriers which were of the highest concern, excluding accumulated scores of barriers which rated mid-scale. Poor weather again had the highest score. Other top-scoring barriers were travel time, strong wind, automotive traffic, safety risk, and difficult route (in descending order). Low-scoring barriers included health issues, pedestrian traffic, and unprofessional images (their summed scores of 5 and 6 were the lowest).

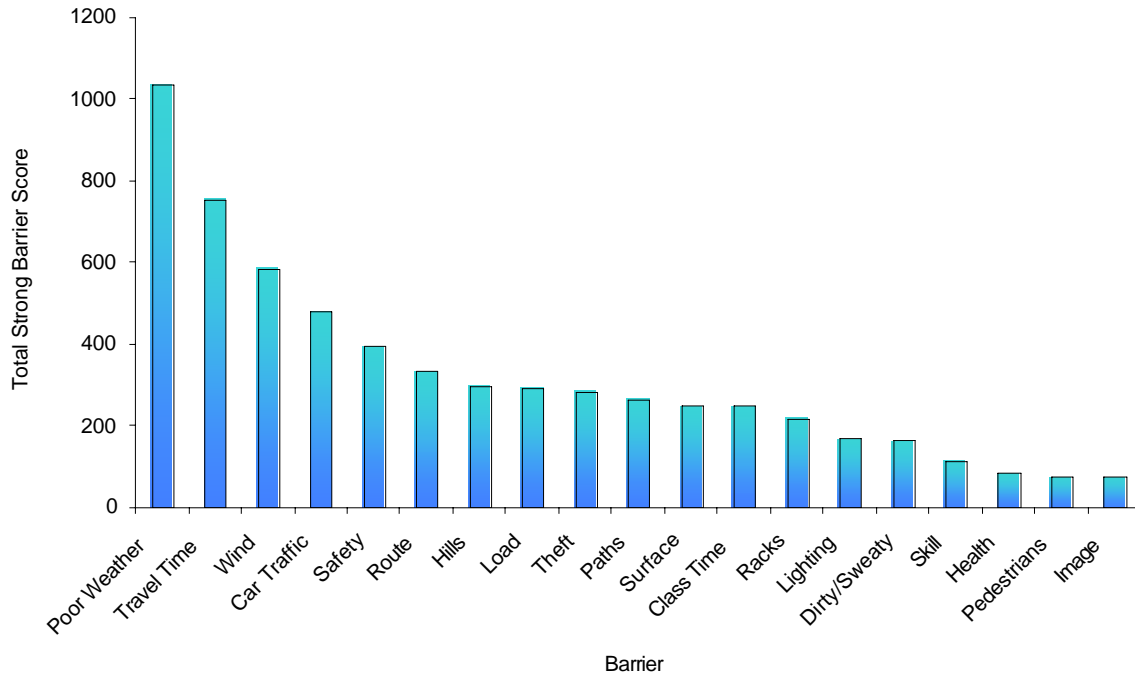


Figure 3: Top-Scoring Barriers

Regression analysis was used to evaluate the relationship between various barriers and number of trips by bicycle. Total barrier strength vs. modal share by bike showed a significant negative relationship ($p < 0.001$), indicating that respondents were less likely to bike as the strength of perceived barriers increased. However, little of the variability in trips by bicycle was explained by variation in total barrier strength ($R^2 = 6.8\%$), meaning that other factor(s) largely determined number of trips by bicycle.

To see if individual barriers could explain this variation more effectively, the top five high scoring barriers were tested against the number of trips by bicycle as well. The barriers selected for these analyses included weather, wind, travel time, motor vehicle traffic, and safety. These barriers were selected not only because they had a high total score, but also

because a high frequency of respondents rated them as high scoring barriers (strong and very strong impediments to bicycling). In all cases a significant negative relationship was found between each barrier and the number of trips by bicycle ($p < 0.01$). However, they were likewise found to explain little of the variability in number of trips by bicycle. Weather, the top scoring variable, accounted for a negligible portion of the variability ($R^2 = 1.2\%$), as did wind and travel time ($R^2 = 2.4\%$ and $R^2 = 4.8\%$ respectively), and motor vehicle traffic and safety concerns ($R^2 = 2.4\%$ and $R^2 = 1.8\%$ respectively). Individually, the top scoring barriers accounted for slightly more of the variability found in modal share by bicycle than did total perceived barrier scores (The R^2 sums exceeded the total barrier strength R^2 of 6.8%). However, they still accounted for very little of the total variability observed, leading to the conclusion that other factor(s) influence the number of trips by bicycle.

4.2 The influence of weather on barrier perception

Figure 4 shows a range of preferred cycling weather conditions. The most favorable conditions included sun and summer, each of which 97% of the respondents that they would bike in. Spring and fall conditions were also considered favorable by 90% and 85% of respondents (respectively). The least favorable condition was hail; 95% of the population indicated that they would not cycle in this weather condition. Other less preferable weather conditions such as snow, below -10c, and winter in which conditions 90%, 90% and 85% of the population respectively indicated that they would not cycle. In general, cycling to school was found to be more acceptable during fair weather.

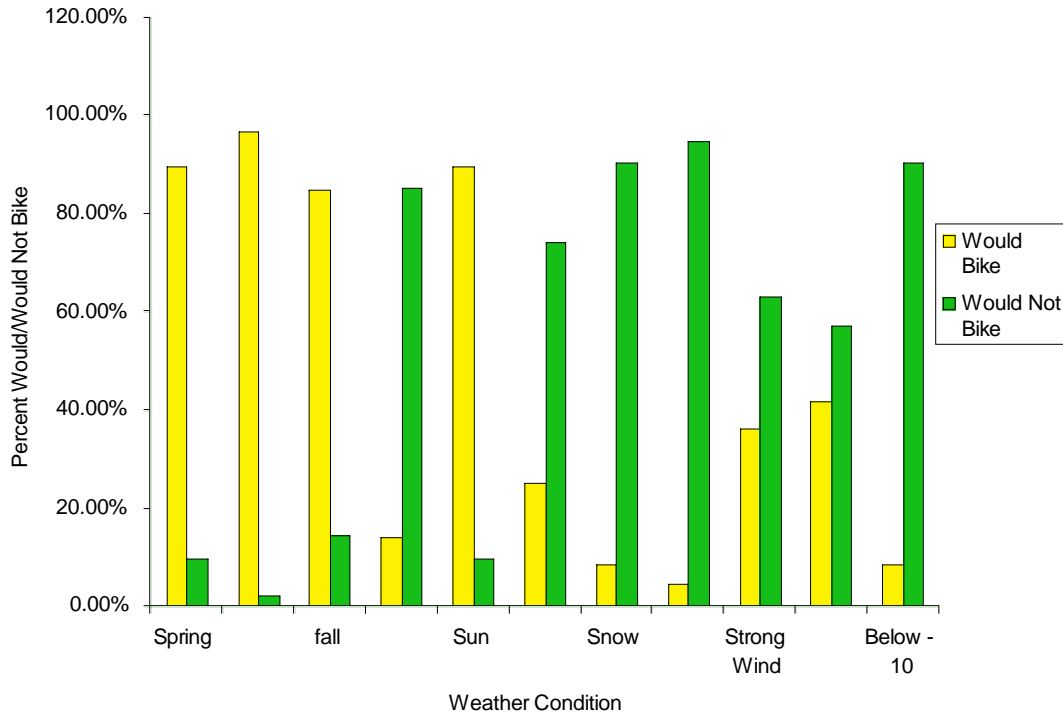


Figure 4 Weather Conditions

4.3 Demographics and social trends

A significant positive relationship was found between both age, and number of years at Dalhousie and number of trips by bicycle ($p < 0.014$ and $p = 0.001$ respectively). However, neither of these variables explained a significant amount of the variability in number of trips by bicycle ($R^2 = 1.1\%$ and $R^2 = 1.9\%$ respectively). No significant relationship was found between gender or level of schooling (undergraduate vs. graduate) and number of trips by bicycle.

Students were found to have a mostly positive perception of various social, economic, ethical, and physical attributes of cycling (Figure 5). Physical fitness (94%), environmental ethics (92%) were perceived to have the greatest positive influence on cycling behavior,

followed by pleasure and cost, which accounted for 86% and 81%. Travel time and social factors had the greatest negative influence; 32% and 20% of the surveyed population, respectively, indicated that they perceived these aspects of cycling negatively. The majority of students felt that bicycling was safe (64%) (Table 2), while an overwhelming majority reported that they enjoyed cycling (87%).

Table 2. Attitudes towards cycling.

Attitude	Yes	No
Safe?	63.67%	34.60%
Biking=Fun?	87.37%	11.42%

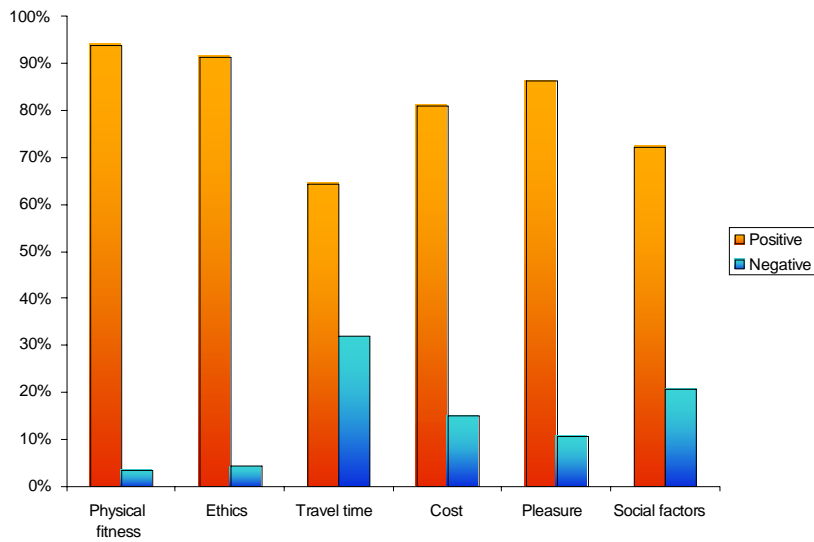


Figure 5 Attitudes towards several aspects of cycling

4.4 Access

Of all students surveyed, 36% were found to have access to a motor vehicle, while 63% did not, which is about the same amount of students who did not have bicycle access (61%) (Table 3).

Table 3: Access to transportation modes

Vehicle Access	Yes	No
Motorized vehicle access	35.99%	62.63%
Bicycle Access	37.37%	61.42%

A significant positive relationship was found between access to a bicycle and number of trips by bicycle ($p < 0.001$). Access to a bicycle explained a minimal amount of the variability in number of trips by bicycle ($R^2 = 16.2\%$). A significant negative relationship was also found between access to a car and number of trips by bicycle ($p = 0.02$). However, access to a car explained a negligible amount of the variability in number of trips by bicycle ($R^2 = 0.9\%$)

4.5 Infrastructure

Over 75% of those individuals surveyed felt that they lived within cycling distance from campus (Table 4).

Table 4. Percentage respondents who felt they lived within biking distance.

Yes	No
75.26%	23.36%

Despite this, commute distance from campus was thought to have explained some of the variability in number of trips by bicycle. Regression analysis was used to test for a relationship between commute distance and the perception that this distance was reasonable to commute by bicycle. A positive significant relationship ($p < 0.001$) indicated that as commute distance from campus increased, the number of respondents who felt that the distance was too far for a commute by bicycle increased ($R^2 = 30.9\%$). A chi-squared analysis was used to determine the threshold distance at which the majority of commuters felt the distance was too far to commute by bicycle. This distance was found to be between five and six kilometers (Figure 6). Regression analysis was used to test for a relationship between commute distance from campus and number of trips by motor vehicle. A significant positive relationship was found ($p < 0.001$), however, a minimal amount of the variability in number of trips by car was explained by commute distance ($R^2 = 17.4\%$).

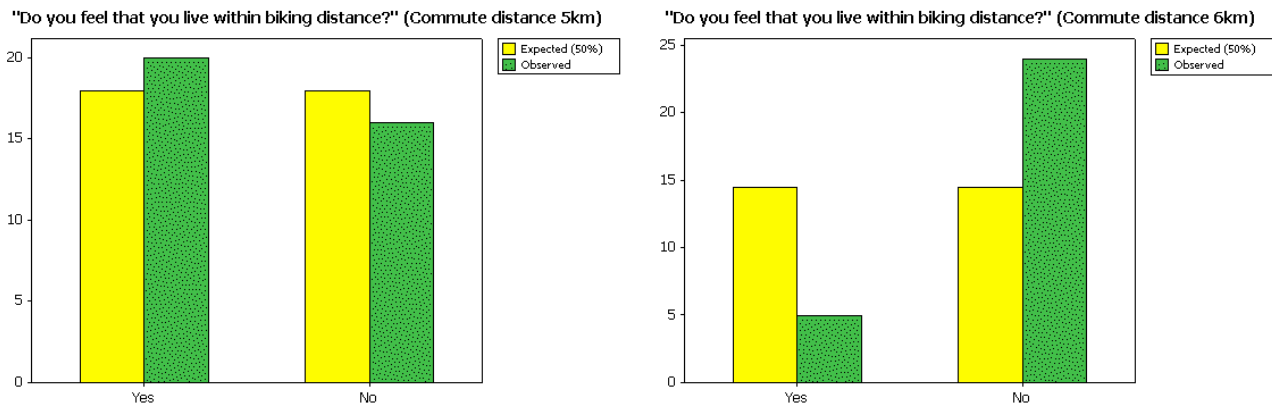


Figure 6 Threshold distance between which commuters felt that they no longer lived within biking distance.

When asked which routes they preferred when cycling, the 35% of respondents chose fast/short routes over all other routes (Table 5), 31% chose side roads, and 21.5% chose main roads. Only 7% chose paths.

Table 5. Route selection

Route	Percent Selected
Main Roads	21.50%
Fastest/Shortest	35.84%
Side Roads	31.12%
Paths	7.34%

Route selection was based on several factors (Figure 7). The majority of commuters selected speed (45%) as their primary reason for route selection. Safety was the second highest factor; 30% of students claimed to select their route with safety in mind. Half as many selected their route based on congestion and traffic patterns (16%). Surface condition (4%) and avoiding obstacles (4%) did not heavily influence route selection.

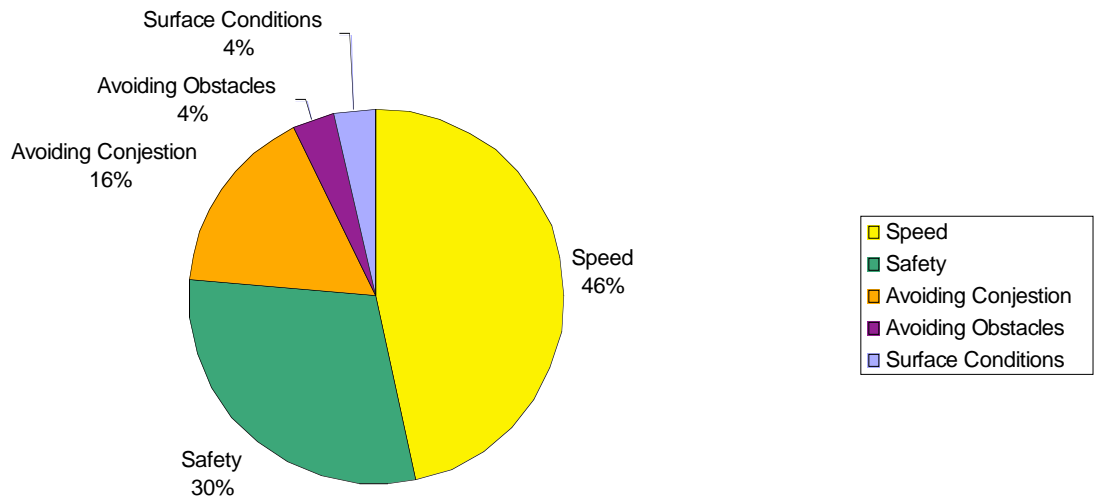


Figure 7 Reason for Route Selection

When asked if they considered maintenance to be an impediment, 26% of the respondents replied that they did, while 74% indicated that they did not (Figure 8).

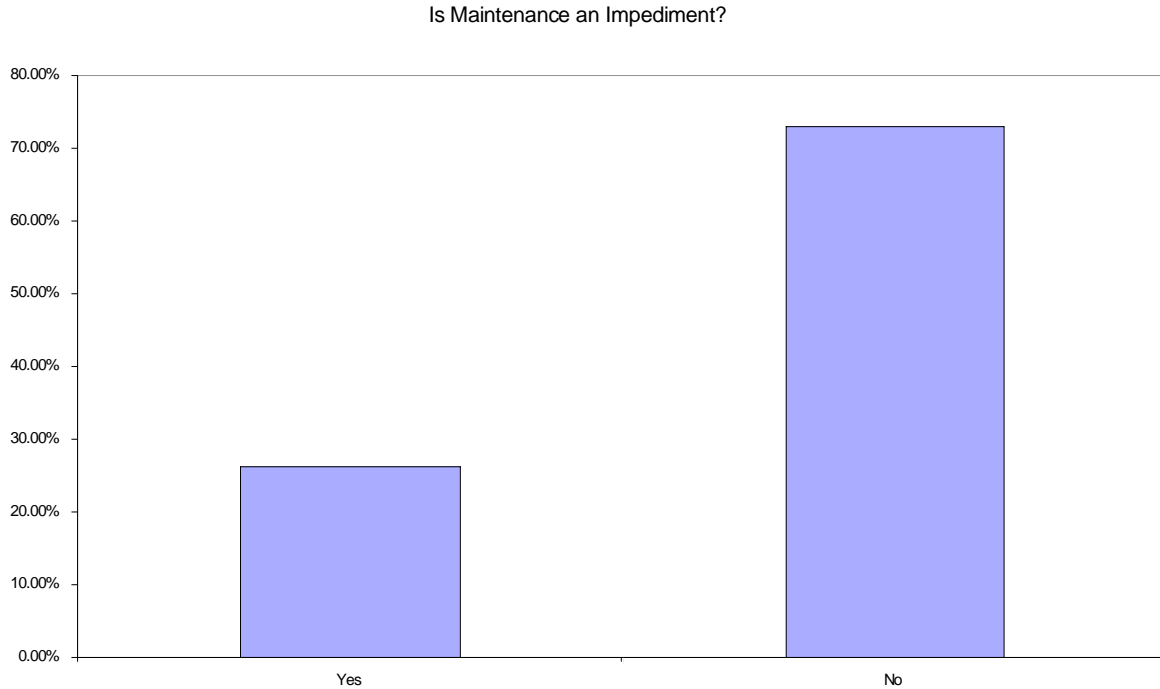


Figure 8 Maintenance as an impediment to cycling.

5.0 Discussion

5.1 Examining the Research Process

The results of this project have revealed a few key limitations in the research process itself. The first of these was the spatial challenge of the research period. This project was carried out in the winter semester, a time in this northern climate where weather related barriers are understandably stronger. The fact that weather scored as the strongest barrier (see Figures 2 and 3) was perhaps overly influenced by this research time frame. This result is also regionally specific. It is likely a much more influential factor in Halifax than in comparable research carried out in a more southern climate. As such the research could have been designed differently to account for regionally specific limits to bicycle utility.

The second major challenge exposed by the results of this research is the unexpectedly low numbers of cyclist respondents (Figure 1.). Although the study was designed to be inclusive of both cyclists and those who choose other modes, there was some unconscious reliance on results from actual bicycle experience to balance with what is perceived by users of other modes. It is very possible that students with no experience with the real conditions of cycling to and from Dalhousie may be carrying preconceived perceptions developed in other communities. This would create a disproportionate influence on barriers that may not actually be locally as important (Figure 2). The low numbers of cyclists also created challenges to the regression models. Essentially there were so few trips taken by bicycle compared to other modes that the much the larger set of variables in barrier responses had to be correlated to too few trips. The variability created by this relationship may have weakened the relationship between barrier strength and bicycle behaviour to a disproportionate extent (See results section on Behaviour and Barrier Perception). Although the research was deliberately inclusive to users of all modes, these limitations suggest it may have actually been more accurate to design in some controls that separated cyclist responses from those of non-cyclists.

The final issue in the research process that was exposed in the results was the lack of data collected that could examine a null hypothesis. Although the basic research question was exploratory in nature, the data collected was clearly geared toward the hypothesis that barrier perception did strongly affect and explain behaviour. Most questions were then based on trying to understand which factors were most important so that sustainability planning could focus efforts on addressing those barriers. However, with such a weak relationship between barriers and actual travel behaviour, the implications or possibility for recommendations from this research is much diminished. The research is also left with the somewhat ambiguous conclusion that social factors must be the primary influence on travel behaviour (see Demographics and social trends section and Figure 5). Had the methods sought to further define “social factors”, results may have been more conclusive.

5.2 Theoretical Results Explored

The primary implication of the results in this research is the fact that barrier perceptions are shown to have limited influence on commute mode selection (see Behaviors and Barrier

Perception in Results). Because the barriers examined were more physical in nature (based on literature reviews and inductive research), the implications is that psychological factors are the stronger influence. Unfortunately these ill-defined “social factors” have not been adequately examined by this research to draw many conclusions. This result is challenging to greening the campus initiatives because it suggests that a campus attempt to increase the sustainability of transportation choices is a complex (or “wicked”) problem. A recommendation to address the cultural barriers to bicycle use is not nearly as simple to enact as one to create a bike lane. This result highlights a need for future studies specific to social influences on transportation behaviour, as well as for sustainability initiatives that can affect decision making at a psychological level.

Another interesting implication of these results is the unexpected high level of walking and public transit (Figure 1). As stated in the Behaviours and Barrier Perception section in the results, 87% of commute trips can be considered to use sustainable modes (mostly walking and transit). Although the level of biking is low (7%) there is no indication that this has a consequence of a high level of driving. In that light one has to ask whether or not low levels of cycling is really a concern that needs to be addressed. There is also the question that if bicycle commuting was encouraged would it not actually just defer walking or transit trips instead of reducing driving behaviour. Some research has suggested that most increases in bicycle use come from people who used to walk (Noland, 1995). If this were to hold true at Dalhousie, a shift to higher levels of biking might actually increase total impacts of travel behaviour.

Somewhat related to the above is the result that 65% of students live within 2km from campus. At this distance there is some question as to the utility of bicycles. Many respondents made comments that “they lived too close to bicycle”. At this trips distance there is the possibility that the added cost of bicycles over walking cannot be justified. Again this affects the type of research that should be carried out in future on sustainable transportation at Dalhousie. Specifically future research should examine the levels of support for this, most sustainable of all modes, at Dalhousie. A study of the pedestrian environment and possible improvements would likely be highly relevant to ensuring this mode of transportation receives a fair and proportional level of support from the university. When

this result is combined with the previous (87% of trips by sustainable modes), Dalhousie can also make a claim of achievement in “greening the campus”. Although this may have been achieved through no deliberate effort by the University, the low need for transportation (short travel distance) and the high level of walking are very positive from a sustainability perspective. As a primary claim of sustainability it will also justify expenditures on supporting and protecting this modal split. For example the university sustainability policy could include the protection of affordable housing in the campus area.

Also related to the figure of 87% of student trips by sustainable modes is the question of how this relates to the large amount of infrastructure and expense devoted to motorized vehicles on campus. The question raised here is that this infrastructure may either be an inequitable facilitation of the few or that the sustainability of student travel behaviour is being offset by comparatively high levels of driving by faculty and staff. This may not be a fair assumption to make, but it does indicate a need for future study of travel behaviour by these other campus populations.

When looking specifically at barriers to bicycling, the two strongest are listed as weather and wind (Figure 2). The non-infrastructure nature of these influences on travel behaviour can be seen to reduce the means for increasing the sustainability of transportation. There is also an important consideration that this result and may suggest a locally relevant limit to the utility of bicycles as a transportation mode. Particularly winter conditions and the frequency of strong winds may provide a limit to bicycle utility for commuting in this particular community. The indication here is that a sustainable transportation strategy for Dalhousie may need to include adjustment strategies between each season and allow for the reliance on mixed mode travel (allowing users to shift modes in response to weather conditions).

5.3 Economic Implications of The Results

Especially because this research was able to collect information on the modal split and distances traveled there was good opportunity to conduct an economic analysis of these results. In doing this there was desire to examine the full costs of transportation behaviour, not simply the internalized costs at the university or only the monetary costs. The model chosen to conduct this analysis was derived from the Genuine Progress Index Atlantic

report on transportation in Nova Scotia (GPI 2006). In this report cost factors were derived from extensive research for a series to indices. These same cost factors were then used on the travel behaviour amongst the Dalhousie Student population as recorded in this research (Table 6.)

The results of this economic study shows that the total costs of commuting at Dalhousie is roughly equal to \$450,00/week. Of this total cost \$100,000 is externalized and must be absorbed by the wider community. A key point to highlight within these cost figures is that all modes carry some level of cost. Interestingly the vehicle operation cost is higher for walking than bicycling. This means that on a calorie to distance ratio bicycling is more efficient. Also interesting is that travel time costs also make walking much more expensive than riding a bicycle.

There is also a note of caution in looking at the figures in Table 6. The final costs are a direct product of the number of trips being taken by that mode. For example walking appears to have the highest overall cost, but it also has a much larger share of the trips than any other mode. To examine the costs in a proportional manner one could look at the share of externalized cost. From this perspective motorized vehicles, 12% of trips, hold responsibility for 56% of the total externalized cost. Public transit, a 22% share of trips, accounts for 42% of the external costs. Bicycling (7%) and walking (58%) of trips have a respective share of 1% and 2% of the external costs. Essentially this shows that the choices made by a few can actually have significant impact on sustainability for the whole university.

Table 6. The full costs of student transportation behaviour at Dalhousie University. Costs are represented per week in 2002 Canadian Dollars.

Mode	Motorized vehicle	Diesel Bus	Bike	Walk		Totals
Passenger Km	135346.22	179969.32	37084.26	230278.68		
Vehicle Ownership	\$19,097.39	\$-	\$1,407.35	\$-	Internal-Fixed	\$20,504.74
Vehicle Operation	\$13,627.75	\$28,685.31	\$562.94	\$6,991.26	Internal-Variable	\$49,867.26
Operating Subsidy	\$-	\$34,149.18	\$-	\$-	External	\$34,149.18
Travel Time *	\$23,454.57	\$47,808.85	\$9,851.43	\$174,781.52	Internal-Variable	\$255,896.37
Internal Crash *	\$5,098.82	\$409.79	\$1,407.35	\$8,739.08	Internal-Variable	\$15,655.03
External Crash	\$3,244.70	\$1,092.77	\$56.29	\$349.56	External	\$4,743.33
Internal Parking	\$4,635.29	\$-	\$84.44	\$-	Internal-Fixed	\$4,719.73
External Parking	\$11,124.70	\$-	\$168.88	\$-	External	\$11,293.58
Congestion	\$15,759.98	\$1,857.72	\$253.32	\$524.34	External	\$18,395.37
Road Facilities	\$1,483.29	\$382.47	\$28.15	\$174.78	External	\$2,068.69
Land Value	\$2,224.94	\$131.13	\$28.15	\$174.78	External	\$2,559.00
Traffic Services	\$1,390.59	\$81.96	\$56.29	\$349.56	External	\$1,878.40
Transport Diversity	\$463.53	\$-	\$-	\$-	External	\$463.53
Air Pollution	\$5,747.76	\$1,010.82	\$-	\$-	External	\$6,758.57
Noise	\$927.06	\$273.19	\$-	\$-	External	\$1,200.25
Resource Externalities	\$2,688.47	\$830.51	\$-	\$-	External	\$3,518.98
Barrier Effect	\$1,390.59	\$207.63	\$28.15	\$-	External	\$1,626.36
Land Use Impacts	\$6,489.41	\$-	\$-	\$-	External	\$6,489.41
Water Pollution	\$1,205.18	\$71.03	\$-	\$-	External	\$1,276.21
Waste	\$185.41	\$10.93	\$-	\$-	External	\$196.34
Internal Fixed	\$23,732.68	0.00	\$1,491.79	0.00		
Internal Variable	\$42,181.14	\$76,903.95	\$11,821.72	\$190,511.86		
External	\$54,325.59	\$40,099.33	\$619.23	\$1,573.03		
Totals	\$120,239.41	\$117,003.28	\$13,932.74	\$192,084.89		\$443,260.32

5.4 Practical Results Explored

Perhaps the most important result from this research is the evidence against simplified sustainable transportation strategies. There is a tendency, both in this research project and others (see HRM Bike Plan) to adopt a standard set of responses to transportation sustainability questions. For example it is often taken for granted that bicycles are one of the

best transportation modes and that encouraging that behaviour will rely on physical infrastructure. The results of this research suggest that a more complete picture and locally specific solutions may be needed to be developed instead. Increasing sustainability of transportation for the student population at Dalhousie may be best derived from a facilitation of pedestrian and public transit activities. If bicycles were a viable option, especially in the reduction of short distance car trips, the provision of infrastructure cannot be assumed to initiate that modal switch. Essentially what the results are indicating is the need for a comprehensive transportation policy at Dalhousie that simultaneously works with all modes of travel. This type of policy would need to address equitable spending practices, so that proportional numbers of students using each mode receive equitable levels of support. The policy should also focus more on the social factors that influence decision-making and not simply rely on improvements to physical spaces. Finally such a policy should be based on strategies of transportation demand management and mixed mode use. This will mean that there is facilitation of travel behaviour that can respond to changing conditions, especially weather related, in order to give students the opportunity to select the most useful mode of travel for that trip (where sustainability is included in the utility equation).

Another result from this research is the expression of how important pedestrian travel is to campus sustainability. This mode is the lowest impact of all possible transportation choices and it has the dominant share of trips for Dalhousie students. However, the full cost accounting revealed that walkers actually carry a fairly high level of personal cost, especially in terms of travel time. This shows some inequality in that faster modes, lower travel time costs, achieve this benefit through their generation of higher externalized costs. If sustainable transportation is desired it is the more sustainable modes of travel, like walking, that should be subsidized by society. This could mean that Dalhousie look at strategies to internalize some of the costs of driving to and from campus, while simultaneously transferring those funds to help cover the higher personal costs of sustainable modes. Essentially this would mean improving the total benefit derived from a walking or biking trip to offset some of the personal cost. For example if travel time costs are high, strategies to add social and aesthetic benefits to the trip could create more equality.

This type of cost transfer is also supported by evidence in other research on transportation. For example the work by Saelens et. al (2003) found a very strong correlation between urban density and mixed used building patterns and increased levels of walking and bicycling. In this type of building pattern travel distances are reduced and trips provide many possible side benefits beyond simply moving from one point to another. For example a trip to campus through a mixed-use neighbourhood might allow for social interaction, a stop at the grocery store, and/or a coffee along the way. These would all add benefit to the trip and would greatly reduce the personal travel time costs. This result suggests then that it might be in Dalhousie's best interests to participate in municipal planning decisions, advocating for this kind of city development. It also means that the campus structure itself could be re-examined to develop possibilities of increased density and mixed-use form. For example academic building could be designed to have street level shop fronts where students can access books, materials, or food while commuting.

Again referring to the research of Saelens et. al (2003) there is also a strong correlation between the provisions of pedestrian environments and increased bicycling. This means that if this project indicates a higher level of need to develop pedestrian commuting it does not exclude bicycling improvements too. This research clearly justifies a need for support to pedestrian travel, but this can also be understood as also an improvement to the bicycle facilities. This presents a type of win/win solution in sustainable transportation planning at Dalhousie.

If specific infrastructure support is given to bicycle activities the results of this project suggest that direct, fast, and safe routes to campus have the best chance of increasing the number of cyclists. For example this might mean that if bike paths are built they should provide road safety and give route advantages over other vehicle traffic (increased speed). One method of doing this is the conversion of residential streets around campus that connect neighbourhoods to roads that are one way travel for cars and designate the second lane for two way bike travel.

Even though the results of this project suggest that social factors are more influential in biking choices than infrastructure, research suggests that these may not be entirely separate

criteria. Nelson and Allan (1997) provide evidence that even when social factors dominate mode selection, the provision of bicycle infrastructure has an effect on those social factors. For example infrastructure specific to bicycling has the effect of increasing social awareness of bicycles as a possible travel mode. This infrastructure also may increase the social acceptance of bicycling and places bicycles in the visual presentation of that city's culture. Some cities have actually gone as far as using the creation of bicycle facilities as a marketing tool to indicate that they are a progressive environmentally friendly city. This has the effect of increase the prestige benefits of actual bicycle use. This perception of prestige has also been show to be one of the dominant influences on the initial choice to use a bicycle rather the daily modal selection (Litman, 2006). This means that regardless of whether infrastructure is actually used it may increase the likelihood of purchasing a bicycle. The research in this project has also shown that once a person has a bicycle the likelihood that they will commute by bicycle increases by more than any of the other factors studied. Dalhousie could take advantage of this effect by increasing the visibility of bicycle commuting in its promotional materials and advertising.

The final implication of the results in this project at a practical level is the understanding of motorized vehicle use. Although this mode of travel has a low share of trips it generates high costs for Dalhousie. The research also shows that these trips cannot be justified by a stated need to travel longer distances to campus and the accompanying poor access to alternative modes. In fact there was no correlation between commute distance and motorized vehicle use. It would appear that many car trips are actually made over short distances on routes that had good access to alternative modes, including walking and bicycling. These results suggest that future sustainable transportation studies at Dalhousie examine way to reduce these trips. Perhaps the conversion of this travel is best place to attempt increases bicycle commuting. Specific marketing to this group could highlight that bicycles can provide many of the same benefits, especially travel time, load carrying, and flexibility, as car travel.

6.0 Recommendations and Conclusions

Barrier perception was not found to significantly influence bicycle-commuting behaviour. This result was unexpected. It possibly suggests that deeper social and cultural attitudes, rather than specific physical impediments, influence the decision not to cycle. The unexpectedly high number of respondents who felt that social factors were a negative aspect of cycling (20.8%) supports this suggestion. This is why we are suggesting that further research needs to be done into the social factors affecting commuting behaviour. In addition to more research, an education or poster campaign could be initiated to inform people about the social and cost saving benefits of bicycle commuting.

The results also suggest that infrastructure development strategies may not influence bicycle ridership. Not only were barriers poorly correlated with cycling behaviour, the highest scoring barriers were non-infrastructure related (poor weather/ wind/ travel time). For this reason we feel that in terms of support money it would best be spent on public transit and pedestrian initiatives. Having said this, some pedestrian friendly infrastructure could also promote biking. For instance, because wind is a strong barrier, tall shrubbery could be planted on the windward side of exposed walkways/bike paths on campus to reduce the winds intensity during commutes.

Although most student commuters were found to choose sustainable transportation modes (public transit, walk, bike), our GPI analysis found that the small percentage of students who commute by motor vehicles to Dalhousie account for more than half the total external

transportation costs. Therefore, in order for commuting greenhouse gases to be reduced at Dalhousie University future efforts should focus on reducing the number of short distance vehicle commuting within biking distances. In order for this goal to be realized a set of transportation policies needs to be created for Dalhousie. These policies should outline equitable spending practices, so that a proportionate numbers of commuters receive equitable levels of support. In addition, to make these policies more relevant to the University as a whole, faculty-commuting habits should be explored to see what their contribution is in this area. One strategy these policies could address is to co-operate in municipal planning decisions, advocating mixed-use land planning (on and off campus), a population density increase around campus, and a commuter challenge week that challenges students to reduce their commuting impacts for a specified amount of time. As with many planning strategies, how to increase people's awareness of these programs should be of utmost importance.

Finally, because studies have shown that if a person has access to a bicycle the probability of them commuting with it increases; an exchange program where students pay a rental fee and refundable deposit in return for a bicycle rental may increase ridership. Refundable deposits would be reimbursed upon the safe return of the borrowed bike. This program could be an initiative to help reduce the short commutes in personal vehicles within biking distance.

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US Department of Transportation Federal Highway Administration National Bicycling and Walking Study Case Study No.1: Reasons Why Bicycling and Walking Are and Are Not Used More Extensively As Travel Modes, US Department of Transportation, Washington, DC.

Appendix I: Survey

Age? (circle) ≤15 | 16-20 | 21-25 | 26-30 | 31-35 | 36-40 | 41+

Sex? (circle) male | female | other

Your level of study (circle): Undergraduate student | Graduate Student

How many years have you been studying at Dalhousie, including this year? (circle)
≤1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+

When commuting to Dalhousie what mode(s) of transportation do you typically use? (circle the average number of one way trips/week)

Motorized vehicle:	0		1-5		6-10		11-15		16-20		21+
Public Transit/Carpool:	0		1-5		6-10		11-15		16-20		21+
Bicycle:	0		1-5		6-10		11-15		16-20		21+
Walking:	0		1-5		6-10		11-15		16-20		21+
Other:	0		1-5		6-10		11-15		16-20		21+

Please specify: _____

Do you have access to a motorized vehicle? (circle)

Y | N

Do you have access to a bicycle? (circle)

Y | N

Do you think you live within biking distance from campus?

Y | N

Do you think commuting by bicycle is safe?

Y | N

Do you commute between campuses regularly?

Y | N

Do think cycling for recreation is fun?

Y | N

When deciding how you will commute to school, how strongly do you consider the following an impediment to bicycling: 1(not an impediment at all) - 6(strong impediment)

Travel time	1		2		3		4		5		6
Poor Weather	1		2		3		4		5		6
Strong Wind	1		2		3		4		5		6
Difficult Route	1		2		3		4		5		6
Hills	1		2		3		4		5		6
Lighting conditions	1		2		3		4		5		6
Pedestrian traffic	1		2		3		4		5		6
Automotive traffic	1		2		3		4		5		6
Surface Condition	1		2		3		4		5		6

Bike rack availability	1		2		3		4		5		6
Lack of pathways	1		2		3		4		5		6
Safety risk	1		2		3		4		5		6
Theft risk	1		2		3		4		5		6
Unprofessional image	1		2		3		4		5		6
Dirty/Sweaty	1		2		3		4		5		6
Health issues	1		2		3		4		5		6
Class start/end time	1		2		3		4		5		6
Difficult/awkward load	1		2		3		4		5		6
Riding confidence/skill	1		2		3		4		5		6
Other:_____	1		2		3		4		5		6
Other:_____	1		2		3		4		5		6

If you were to bike to school, which conditions would you bike in? (circle all that apply)
 spring | summer | fall | winter | sun | rain | snow | hail | strong wind |
 hurricane | tornado | below 0°C | less than -10 °C

Do you consider maintenance a deterrent to bicycling?
 Y | N

If /When selecting a bike route to school you (choose the one most representative)

- a) Select main roads
- b) Choose fastest/shortest even if it requires crossing busy roads or riding in traffic
- c) Select side roads and quiet streets
- d) Look for designated bike paths

What influences your selection of route (choose the one most representative)
 speed | safety | avoiding congestion | avoiding obstacles |
 | surface condition | other (please explain): _____

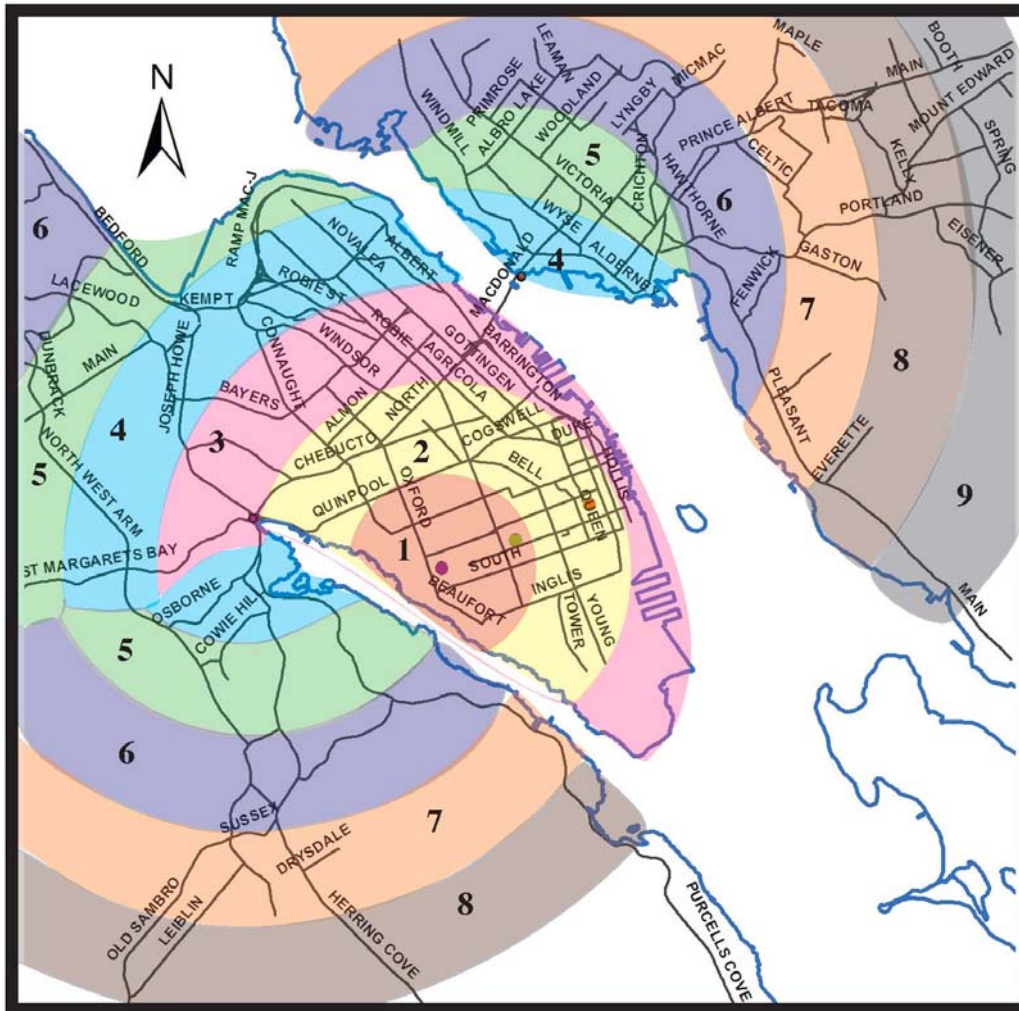
Using the map provided, your commute to school takes you :
 From zone _____
 To campus _____

Do any of the factors listed below influence your attitudes towards biking in a positive or negative way?

Physical fitness:	Pos.____	Neg.____
Environmental ethics:	Pos.____	Neg.____
Travel time:	Pos.____	Neg.____
Cost:	Pos.____	Neg.____
Pleasure:	Pos.____	Neg.____
Social factors:	Pos.____	Neg.____

Dalhousie Bicycle Survey

Please Locate Trip Origin and Destination Zone Numbers



Appendix II: Information Letter

March 2007

Dear Participant,

Thank you for taking the time to consider participating in this research.

The survey attached to this letter is for the purpose of understanding bicycle commuting behaviour on Dalhousie campus. Participation in this survey is **completely voluntary** and **no personally identifiable information** will be requested, recorded, or reported. The research is being conducted by students in an environmental problem solving course at Dalhousie University for the purpose of helping to increase campus sustainability. It is our intention to provide results in the research that you might find beneficial to your own commuting choices. The final results of the study will be made publicly available on the Environmental Programs website at http://environmental.science.dal.ca/pages/envs3502_projects.htm in April 2007.

The attached survey will take approximately **five minutes** of your time to complete. Should you have any questions on the project itself or in answering the survey, please don't hesitate to ask the researcher.

Thank you again for considering participating in this research. We value your time and input greatly.

Sincerely,

Research Team
Uni-Cycle: Bicycle Commuting at Dalhousie
Dalhousie University Students
Envs. 3502