UNDERSTANDING COMMUTING DECISIONS

UNDERSTANDING COMMUTING DECISIONS
A CASE STUDY OF STUDENTS AND STAFF
AT MCMASTER UNIVERSITY

By

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ABSTRACT

This thesis outlines the methods, results, recommendations, and conclusions of a study conducted on the parking problem at McMaster University in Hamilton, Ontario, Canada. By taking the approach of studying the commuting behaviours undertaken by the staff and the students, this study not only is the first conducted at the university to connect travel behaviours with a parking problem, it is also able to provide meaningful recommendations towards successful travel demand management (TDM) that will help alleviate the parking crunch. A variety of research methods were employed including some exploratory analysis, employing Geographical Information Systems, and multivariate statistical analysis. Results are compared with relevant literature to produce recommendations towards the components of a well-developed TDM scheme, the most important of which are to employ many strategies simultaneously, and to have regular public input. The thesis concludes by summarizing the most easily employed strategies, implemented outside of the large-scale TDM plan, that would entice drivers to switch to alternative transportation modes of personal cars.

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Chapter 1: Thesis Introduction

In North America, the prevalence of the private car as the primary transportation mode of choice is a well-known and observable phenomenon. As such, it is not surprising that many of the continent's post secondary institutions have, at one point or another, experienced the problem of the on-campus "parking crunch." This is defined as the demand for parking exceeding the supply, and has various implications that are site-specific. In the case of McMaster University, its true "crunch" came in the form of requiring a lottery in 2002 to allocate the undergraduate parking permits, such that all of the students who applied prior to the due date were too numerous to be guaranteed permits. On a more regular basis, the campus experiences high traffic and congestion on its easternmost lots, as a result of their proximity to the administrative buildings and the majority of services on campus (see Figure 1, page 8). Parking permits for those lots are few and far between, as the parking policy dictates that staff and graduate students may apply for a permit in any lot, subject to availability. Typically, availability is only within the westernmost lots, which are not only the farthest from the administrative buildings, but also off of the main campus, requiring a ten-minute walk or a short ride on the shuttle bus. These outermost lots are rarely full, even during the fall and winter when the policy is to oversell the permits of all lots by 10%. Therefore, in terms of overall parking supply, there is no shortage; but if only the most preferred lots are considered, there would appear to be high competition on a day-to-day basis for many drivers that are arriving for work at around the same time in the morning to find a parking spot.

Perhaps the root of the problem in recent years, as identified over the course of this study, is the result of the university's expansion. In response to the incoming Double Cohort, new residences were built, and they were placed on former parking lots. The anticipated increase in the number of students prompted the upgrading of facilities, and also required an increase in the number of staff and faculty to serve these students. Most recently, in light of the multi-million dollar deficit, focus has been primarily directed upon the recruitment of many more students following the recent graduation of the Double Cohort class. All of these expansions in a relatively short amount of time led to a shift in the location of parking supply, as well as an overall loss. The university has facilitated an increase in the GO transit service to and from campus, installed bike lockers, and established the Alternative Commuting and Transportation (ACT) office, yet the popularity of commuting by car remains high, most especially among staff. The university also hired an external consulting firm to evaluate its then-current parking facilities, in 2000, in terms of its adequacy in anticipation of the Double Cohort, the results of which strongly suggested the development of a travel demand management (TDM) scheme. It is unclear whether or not such a scheme was ever created. Most recently, a report was prepared of suggestions pertaining to increasing the efficiency of the management of the parking facilities, and as a result, automated gates will be installed on all the campus lots within the next two years (Sullivan and Pagel, 2006).

The above discussion indicates a very important deficiency within the research that has been previously conducted since the focus has been exclusively on parking, and parking management, but not the underlying behaviour that ultimately requires parking: choosing to drive to the campus. If a commuter, staff or student alike, does not choose to drive, then that commuter does not require parking, and is one less car adding to the congestion, pollution, and competition that occurs on a regular basis. The study of parking management, and parking behaviour, has been well documented, as has the study of transportation modal split and the underlying factors leading to travel behaviours. However, very few studies, if any, have examined the association between parking and travel behaviour. Furthermore, while it is possible that by increasing the efficiency of the management of the parking facilities on campus will help alleviate some congestion, it does not address the possibility that parking demand will continue to rise unchecked as the university continues to focus on recruiting efforts.

In order to best address the parking issues on campus, and present balanced solutions, it is essential to study the actual modes being chosen to travel to the campus. If the university is to most effectively alleviate the problem of too many commuters expecting parking on a land-locked campus, it must recognize the key factors and considerations leading to the commuter's choice of using the car. Then, the university can design policy that will be more effective in curbing car use and will encourage alternative modes – since, in this case, the only solution to having too much demand is to eliminate some of it rather than increase supply. This study has not only identified the main factors leading to the driving behaviours among both staff and undergraduate students, but also used these results to provide and discuss viable and relevant strategies to be implemented as a group within a potentially successful TDM plan. By working towards changing the travel behaviours of the staff and students, rather than only changing parking policy and pricing, not only will the parking problem be sufficiently contained, but secondary benefits, such as lowering the air pollution on campus, may be attained.

This thesis consists of six chapters. The second provides relevant and important literature context by discussing previous studies conducted on parking behaviour, and addressing transportation issues of a university campus. The third discusses, in detail, the methods employed within this study. Data collection and formatting will be explained, as well as the theoretical modeling framework. The forth chapter presents and discusses the results of the model and chart analyses conducted on the data. Finally, the fifth chapter details the connection between the findings made within the third chapter, the most common strategies of a successful TDM plan and how McMaster can implement them, and specific strategies that could be implemented within short order to help alleviate the problem as best as possible prior to the launch of a large-scale TDM scheme.

Chapter 2: Context and Background

Introduction

Despite its establishment as a topic of research within civil engineering, there exists little formal study on parking demand and management in the context of a university setting. Furthermore, the current literature tends to focus on drivers' behaviour at the point in time when parking is required, rather than the factors that led to the choice of driving in the first place. There is a wealth of information regarding modeling central business district (CBD) parking demand and its effect on traffic flows (Petiot, 2004; Gillen and Westin, 1978), the influence on CBD parking availability/cost and the choice of transit mode for the work commute (Gillen, 1977; Hensher, 2001; Arnott *et al* 1991), and the behaviour of drivers in response to various characteristics of parking conditions (Bonsall and Palmer, 2004; Anderson, Das, and Tyrrel, 2006), to name a few parking demand-focussed studies.

As the population of McMaster University's staff, students, and faculty continues to grow, it is important to assess the effect this growth will have on the demand for use of the campus' parking facilities. Table 1 shows the growth of the university in terms of undergraduate population from 2001-2, to 2006-7.

Academic Year	Undergraduate enrolment
2001-2002	12 691
2002-2003	14 110
2003-2004	16 111
2004-2005	17 033
2005-2006	18 283
2006-2007	18 743

Table 1: Undergraduate Enrolment 2001 - 2006
(Source: McMaster Department of Planning and Analysis)

Table 1 shows the relative jump in enrolment between the 2002-2003 and 2003-2004 academic years, indicating the influx of the Double Cohort by approximately 2000 students. Between all other academic years, the increase in enrolment was approximately 1000 students. This increase of enrolment resulted in a strain in many facets of University resources, including parking.

The university cannot partition any ground space for additional parking facilities and is greatly interested in encouraging and facilitating alternative transport. To date, it has not yet attempted to formally address this situation by investigating the motivations behind the commuting behaviour itself. The opportunity to address this is provided by the Alternative Commuting and Transportation (ACT)'s transportation behaviour surveys (see Appendix for copies of the 2004 surveys). Through critical literature review, this chapter demonstrates the importance of studying the commuting habits of the population of McMaster University. The context of the problem is also discussed in detail.

Current Parking Supply and Management Policy

McMaster University (at time of writing) has a total of 4819 parking spaces. Of this, 105 spaces are located at the Downtown Centre campus. For the purposes of this study, the Downtown Centre and its parking will not be considered, as the nature of the satellite campus is a continuing education centre (i.e. part-time studies), with different properties and characteristics in terms demand for parking. The main campus located in Westdale, therefore, has 4714 parking spaces for faculty, staff, students, and visitors (Figure 1, page 8). These spaces are divided between eight numbered "Zones" (subject to renaming by September 2007), and two named lots: "Divinity College" (on campus), and "Ward Ave" (three blocks south of campus). The largest parking zones are located west of the main campus, Zone 6 and Zone 7. The locations of these zones are sufficiently off site from the main "core" of campus to necessitate a shuttle bus service for the commuters who park there. This improves the convenience of parking in these zones, and also reinforces security within the area. Figure 1 is a map of the campus with its current layout of parking facilities.

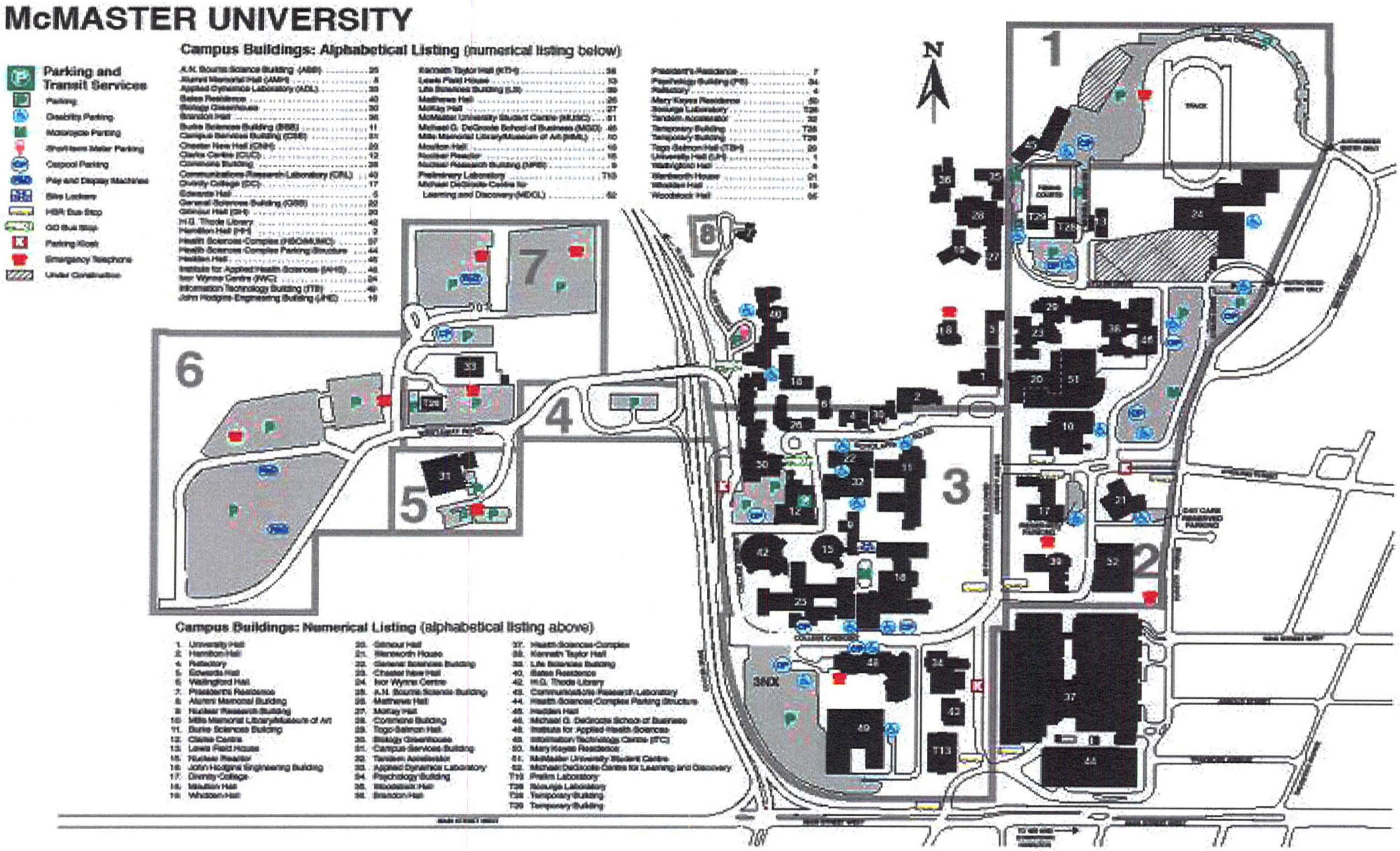

Figure 1: Map of McMaster University Parking Lots
(Source: McMaster Parking and Security Services)

In the current situation, there are three kiosks that provide temporary parking passes for visitors to the campus, and to faculty, staff, and students who bring their cars on campus for the day. These kiosks are located off the Cootes Drive (west) entrance, the Main Street (south) entrance, and the Sterling Street (east – formerly Main Gate) entrance. The kiosks allocate daily parking permits in exchange for a deposit (which varies throughout the day) and parking staff patrol the campus to ensure that cars display a valid parking permit. Since there is a kiosk at each entrance to the university campus, each car coming on to campus must pass one. Beginning in September 2007, some of the parking lots on the main campus will have parking gate technology installed, automating the process of obtaining a daily permit to gain entrance to the lots. At time of exit, the driver will then pay the parking fee for the amount of time that was spent parked.

Monthly "unlimited" parking permits are issued on a first-come, first-served basis, and must be applied for at the Parking and Security Services office. The following information was taken from Parking and Security Service's policy, published online at their website (Parking and Security Services, 2007). Full-time faculty, staff, and graduate students are eligible to apply for a permit in any zone, and are be assigned based on availability. Part-time faculty and staff, temporary employees, casual employees, part-time graduate students, external agencies, and visitors that require parking for longer than 30 days but less than 12 months are restricted to applying for a permit to park within the outermost parking zones.

Undergraduates may only apply for the remaining spaces within Zone 6, and those that do not apply prior to the last business day of July are entered onto a waiting list. In 2002, the number of applicants for these particular spots had exceeded the number of spots available, and the permits were allocated by a lottery (Thomson, 2002). This situation requiring a lottery has not been repeated. Students living in residence may only apply for parking in Zone 7. Of course, members of the University, or visitors to the campus, with a disability and with the accompanying documentation are afforded priority parking at any time. Finally, retirees are eligible to apply for parking permits without fees, subject to certain conditions and availability.

The Campus Parking "Crunch"

As mentioned in the introduction to this thesis, there is no "crunch" in the overall parking supply, but congestion and temporarily insufficient supply occurs regularly in the upper, easternmost lots. Expansion of the university in recent years has also lead to an increase in overall parking demand with the growing population of staff and students. The undergraduate student population had been elevated higher than previous years since 2003 due to the "Double Cohort", which graduated as the class of April 2007. (The Double Cohort refers to the two sets of high school graduates in the province of Ontario when grade 13 was phased out to incorporate a four-year (instead of five) high school degree. This resulted in the last class of grade 13 graduating with the first class to graduate following grade 12). In essence, demand has increased at a relatively steady rate while supply has either remained the same, or decreased.

McMaster shares a number of characteristics in terms of a parking demand problem with many post-secondary institutions across North America. In general, the literature will attribute a parking problem to growing population, poor management of current facilities (Watson, 2003; Litman, 2006), a "landlocked" campus (leading to inability to expand current facilities) (Isler, Hoel, and Fontaine, 2005), loss of facilities due to construction of new buildings, and its lower importance on a university's facility management agenda (Belaire, 2001; Litman, 2006). Unlike studies from the past, this study's purpose is to focus on the behaviour leading to parking demand, which is that of car use as a mode of transportation taken to the campus. In doing so, this study is able to present relevant and viable solutions to the growing parking demand by addressing these behaviours with suggestions on how to encourage a shift from driving to alternative modes. This shift will then decrease car use, and therefore, parking demand.

The McMaster University Policy

The university published the Master Campus Plan in 2002, which devoted Chapter 5 to the outlining of "A Strategy for Circulation and Parking." The chapter addresses the parking crunch, and provides a number of recommendations in terms of both infrastructure changes, and travel demand management policy changes. It is interesting to note that on page 5-3, the Master Plan reads "...McMaster's current rate of parking provision is below the average. This relative position should be continued." In this way, the Master Plan is indicating that the amount of parking that is available should not be greatly increased. Theoretically, this should force commuters unable to obtain permits to seek alternative modes of transportation to the university, and also helps keep up the "pedestrian priority" that the administration maintains as an important part of the McMaster campus. Despite this, the Master Plan does acknowledge the parking dilemma, and suggests addressing the problem using travel demand management strategies before providing new infrastructure.

The Master Plan has outlined "specific provisions" in terms of the circulation and parking strategy. Some of these strategies have been put into effect, such as higher pricing schemes for the parking zones closest to campus, retaining the shuttle bus system, opening up a new Main Gate access from Main Street (to better accommodate transit), an on-campus GO transit terminal, and the gradual increase of parking fees from year to year (which helps address rising costs of maintaining facilities, as well as to discourage commuters from driving). Others have yet to be implemented, such as the improvements to transit, pedestrian, and cyclist access as a priority, the Cycling Plan, change and shower facilities for cyclists, and an on-campus local transit (i.e. Hamilton Street Railway, or HSR) terminal. However, improvements in access to alternative transit and facilities have not been met with the anticipated participation increase due to lack of management policy that discourages driving and rewards modal change.

The Plan is meant to cover the growth of the University for thirty years from 2002. This implies gradual changes, but the majority of the circulation and parking problems are an issue at the present time. Therefore, the sooner the recommended changes be undertaken, the sooner the University will be better able to alleviate the congestion and parking crunch. Familiarity with the University's standpoint and current policy is important to be able to provide practical suggestions to policy change as revealed by this study's analysis and results.

Addressing the Problem

The establishment of the Master Plan is a specific example of McMaster's response to the perceived on-campus parking crunch. Other institutions have responded to these pressures by increasing parking rates to finance the construction of new facilities (Emerson, 2006; Evans, 2005; Wheat, 1999; Perez, 2001). Surface parking lots are the least expensive to invest in (Litman, 2006), but when there is no more land to expand upon (such as at McMaster), the remaining option is to build "up" in the form of parking garages. This option is least favoured due to the immense cost of construction, the aesthetic displeasure that they cause, and that providing new infrastructure will encourage commuters to continue driving, or begin to drive, when other alternatives are available. The addition of increased parking supply has also traditionally been considered a failure as a response to decreasing parking demand (Faulkner, 2006; Litman, 2006; Lucas, 2006; Perez, 2001; Thomas, 2003; Verhoef, Nijkamp, and Rietveld, 1995). In recent years, environmental sustainability has become an important part of expanding post-secondary institutions (Van Raay, 2005; Bishop, 2006; Shannon *et al*, 2006; Bizjak, 2006; Tolley, 2006). In response, a number of administrations have developed schemes and policies to encourage alternative modes of transportation (public transit, walking, cycling, etc.). In 2002, McMaster established the Alternative Commuting and Transportation (ACT) office for this very purpose (Thomson, 2002). The ACT is discussed in more detail below.

Two formal studies have been commissioned by the university in the past to evaluate the parking supply and its management. In 2000, a private consulting firm (Marshall Mackin Monaghan) was commissioned to conduct a review of the parking facilities, and what changes should be made to address the expected upcoming pressure from the incoming Double Cohort in 2002. Their recommendations were to spread classes out more throughout the day, and to implement a greater number of facilities and travel demand management (Curwin, 2001). McMaster responded with actions such as the opening of an off-campus parking lot (Thomson, 2003), temporary parking solutions (e.g. converting the tennis courts into parking (Cox, 2005; Faulkner, 2005; Down, 2000)), and as mentioned above, the opening of the ACT office. In late 2005, a McMaster graduate student (Michael Pagel) indicated a recent study focused exclusively upon the management of the parking facilities. The report, summarizes the justification leading to the automation project being undertaken at the present time (Sullivan and Pagel, 2006).

The ACT office

ACT provides information and education about the various services and transportation modes available to the university, and also surveys staff and students bi-annually to determine which modes are most popular and why. ACT then uses the results of these surveys to lobby the transit companies (i.e. GO transit, and Hamilton Street Railway (HSR)), to fulfill an identified demand to the campus. The increased GO service to and from McMaster on a daily basis during the fall and winter terms is a direct result of the lobbying done by ACT on behalf of the staff and students of McMaster who identified a need for this service. This GO service has become so popular that a GO terminal, initially slated to be constructed on campus by the fall of 2006, opened early in 2007 (Daily News, 2006, 2007).

The ACT is also responsible for the implementation and operation of the carpooling programme on campus (ACT 2003; Dawson, 2005). Carpool programmes are commonly implemented to address parking problems in many contexts at many places (Bannister-Andrews, 2006; Brown, 2006). The McMaster programme encourages drivers to carpool by offering incentives such as a "prime" parking spot, fuel coupons/vouchers, free taxi rides, and complimentary parking permits if someone must drive alone on any given day. The incentives are offered to reflect current preferences and what has been successful in the past for other carpooling programmes elsewhere, as well as by popular suggestion. Drivers may apply for a carpool partner and are matched based on the driver's origin and schedule. The programme has fostered modest success from the staff of the university, but has not yet become popular with the students. This may be due to students having varied schedules between them, as well as personal bias against having to drive with a "stranger".

The previous discussion has identified the lack of literature that is available on the subject of managing parking from the perspective of the driving behaviour itself. Through this study, the university will be better informed upon strategies to more effectively encourage a modal shift from the personal car to alternative modes. In this way, the administration will be able to best address the needs of all the university community, and to avoid focusing only on the needs of those that drive.

Parking Costs and Mode Choice

The literature has demonstrated that increasing parking prices alone is not an effective strategy to address, and attempt to alleviate, traffic congestion on streets (Glazer and Niskanen, 1992). Rather than shifting drivers to other modes, increasing parking fees is more likely to result in drivers seeking parking off-site, thereby not solving the fundamental issue of commuters choosing to drive at all. Pricing is most effective as a determinant to where drivers are more likely to park, especially if pricing varies depending on location (Litman, 2006; Arnott and Rouse, 1999). Despite this, parking pricing also has an influence on the modal choice of a few individuals. Gillen (1977) investigated the effect of parking pricing on modal split by creating a model of household transportation choice alternatives. His results indicate that parking pricing had very little effect upon influencing drivers to switch to alternate modes. However, Hensher and King (2001), and Noland and Kunreuther (1995) have found that this is not likely the case. Increasing parking prices will discourage driving to a certain degree; as discussed by Litman (2006). The level of influence parking prices will have depends upon the specific characteristics and situation that is being investigated. In some cases, this will lead to a modal shift; in others, a displacement of where drivers decide to park.

In regards to McMaster, parking permit fees have increased at a steady rate since 2002 (Campus Master Plan; Van Raay, 2005). While this may have influenced the travel behaviour of those who used to drive in the past, new drivers that are unfamiliar with what prices were will not be immediately swayed, unless the prices are clearly more expensive in comparison to other available modes (public transit, cycling, walking, etc.). As parking fees increase, more and more commuters, students in particular, will opt to park "off campus": on a side street in one of the surrounding neighbourhoods to avoid the fees (Emerson, 2006; Pona, 2007). These drivers then will walk or take transit to the campus from that location. The University Master Plan indicates that this type of behaviour should be strictly monitored, and the parking bylaws be enforced as strictly as possible to discourage drivers from behaving in this way to ensure the relationship between the university and its surrounding community remains friendly. The increased on-street (off-campus) parking results in the additional issue of neighbourhood safety and congestion (Beck, 2005; Dulaney, 2006). Residents often do not enjoy having their street parking used up by students, since these spots are better used by the residents themselves, or their guests, for whom they are intended (Oakes, 2005). This on-street, off-site parking behaviour reflects the findings of Hensher and King (2001): rather than changing modes, drivers opt to park as close as possible for the least amount of money possible. As the impending parking ticket does not seem to be a strong enough deterrent for these drivers, this study, by providing insight as to where drivers are coming from, will attempt to determine the other factors that lead commuters to drive to the campus. Therefore, more effective travel demand management schemes can be devised such that better alternative transportation incentives can be offered that will lead to greater participation in a modal shift from the private car. As a result, this may decrease the frequency of off-site parking by decreasing car use overall, which will lead to a better relationship between the university and the community, as well as reducing on-street parking congestion.

Parking Management and Mode Choice

In some cases, university campuses experience an overabundance of parking that is poorly managed, this leading to the congestion and frustration that drivers experience on a day-to-day basis (Thomas, 2003; Watson, 2003; Evans, 2005). This can also result from parking permit "hunting licenses", allowing permit holders to park wherever they would like. This leads to congestion, as many drivers will attempt to park near campus buildings, rather than using the outermost lots. These outlying lots are then rarely full, but due to their seemingly inconvenient location (and in some cases, seriously questionable safety) they remain unpopular (Huston, 2005). McMaster University campus hosts two such outlying facilities, Parking Lot Zone 6 and Zone 7, discussed below. Since McMaster issues permits on a zonal basis, restricting permit holders to park in the zone they have been assigned to, congestion still occurs, as the permit allows a driver to park anywhere within the zone. The zones closest to the university buildings exude the greatest competition between drivers for the spaces closest to the buildings. For example, in the case of Zone 2, one permit allows a driver to park in any of three lots. In this case, a driver may end up driving excessively through all three lots in search of the closest parking stall. By identifying where drivers are coming from using a combination of appropriate survey tools and GIS, more effective travel demand management can be developed and implemented that can address the spatial-specific deficiencies in access to reliable, direct-route transit. As such, TDM can be implemented to alleviate, or at least reduce, the congestion. The implications of this are greater air quality (due to decreased emissions), less traffic on the campus, and fewer frustrated drivers.

As mentioned earlier, Isler *et al* (2005), and Narragon *et al* (1973) have observed that many campuses are "landlocked": this means both physically being constrained to a set amount of land surrounding them, as well as by budgetary limits. This is the reason parking management for a university campus has its own category of problems to be addressed than a city. The McMaster University main campus is limited by where it may expand due to being landlocked, as described above.

A university campus parking lot will experience a greater amount of turnover than a parking lot in a city's CBD, for which a large number of parking studies and management strategies have been developed (Arnott, de Palma, and Lindsey, 1991; Collins and Chambers, 2005; Curtis, 1997; Gillen, 1977). This is due to the characteristics of the people who are parking within the lots themselves. An employee parking in the CBD will exude different parking behaviour than a student: the employee is much more likely to park for the same number of hours each day of the week, but a student is more likely to have a schedule that differs by the day of the week, though the pattern will be similar on a weekly basis. This study, and its report will therefore be adding to the body of parking management literature that is lacking in research on the university campus setting by focusing on both the regular patterns of the staff and faculty, and the irregular schedules of students.

At time of writing, one study was conducted using center of gravity models to estimate the most advantageous place to erect a new parking garage on the campus of California State University at Northridge. The study, conducted by Klassen *et al* (2002), used the university's class timetable information to best estimate the parking demand on a day-to-day basis, and total enrollment figures. The study did not have information on the parking permit holders, and could not estimate the number of day pass holders to any detailed extent. Despite this, the authors were able to estimate a maximum demand and make policy suggestions in terms of parking management, as well as a potential location for a new parking garage. This study will be able to build upon the progress of Klassen, Kumar, and Trybus, by employing the use of data that include the address information of the drivers/permit holders, and running modal split models to investigate the possible forces that compel them to drive to the campus. By taking the perspective of looking into who drives, the university may design a policy of enticing these drivers in changing to a more sustainable, environmentally friendly, and better managed alternative, rather than to plan for more infrastructure.

Chapter Summary

Civil engineers have studied, and continue to study, the phenomenon of parking. Many studies document the varying angles taken to study parking within the CBD of cities as a function of drivers' behaviour. More recently, models have been developed that predict demand, while some will simulate the in-car experience of a driver. While many of the findings of these studies have helped fuel the travel demand strategies of efficient parking management, very few have focused on the unique parking needs and situations that accompany university campuses. Fewer still have been conducted on the connection between parking, and transportation modal choice behaviour.

McMaster University's parking "crunch" is similar to parking situations occurring at many institutions across the continent. Some of the ways in which its administration has responded mirrors other responses taken by universities to help reduce congestion, as well as demand, for parking on campus. While many of the measures combined have helped to increase supply, the demand for parking continues to rise on a yearly basis. New approaches and incentives are introduced yearly to entice commuters to use alternative modes, yet demand continues to rise and congestion remains a problem. This study will help identify some travel demand management strategies, as well as policy changes, that may be implemented to better address this problem than has been in the past. Since parking management has been studied extensively, including at McMaster University, identifying where driving commuters originate from, the various factors that lead to the driving behaviour, as well as re-evaluating parking permit policy and studying modern parking management, will be able to help solve the parking problem at McMaster

University. It will also add to the small body of literature that deals explicitly with campus parking problems, and the effective responses to them.

This chapter has provided a discussion of the literature reviewed in the context of this study. It has shown that the majority of studies conducted on the subject of parking has been taken from the perspective of civil engineering or business/economics. As such, the studies have focused primarily upon the behaviour undertaken by drivers when presented with the situation where parking is required, or how such parking behaviour can be better managed to be more efficient and beneficial to both drivers and those managing the parking facilities.

Chapter 3: Data Collection and Methods

Introduction

As previously discussed, the purpose of this study was to investigate the commuting behaviours of the staff and students at McMaster University and to present a solution to the parking "crunch" on campus. To do so, survey data were required, to enable the estimation of a multinomial logit model. By such estimations, modal utilities were developed with variables used to explain the modal choices being made by the commuters. A number of steps were required to both acquire the data, and set it up to be used within the LIMDEP software, employed to run the model. This chapter will describe the acquisition and description of the data used within the models, the description of the initial undertaken statistical analysis, and a theoretical description of the model itself and why it was used, the tables of variables created to be used within the models.

Data Acquisition

At the outset of this project, it was suggested that data from the Parking and Security office could be used to the behaviour of those choosing to drive to the campus on a regular basis. However, due to the nature of their parking management software, it was not possible to extract important information that is typically used within a modal split model: specifically, a staff member's position on campus (administrative, faculty, etc.), relative income, household size, etc. In some cases, staff provided only the address of their offices or the departments within which they worked on campus, as opposed to their home addresses. Furthermore, discussions with the Human Resources department on campus had seemed hopeful regarding being able to retrieve some such data if names were submitted (from the parking office data), proved impossible due to a recently passed privacy act. As such, the information extracted from these data was rather limited, as it was a large list of all who had ever purchased a parking permit since 2002.

The data used for this project were the results of the staff and student 2004 ACT travel behaviour surveys. There were two separate versions of the survey, one for the staff, and one for the students. Examples of both surveys may be found in the Appendix. The main differences between survey versions consisted of fewer questions on the student survey (14 rather than 18 on the staff survey), and the travel behaviour section for the student survey was "larger" to accommodate the observed patterns of the students, which differed from those of the staff. For example, the students had an extended number of "parking" options which included "Park off campus and walk", "Park off campus and take [transit]", and "Park in on-campus lots" within both the "Drive alone" and "Carpool" options. The staff survey did not include any such parking options, indicating the assumption that those with permits always parked on campus, and those without did not drive to the campus. The respondents were asked to indicate the "percentage" of all trips taken to the campus, both on weekdays and weekends, taken by a certain mode. For the purposes of this study, only the "weekday" responses were kept, which is when the University experiences the majority of its traffic and therefore, the entirety of its parking and congestion problems.

The survey also asked respondents to provide information on age, programme level or staff position, as well as a postal code or street address. However, it did not ask socio-demographic or socio-economic information, meaning variables such as household size and income could not be extracted from the survey. These types of variables are typically present in modal split model estimations, due to both their logical and tested importance in the set of factors most commonly determining modal choice. Furthermore, the survey did not ask the respondents for any mode-specific information such as travel time, travel costs, parking costs, and transit access time. As with the socio-demographic information, these variables are demonstrated as important when included within the logit model framework, as it helps explain the unattractiveness of a given mode, and allows for later calculations of elasticities. A number of these variables were estimated manually, as discussed below.

At this point it would be important to note two things about the survey: how the data were collected, and their relative representativeness of the population of both staff and students. Students were solicited during class, meaning that representatives from the

ACT office would enter classes, and conduct the surveys. For staff, paper copies of the survey were left within the various departments around the university (including the Downtown Campus), and staff members were encouraged to "pick up" a hard copy of the survey to fill out. Thus, it is not easy to infer how well the sample represented the population at large for both staff and students. Since data from Human Resources was unavailable, it was not possible to compare distribution of various characteristics of the sample against the population. While the ACT does its best to collect data from all points of staff and students to maximize representativeness, the degree to which the data are representative is not known. However, due to the immense effort taken in an attempt to gather a representative sample, and the uselessness of the data from parking services, as well as being unable to obtain anything from Human Resources, the data from the ACT were the best option especially considering the information that was ultimately surveyed.

The staff survey data were provided "clean", meaning that personal information that had been provided (e.g. e-mail addresses or names) was removed by ACT prior to the data being obtained, and consisted of 374 records. However, further "cleaning" for the purposes of this project was required prior to these data being used. Observations that related to staff members from the Downtown Centre were eliminated. The remaining data were then further cleaned by removing entries that did not provide a postal code, thus making it impossible to geocode and subsequently to calculate the distance and driving time between the place of residence and the university campus in later steps. Also, there were some entries that did not provide travel behaviour information (i.e. did not indicate their modal choices), which were also removed from the data. After cleaning, the staff data contained 300 records.

The student data were also obtained having been cleaned by ACT, and contained 1163 records. It also required further cleaning in much the same manner as for the staff data. These data also included records of students who had resided on campus, which were removed due to the fact that these students would not be commuting to the campus in any way during the week. There were a greater number of instances in which students did not provide a postal code. An explanation for this is that some students living in off-campus housing never need to learn the postal code of the residence. Also, there were a large number of records where students did not fill out the travel behaviour section (e.g. zero trips, or zero modal usage), and were eliminated from the dataset. Those records were unusable. The final dataset included 493 entries. Upon review of the results, it is obvious there is a discrepancy between the number of entries in the final dataset, and the number listed within the results (i.e., n = 465). All 493 entries were recognized and accepted by the LIMDEP software, but during trials the results would indicate "28 bad observations", but not which exact entries were left out. Accompanying manuals and online resources did not have any explanation for what constitutes a "bad observation", therefore at this time there is no explanation for why the software would have omitted these entries, especially since there was no way to determine which entries the software was omitting..

The geocoding of the staff and student data was completed using the built-in geocoding tools within ArcGIS 9.2's ArcToolbox. The "address locator" required by the tool was created with the postal code information from the 2004 DMTI CanMap Street Files. The dataset derived from the ACT survey results contained only records with the respondents' postal codes, and therefore, their places of residence. The road network travel distances and driving times were calculated using TransCAD 3.65 and the 2004 DMTI's RouteLogistics files for Ontario. The RouteLogistics files contained a shapefile with the road network of the province, as well as the additional information of travel times, speed limits, and road directions. Using the travel times, the algorithm within TransCAD was able to calculate network travel distances and driving times for each of the points which were previously geocoded to the "McMaster University" point. Travel distances were calculated in meters, later converted to kilometers, and travel times were returned in minutes. This is due to the information from the original RouteLogistics files being stored in those units.

Transit times were estimated manually, due to constraints in time requiring that actual route files could not be obtained in a timely manner. Since a bus stop point file was available, a spatial join was performed to calculate distances between place of residence points and the nearest bus stop. The digital image versions of the HSR and Burlington Transit route maps were given spatial information manually through the Georeferencing tool within ArcMap 9.2 using the DMTI CanMap Street Files. This allowed for the manual updating of the geocoded point file with the route associated with each point's nearest transit route. At this time, records were also made identifying whether or not the respondent would require a transfer of transit routes to reach the destination. To determine an estimated transit time, each route's schedule was consulted between the point of pick up and either the destination, or the point of transfer. For those records requiring transfers, the individual "pieces" of the journey were added up together to provide a total transit time.

Statistical Exploration of Data

The data were cross-tabulated to compare modal usage against itself, the "Drive alone" mode individually against place of residence distance from the university campus, and the same modes against the percentage of the total using those modes for at least 60% and 80% of all trips. This allowed for the initial determination of hypotheses to be tested during modeling, as well as for observing any possible trends that may be present within the data. Therefore, by performing statistical analysis, the hypotheses formed could be further tested during the modeling exercise. In this case, as will be discussed in Chapter 3, the results from the modeling sufficiently affirmed the hypotheses formed during the statistical analysis.

The Multinomial Logit Model

To explore the possible factors leading to choosing a mode of travel, the multinomial logit model was applied. Developed in econometrics, this model has been applied in a transportation analysis context since the 1950's and has been used extensively as a modal split model in many forecasts and studies since then. The purpose of the model is to estimate utility functions for each of the alternatives provided, which can then be used to predict probabilities. In this case, the model would predict the probability a certain individual would choose a particular mode, based on individual and alternative mode characteristics. This probability is relative to the remaining alternatives, therefore, the sum of probabilities for all the alternatives for any given individual must add to one. The model has been widely adopted and used for many years due to its ability to provide logical and useful results, and is still applied in many econometric and transportation analysis studies.

The multinomial logit model can be expressed as Equation 1, below:

$$P_{iq} = \frac{e^{V_{iq}}}{\sum_{A_j \in A(z)} e^{V_{jq}}} \tag{1}$$

Where:

P_{iq} is the probability individual q will choose alternative i;
e is Euler's constant;
V_{iq} is the utility of mode i for individual q;
V_{jq} is the utility of mode j for individual q.

The utility function can be simplified as Equation 2, below:

$$U_{jq} = V_{jq} + \varepsilon_{jq} \tag{2}$$

Where:

U_{iq} is the utility of alternative i for individual q;
V_{iq} is a linear-in-parameters function of the measured attributes, **x** (see Equation 3);
ε_{jq} is an immeasurable random component to capture the "taste" preferences of individual q.

The V_{iq} function can be demonstrated in Equation 3, below:

$$V_{iq} = \beta_1 x_{iq1} + \beta_2 x_{iq2} + \cdots + \beta_k x_{iqk} \quad (3)$$

Where:

V_{iq} is the systematic component of alternative i for individual q;
β is a parameter from the vector $\beta = [\beta_1, \beta_2, \ldots, \beta_k]'$ of K unknown parameters.

The model itself can only be employed under strict assumptions. One of these assumptions is that the sample is understood as a set of rational individuals. This means that the individuals are assumed to choose the mode that will provide the greatest utility, based on a number of personal and mode specific characteristics. This is a strong assumption, as it is inferring something of human behaviour. However, the theory of individuals seeking to maximize their utility of a given mode has shown to be fairly accurate, as numerous studies have been able to successfully use the results of multinomial logit modeling to logically explain the travel behaviours identified within their analyses.

A second assumption of the multinomial logit model is that of the Independent of Irrelevant Alternatives (IIA) assumption. This is typically explained by the "red bus-blue bus" problem, described the best by Ben-Akiva and Lerman (1985). To avoid this problem, within the ACT data, those choosing to use the HSR, GO, or any combination of these transit options were all grouped into a single "Transit" option, for both the staff and the student data. This was also part of the "cleaning" process, described above. Another method to avoid violating the IIA is to further complicate the model structure by adding additional "nests" below the main structure which will feed into the structure above it. This was done for the staff data, where a parking lot choice "nest" was placed below the "Drive alone" option in the upper nest. Due to software problems, the nested logit model was run in a step-wise function, as opposed to running the model "full information" (i.e. all at once), meaning the lower nest was estimated, and an inclusive value calculated separately, prior to running the upper nest which then included the inclusive value as a variable to the "Drive alone" option. The inclusive value was calculated using Equation 4, below.

$$IV = \ell n \sum_{j} e^{W_j} \tag{4}$$

Where:

ln is the natural logarithm;
e is Euler's constant;
W_j the utility of nested choice j.

Regarding the "Transit" aggregation mentioned above, there were not enough records for each of the various transit-type options to create a lower nest, which was the reason for the aggregation. From this, it can be seen that care was taken to avoid erroneous results that would have arisen by a violation of the IIA with these data.

Variable Creation

The model was run using the software LIMDEP version 8.3. All other exploration and organization of the data, especially variable creation and dataset formatting, was completed using Microsoft Excel. Tables 2 and 3 list the Master Table of variables for the staff and student data, respectively. Due to the nature of the information provided by the survey (such as a respondent identifying the "age range" within which s/he fell), most of the responses were converted into categorical variables. Any variables requiring estimation of their values, the calculation is described below the table beside the corresponding bullet.

Table 2: Master Variable List for use in the Multinomial Logit Model: Staff

Variable Name	Description
Driving time	Minimum driving time (min) along shortest route from place of residence to campus
Parking cost	Cost of parking ($/day)[1]
Age Less Than 30	Value is 1 if true; 0 otherwise
Age 30 to 39	Value is 1 if true; 0 otherwise
Age 40 to 49	Value is 1 if true; 0 otherwise
Age 50 to 59	Value is 1 if true; 0 otherwise
Access to Car as Driver: Regularly	Value is 1 if true; 0 otherwise
Access to Car as Driver: Never	Value is 1 if true; 0 otherwise
Inclusive Value	Inclusive Value calculated from the lower Parking Lot Choice nest
Parking Permit Holder	Value is 1 if true; 0 otherwise
Distance from Parking Lot	Euclidean distance (m) from centroid of parking lot to the weighted mean center of campus
Limited/No access to Transit	Value is 1 if true; 0 otherwise[2]
Distance to Nearest Transit Stop	Euclidean distance (m) from place of residence to nearest public transit stop
Access to Car as Passenger: Regularly	Value is 1 if true; 0 otherwise
Transit Pass Holder	Value is 1 if true; 0 otherwise
Transit Time	Minimum transit time (min) along shortest route from place of residence to campus[3]
Transit Cost	Cost per trip ($)[4]
Male	Value is 1 if true; 0 otherwise
Walking Time	Minimum walking time (min) along shortest route from place of residence to campus[5]
Biking Time	Minimum biking time (min) along shortest route from place of residence to campus[5]
Distance to McMaster Campus	Minimum distance (km) along shortest route from place of residence to campus
Transit Stop within 400m of Residence	Value is 1 if true; 0 otherwise[6]

The following notes have been made regarding the six variables with superscript in Table 2:

1. This parking cost was estimated by dividing the total monthly permit cost by 20, the average number of working days per month. Permit costs were referenced based on respondents' identification of the parking lot for which s/he held a permit and the 2004 rates.
2. This categorical variable determined based on if the respondent lived >400m from a transit stop (see note 6).
3. This is in-vehicle travel time based on HSR bus schedules and therefore an estimated 17km/h travel speed, calculated based on the minimum distance for each respondent. Furthermore, each place of residence was manually associated with the local transit route(s) required to make a trip to the university main campus, taking into account the number of transfers required, the frequencies of the route(s), and estimated in-vehicle travel time(s).
4. This transit cost is either HSR per-trip fare costs (estimated based on respondents' identification of use of transit tickets, cash fare, or monthly pass fare) or GO transit per-trip fare costs, depending on respondents' identification of use of these modes (provisions on the ACT survey allowed for these distinctions).
5. Walking and biking times were estimated using the minimum distance calculations and 1998 Go for Green's National Survey on Active Transportation Summary Report which states that average walking and biking speeds are 4.9 km/h and 16 km/h, respectively.

6. Demetsky and Lin (1982). Bus Stop Location and Design. *Transportation Engineering Journal of ASCE*, 108, p. 313-327. This article identified that a reasonable distance to access a transit stop is maximum 400m from the place of residence.

Table 3: Master Variable List for use in the Multinomial Logit Model: Student

Variable Name	Description
Access to Car as Driver: Regularly	Value is 1 if true; 0 otherwise
Distance to McMaster Campus	Shortest path distance along the road network (km) from place of residence to McMaster campus
Driving Time	Shortest path travel time along the road network (min) from place of residence to McMaster campus
Parking Permit Holder	Value is 1 if true; 0 otherwise
Parking Cost	Cost of parking in a campus lot per day ($) if respondent is a permit holder[7]
Distance from Parking Lot	Euclidean distance from center of parking lot to weighted mean centre of campus (km)
Age Less Than 20	Value is 1 if true; 0 otherwise
Age 20 to 29	Value is 1 if true; 0 otherwise
Age Greater Than 30	Value is 1 if true; 0 otherwise
Male Aged Less Than 20	Value is 1 if true; 0 otherwise
Male Aged 20 to 29	Value is 1 if true; 0 otherwise
Male Aged Greater Than 30	Value is 1 if true; 0 otherwise
Female Aged Less Than 20	Value is 1 if true; 0 otherwise
Female Aged 20 to 29	Value is 1 if true; 0 otherwise
Female Aged Greater Than 30	Value is 1 if true; 0 otherwise
Access to Car as Passenger: Regularly	Value is 1 if true; 0 otherwise
Access to Car as Driver: Never	Value is 1 if true; 0 otherwise
Transit Pass Holder	Value is 1 if true; 0 otherwise
Transit Time	Shortest path travel time along the road network (min) from place of residence to McMaster campus (access and waiting time not included)[8]
Walking Time	Shortest path walking time along the road network (min) from place of residence to McMaster campus[9]
Biking Time	Shortest path biking time along the road network (min) from place of residence to McMaster campus[9]

Here are the accompanying notes for the student variable list:

7. This parking cost was estimated by dividing the total monthly permit cost by 20, the average number of working days per month. Permit costs were referenced based on the 2004 rates.
8. This is in-vehicle travel time based on HSR bus schedules and therefore an estimated 17km/h travel speed, calculated based on the minimum distance for each respondent. Access/waiting times as well as out-of-vehicle travel times have not been estimated due to inconsistent bus route frequencies (e.g. some run more frequent than others) and difficulty in determining the possible route chosen due to lack of route logistics files that cannot be provided by the HSR.
9. Walking and biking times were estimated using the minimum distance calculations and 1998 Go for Green's National Survey on Active Transportation Summary Report which states that average walking and biking speeds are 4.9 km/h and 16 km/h, respectively.

Finally, the Master Variable list for the nested parking lot choice model is listed in Table 4.

Table 4: Master Variable List for use in the Nested Logit Model, Staff

Variable Name	Description
Parking cost	Cost of parking ($/day)[1]
Distance to central campus	Distance from center of the parking lot to the weighted mean center of the campus (m)
Walking Time	Shortest path walking time (min) from center of the parking lot to the weighted mean center of the campus[9]
Shuttle Bus Available	Value is 1 if true; 0 otherwise
Shuttle Bus Travel Time	Shuttle bus average travel time (min)
Shuttle Bus Frequency	Shuttle bus average frequency (min)

Chapter Summary

The nature of this study called for a transportation mode choice analysis. In the past, and in the most recent studies, researchers have used the multinomial logit model as a tool for determining the most prevalent factors that lead to the modal choice of individuals. This model was employed to determine the various factors that led to the transportation mode chosen by commuters to facilitate policy suggestions that could be made through the analysis of the results. The data used to estimate the models were acquired from the ACT, and were the results from the 2004 Transportation Survey conducted of the staff and students. These data required cleaning and formatting prior to being used within the LIMDEP software, which estimated the models. Due to the dissatisfaction with the model results from the staff data, further analysis was conducted using tabulations. The results from the model estimations and the tabulations are presented and discussed in the following sections.

Chapter 4: Results and Discussion

Introduction

This chapter will present the results from both the statistical analyses, and the modeling exercises conducted on the staff and the student data. For detailed descriptions of the methods involved, as well as their justifications, the reader should refer to Chapter 2. The results from the staff data are presented and discussed first, followed by the analysis of student data. The discussion of results from both sets of data will indicate there is sufficient information for which suggestions regarding policy implications, and overall conclusions can be made.

Staff Data Results

Statistical Analysis

This sub-section will present and discuss the results of the preliminary statistical analysis conducted on the staff data. Below it will be shown that the majority of the staff are choosing to drive their cars to the campus on a regular basis, regardless of whether or not they live near to, or far from, the university campus. The spatial distribution of the places of residence of the parking permit holders will be explored and discussed, as well as a comparison of the number of permit holders against various distance thresholds (discussed below). This will provide evidence that distance is not a factor in determining the likelihood of whether or not a staff member will choose to drive, while holding a parking permit is.

Figure 2 shows the mode usage against the percentage of the total sample choosing that mode for 20, 40, 60, 80, and 100% of trips. These percentage thresholds were chosen due to their simpler conversions into a value out of five. Assuming the majority of the staff work Monday to Friday, this translates into approximately five trips to the campus a week. Therefore, these percentage thresholds convert directly into 1, 2, 3, 4, and 5 trips out of 5, respectively. This allows for an easier quantification of what a percentage indicates in terms of numbers of trips.

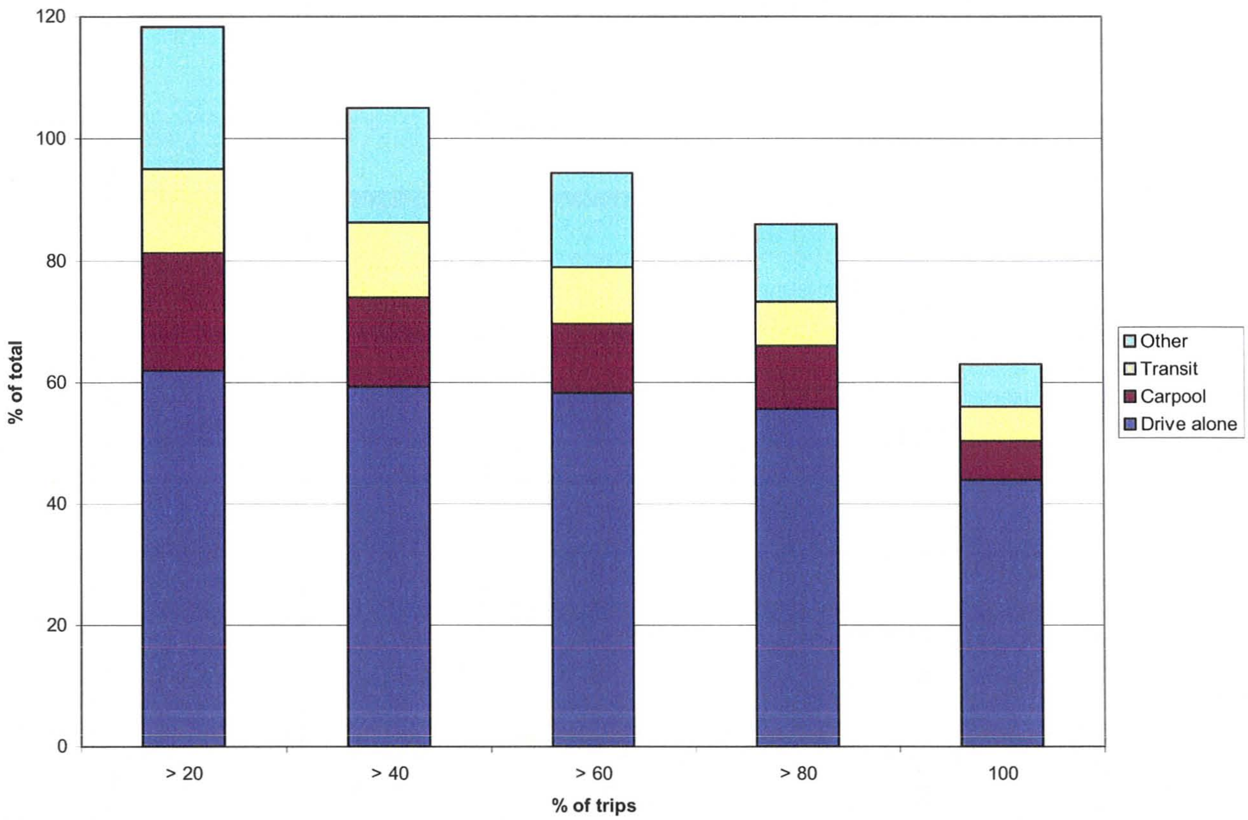

Figure 2: Staff Mode Choice Usage vs. % of Total

At first glance it may appear to make no sense that there would be totals greater than 100% -- however, this is due to the very nature of the data. On an individual basis, the modal usage would add up to no more and no less than 100%, but since this chart is comparing usage across modes and across categories, this is not necessarily the case. Furthermore, it indicates that while there is modal loyalty (discussed below), there is also approximately 20% of the sample that used more than one type of mode on an occasional basis, indicated by the surplus on the first bar.

Another observation is that the "Drive alone" mode is the most dominant mode across the board, as its bars have the greatest heights compared to all others at all thresholds of trip percentages. Carpool and Other appear approximately even, if the latter is not slightly taller on some percentages, and Transit is the least used. The height of the Drive alone bars do not vary much over the different percentage thresholds, therefore it can be observed that its popularity is preserved at all levels. The differences in the total heights of each of the columns indicates that there is variability within the modal choices, accounting for the 20% identified as using different modes throughout the week. This is an important observation that will concern the policy implications, discussed later in this thesis.

Due to its prevalence, the Drive alone mode was explored in more detail and in different contexts such that more meaningful observations could be drawn about the staff's driving behaviour. First, it was interesting to explore on a map the distribution of the staff's places of residence. Figure 3 shows the result.

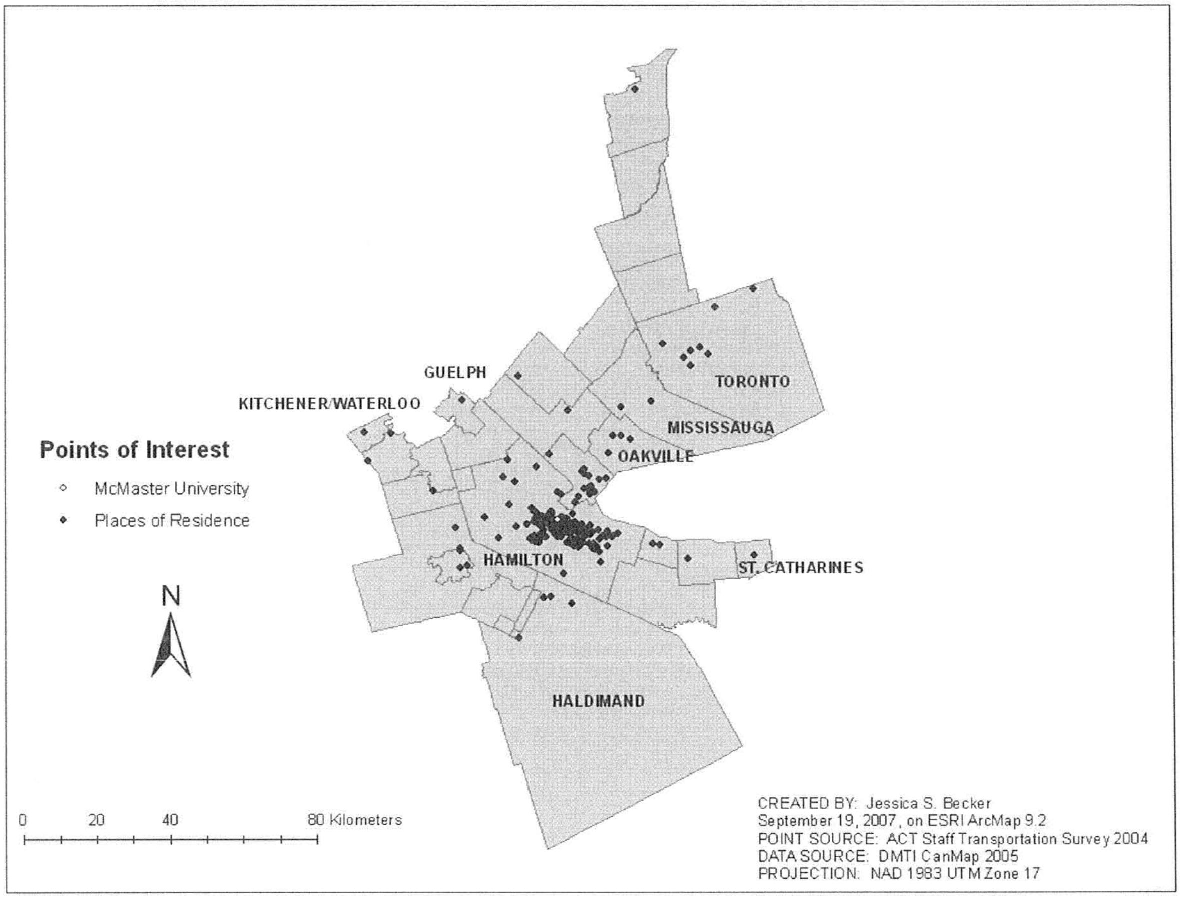

Figure 3: Spatial Representation of Staff Places of Residence

From Figure 2 it appears that the majority of the staff reside in close proximity to McMaster University, with a handful of staff being drawn from farther outlying areas. Following this plotting, it was appropriate to investigate more closely the distance of place of residence of staff from the university. Some "Local Thresholds" were determined that would be familiar landmarks within the city and area. These thresholds, and their approximate Euclidean distances to the university campus, are summarized in Table 5.

Table 5: Summary of Local Landmark Euclidean Distances to McMaster (KM)

Local Landmark	*Distance (KM)*
Downtown Hamilton	4
Ancaster Meadowlands	5
Eastgate Square (Stoney Creek)	13
Hamilton Airport	12
Burlington Central	15

By using these threshold values, subsequent charts compare the percentage staff respondents that live within a specified distance from campus. At this point it would be interesting to note that regarding the current public transit service, there are four routes that service the corridor between the campus and downtown Hamilton during the September to April semesters, when the majority of the students are in town. During the summer months, May to August, there are three. All year there is one direct route from the Ancaster Meadowlands to the university. From this, an argument could be made that those living between the campus and the downtown, and between the campus and the Meadowlands have the best direct public transit routes to the campus. Exceeding these threshold distances, using the transit requires the transfer of one or more routes with the exception of the Beeline Express route that runs directly between the campus and Eastgate Square during rush hours on weekdays.

Following the spatial plotting of the staff's places of residence, their distances from campus were plotted, as shown in Figure 4. This figure is simply showing the chart-equivalent of Figure 3, such that it is easier to quantify the number of staff living within the local threshold distances outlined in Table 5.

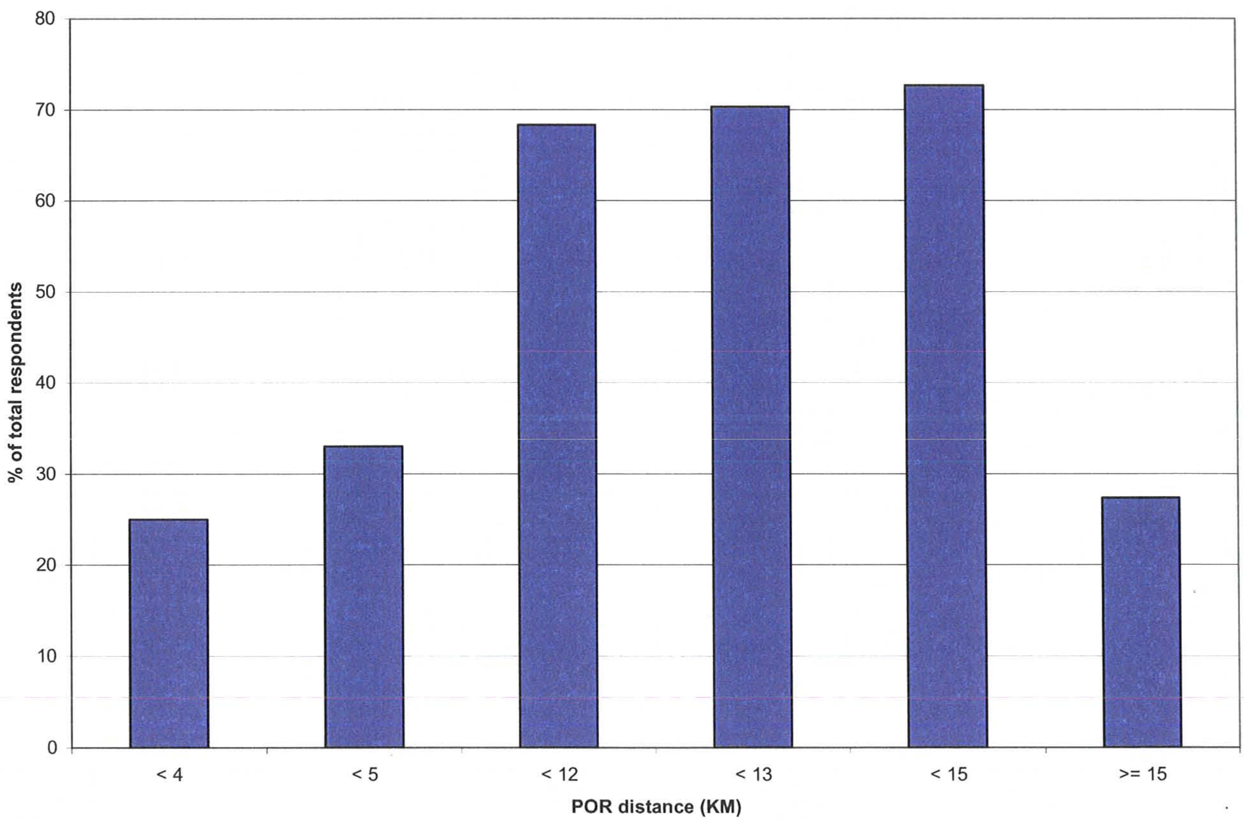

Figure 4: Staff Place of Residence Distance vs. % of Total

This Figure shows that approximately one-third of the staff live within 5 KM of the university campus. The number increases by nearly 40% as the distance threshold increases from 5 to 13 KM, and this is also apparent in Figure 3, where the majority of the points appear within 13 KM of the university when compared to the scale. Just over

25% of staff are shown to be coming from farther than 15 KM, and this again is reflected in Figure 3 by the points that are scattered around the Hamilton CMA. From both of these figures it is shown that the majority of the staff in the sample are coming from the local area surrounding the university, with just over one-quarter coming from places that are outside of the Hamilton CMA. This implies that inducing policy changes that will affect the local area will also be affecting the majority of the staff at the University.

More charts were created to explore the effects of distance on the parking permit holders. Within the sample, 202 of the 300 records were identified as being parking permit holders, which is approximately 67%. Figure 5 shows the breakdown of these permit holders against the distances between the university campus and their places of residence.

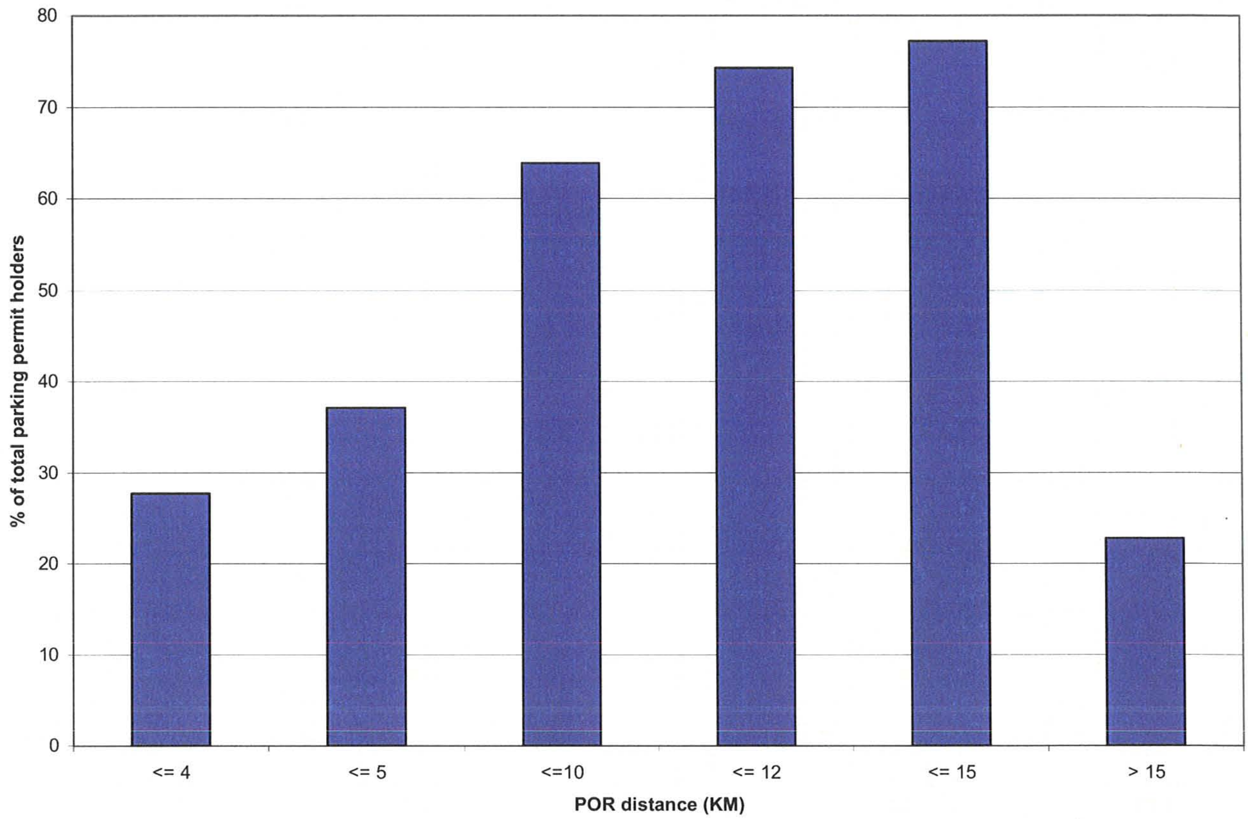

Figure 5: Staff Place of Residence Distance vs. % of Total Parking Permit Holders

In a quick comparison with Figure 3, the heights of the bars at each of the thresholds appear to be very similar between these two Figures. Approximately 27% of the parking permit holders in the sample live within 4 KM of the university campus – arguably the most heavily-serviced area regarding public transit to the campus. This number increases by nearly 10% with the addition of 1 KM to this radius, and this indicates that over one-third of the staff in the sample are parking permit holders that live within 5 KM of the campus. This number increases by 35% for 10 KM, and this makes sense. Past the 5 KM threshold, both towards the south up into Ancaster, and in the eastern direction towards Stoney Creek, taking public transit to the university begins to become inconvenient as transit transfers are required, and travel time quickly begins to increase to become, in some cases, triple the time it would take if there were only one direct route with no transfers. This figure also indicates that distance does not appear to be a factor regarding whether or not staff will opt to purchase a parking permit. Therefore, it is important to recognize that the staff are choosing to purchase parking permits whether or not there is high or low transit service near their place of residence. This was also identified within the logit model results (discussed later) as a positive factor leading to choosing to drive alone. In this way, this chart analysis observation holds with what the logit model also identified as a factor.

Regarding actual driving behaviour, the permit holders were analyzed again based on their places of residence, but for Figure 6, only those that chose Drive alone for 60+% of trips, i.e. for a minimum of 3 out of 5 trips per week.

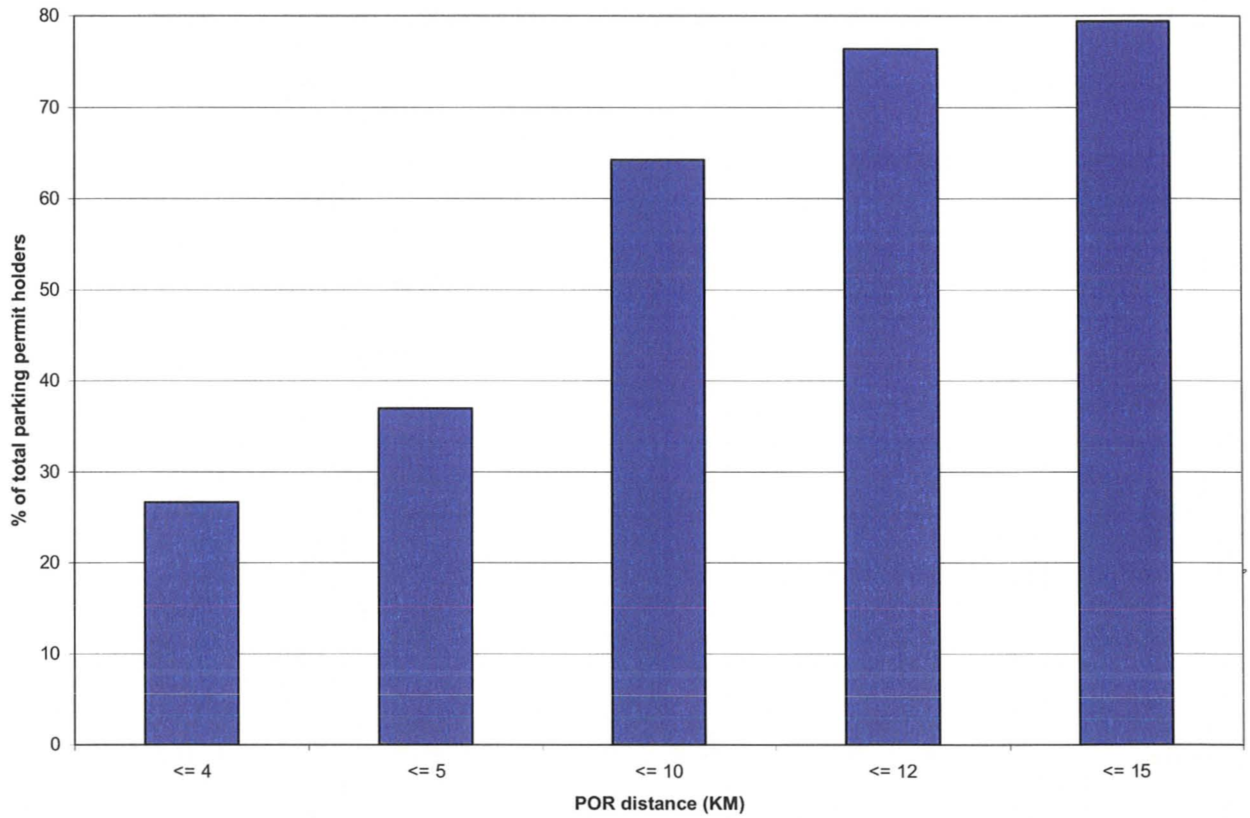

Figure 6: Place of Residence vs. % of Total Parking Permit Holders, Staff choosing "Drive Alone" 60+% of Trips

Once again, the Figure looks similar to both Figures 4 and 5. This indicates two things: that the staff appear to be driving regularly whether or not they live near or far away from the campus, and that being a permit holder will lead a staff member to drive to the campus on a regular basis. Both of these inferences support the results that were returned from the multinomial logit modeling: that distance was not a significant factor in determining whether or not a staff member will choose to drive alone, and being a permit holder had a positive influence on the probability of driving alone. To test that driving regularly is not affected by distance, another chart was created in the same manner as Figure 6 but for those driving alone 80+% of trips.

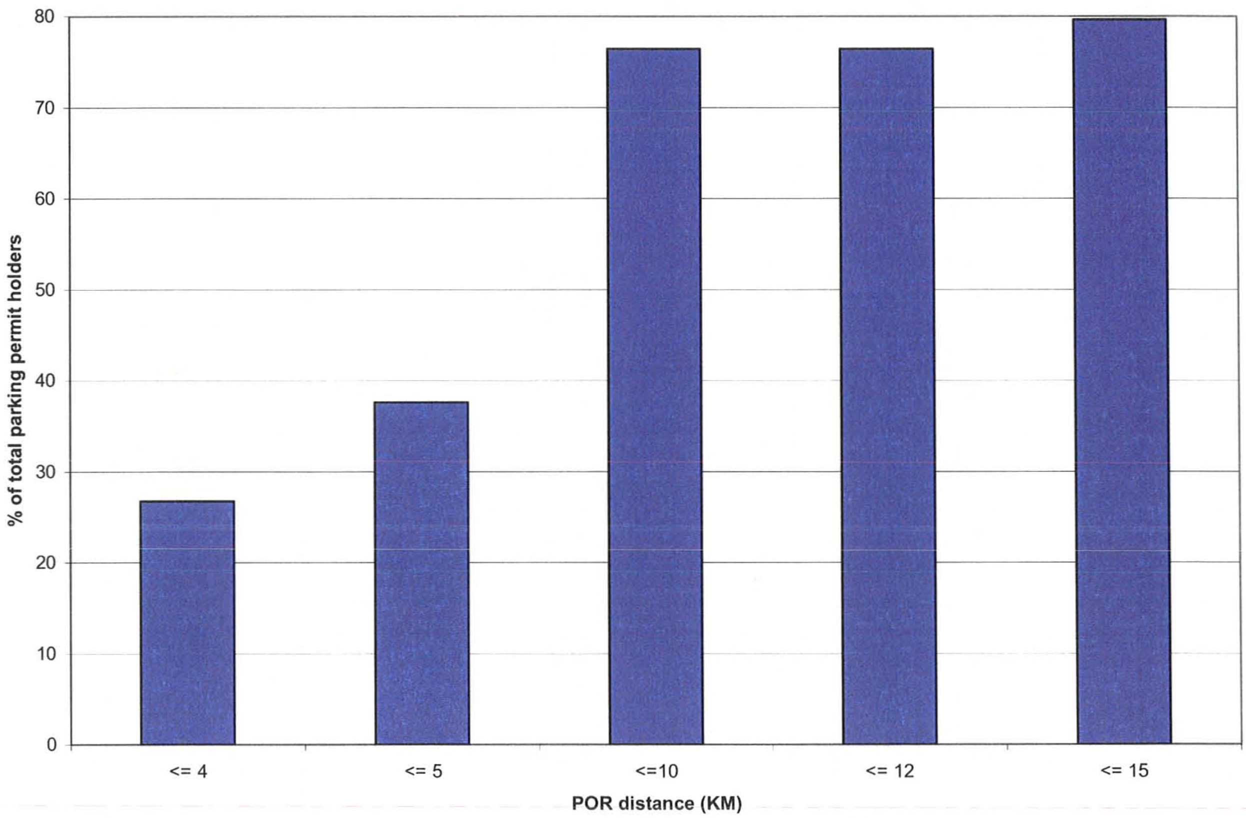

Figure 7: Place of Residence vs. % of Parking Permit Holders, Staff choosing "Drive Alone" 80+% of Trips

Figure 7 is another that appears to be following the similar distribution pattern of Figures 4, 5, and 6. As is consistent with the previous three Figures, just over one-quarter of the staff who live within 4 KM are driving alone for at least 4 out of 5 trips per week. This increases by 10% with the addition of 1 KM to this radius, such that over one-third of the staff are driving to the campus on a regular basis despite living within the best transit service area to the campus. This Figure further indicates that not only are staff driving regularly from nearly any distance from the campus, it also indicates again that permit holders are likely to drive on a regular basis and for that purpose they acquire a permit. This is supported by the similar distributions within each of the previous four Figures, which have plotted different information against place of residence distance, and yet have had very similar distributions across each of the distance thresholds used within them.

The above discussion has lead to the following hypothesis: that the majority of the staff are choosing to drive to the campus on a regular basis, the major factor leading to this being whether or not the staff member is a parking permit holder as opposed to the place of residence distance. This hypothesis was further tested, and affirmed, by the modeling exercise, discussed below.

Model Results

This sub-section will present the results and detailed discussion following the multinomial logit modeling performed upon the staff data. The modeling results sufficiently affirmed the hypothesis formed as a result of the statistical analysis, discussed earlier within this section.

Parking Lot Choice Lower Nest

A parking lot choice model with four alternatives was found to be both the best in terms of results and fitness, as well as logical. This is due to the fact that, while there are seven parking "zones", there were, in reality, only four unique pricing schemes. Therefore, the parking lot choices were grouped together based on the pricing schemes. Table 6, below, summarizes the best parking lot choice model obtained by running a multinomial logit model on the four parking lot choice alternatives.

Table 6: Parking Lot Choice Model Results

Variable Name	Model Results (p-value)
Parking Zone 1&2	
Constant	206.4 (0.0000)
Parking Cost	-220.88 (0.0000)
Parking Zone 3	
Constant	395.5 (0.0000)
Walking Time	-96.14 (0.0000)
Parking Zone 4&5	
Constant	-306.7 (0.0000)
Parking Zone 6&7	
Parking Cost	-75.80 (0.0000)
Walking Time	-36.64 (0.0000)
Shuttle Bus	386.6 (0.0000)
n = 202	R^2 = 0.4069
	L(*) = -166.0895
	L(C) = -254.6100

The parameters of the variables that are present returned with the expected sign, and therefore they make sense. The alternative-specific constants within the Zones 1 and 2 utility, and the Zone 3 utility, have positive coefficients, indicating that these would be the most favoured lots compared to the others if all else is held equal. These are also the lots located closest to the campus' administrative buildings. The constants appear to be capturing the immeasurable factors that influence parking lot choice. Parking Cost, significant within the Zones 1 and 2, and Zones 6 and 7 utilities, are returned with negative coefficients. This indicates that the cost of parking within those zones is a disutility in the probabilities of making these lots a parking choice. The Walking Time variable is also returned with negative coefficients, indicating that as the walking time increases, the probability of Zone 3 and Zones 6 and 7 being chosen decreases. Finally, the Shuttle Bus variable increases the utility of Zones 6 and 7, indicating a compensation for the inconvenience of parking in a distant lot from the center of campus.

The relative fit of this model, called a pseudo-R^2, is approximately 0.41, indicating an acceptable fit. Therefore, the use of four alternatives is further rationalized such that setting up the model in this way allowed for it to capture the variability fairly well.

Transportation Mode Upper Nest

The methods chapter discusses in greater detail the equation employed to calculate the inclusive value that appears in the table below. Table 7 summarizes the "best" results obtained from running the multinomial logit model on the upper nest of the staff data.

Table 7: Transportation Mode Choice Model Results, Staff

Variable Name	Model 1 (p-value)	Model 2 (p-value)
Drive Utility		
Constant	-1.588 (0.0010)	-1.665 (0.0005)
Access to Car as Driver: Reg.	2.361 (0.0000)	2.289 (0.0000)
Parking Permit Holder	1.810 (0.222)	2.648 (0.0000)
Inclusive Value	-0.0016 (0.3959)	-
Carpool Utility		
Constant	-0.1089 (0.7557)	-0.1155 (0.7343)
Access to Car as Passenger: Reg.	2.619 (0.0000)	2.748 (0.0000)
Transit Utility		
Constant	-0.3974 (0.1945)	0.1317 (0.6224)
Transit Pass Holder	5.607×10^{-17} (0.0000)	-
Other Utility		
Male	1.272 (0.0012)	1.355 (0.0004)
n = 300	$R^2 = 0.3034$ L(*) = -289.7175 L(C) = -415.8883	$R^2 = 0.4703$ L(*) = -220.3052 L(C) = -415.8883

A comparison between these results and the Master Variable list associated with this dataset (Table 2 in Chapter 2) will quickly indicate that many of the variables created from, and for, the dataset do not return as significant in the final results. Additionally similar to the parking choice model, summarized in Table 6, a number of what would traditionally be considered "important" variables are absent in these results. Specifically, these variables are those of Transit Time, Transit Cost, as well as those indicating a "distance from campus", such as the Distance variable and its proxy variable, Driving Time. Also in Table 7, the Inclusive Value does not return as significant in Model 1 and was dropped during the specification of Model 2. The Inclusive Value was calculated from the Lower Nest model in Table 6, and its insignificance reflects the notion that parking lot choice does not have a bearing upon the Drive Alone utility. This may be explained as the reality that the parking permit policy indicates staff may apply for a permit in any of the lots on campus, but permits are ultimately issued on a first-come, first-served basis; therefore, a parking lot with space available is the one for which a permit will be issued, regardless of the applicant's preference.

The insignificance of the Inclusive Value also indicates that the parking lot in which staff end up leaving their cars does not influence whether or not that staff member will choose to Drive Alone. Instead, as indicated within Table 7 in both Models, the factors that lead to choosing this variable are the Access to a Car as a Driver: Regularly, and being a Parking Permit Holder. In simpler terms, this means that if a staff member has access to a vehicle as a driver, and is a parking permit holder, that staff member will be more likely to choose to drive to the campus. The absence of Distance or Driving Time variables, as mentioned above, further indicate that the required distance to travel to the campus is not as important as being enabled to drive to the campus.

Distance and time do not appear to be significant within the utilities of the remaining alternatives of Carpool, Transit, and Other. Within these utilities, the only difference between Models 1 and 2 is that the Transit Pass Holder variable was first specified within the Transit utility of Model 1, and then within the Drive Alone utility of Model 2, to observe the effect being a transit pass holder may have upon whether or not a staff member will choose to drive alone. Since it did not return as significant within Model 2, it was dropped out from the summary of the results.

Overall, despite the seemingly strong pseudo-R^2 for both models, the absence of expected variables to be returned as significant indicates that the model is demonstrating the staff who choose to drive are doing so irregardless of cost or distance. This finding, while disallowing further calculations of elasticities to present policy implications, is important in itself, and is further supported by the earlier analysis. This is not only due to a lack of important variables, as discussed above, the constants in both the Carpool and Transit utilities are returned as insignificant, meaning they cannot be differentiated from zero. Therefore, if all things are held equal, the only utility that appears to be favoured over all others is that of Drive Alone. Furthermore, it appears that this utility is being favoured for immeasurable factors such as preference and taste, since increasing Distance or Time does not appear to influence the utility in any way. As the multinomial logit model takes its theoretical bases from econometrics, it assumes that the individuals being modeled will behave in a rational fashion. In this case, the rationale presented here indicates that the majority of the staff will choose to drive, under these circumstances. Cost or distance has no bearing on whether or not a staff member will choose to drive, so long as s/he has access to a vehicle and a parking permit. Additionally, traditional modal split models employ the use of socio-economic and socio-demographic information, as these variables have proven to be significant in explaining the behaviours of people who participate in these types of analyses. Unfortunately, the survey tool did not allow for the collection of some key characteristics, and any attempt to retrieve these data were met with no success due to university policies regarding release of personal information of its staff.

Staff Results: Summary

This section has demonstrated a number of points. The charts created for initial analysis helped to inform the modeling exercise, as well as to set up a base hypothesis to be tested. By use of a map and a chart, it became apparent that the majority of the staff in the sample (nearly 70%) lived within the Hamilton CMA, and therefore, most of the staff of the university were being drawn from the local area. Comparing the permit holders against their place of residence distance to the campus showed that just over 33% of the permit holders lived within 5 KM of the university, the distance threshold within which public transit access to the campus is the most convenient (the most direct routes, no transfers, shortest travel times, etc.). Between 5 and 10 KM thresholds to the campus, however, the number of permit holders increased by 40%, which may also be due to the crossing of the threshold where transit access becomes increasingly inconvenient. However, the analysis of the spatial distribution of the parking permit holders emphasized a finding from the modeling: distance is not a telling factor to predict whether or not a staff member will purchase a parking permit.

Continued analysis using the parking permit holders revealed two important findings that are reinforced by their consistency throughout the analysis. The first is that distance is shown, again, to be no significant factor to determine whether or not a staff member will choose to drive to the campus on a regular basis. The second is that, as also shown within the modeling results, being a permit holder is shown to be a significant factor leading to a staff member choosing to drive on a regular basis.

The multinomial logit model results identified that typically important variables, such as cost and distance, do not factor into the driving behaviour of the staff in this sample, under these circumstances. This affirms the similar observation made during the statistical analysis. The model did indicate that having regular access to a vehicle as a driver, as well as being a permit holder, were significant factors in choosing to drive alone. The lack of the driving distance or driving time variables to return as significant in the model trials was further investigated, since these variables traditionally return as significant disutilities for any mode. The model also failed to return the Inclusive Value as positive and significant, indicating that parking lot choice is not an important factor leading to whether or not a staff member will choose to drive alone. Since there is no true parking lot choice for permit holders – they park where they are assigned based on a first-come, first-served basis – these findings make sense in this context.

These findings have particular policy implications. While the university can have no control over the access to a vehicle a staff member may or may not have, it is possible to recognize the prevalence of driving regularly to the campus from short distances that could easily be substituted for public transit use. It is important to recognize the patterns identified in this analysis to enable the creation of a Travel Demand Management (TDM) scheme that will address the specific commuting behaviours exhibited by the staff at McMaster University.

Student Data Results

This section will present the results of the statistical analysis, as well as the best model result from the undergraduate student survey data. As discussed in the previous chapter, like the staff data, the preliminary statistical analysis allowed for the formation of a base hypothesis to be tested within the modeling exercise. Unlike the staff, analysis and modeling of the student data indicated that the students are influenced by place of residence distance, both in terms of modal choice, as well as in the choice of whether or not to purchase a parking permit. These findings are demonstrated, and further discussed, below.

Statistical Analysis

To obtain a visual illustration of the travel behaviour present within the dataset, the student data were also plotted onto charts. Similar to the staff charts, the student data analysis employed the same percentage usage thresholds, and distance thresholds, under the same justification provided in the above section. Figure 8 shows the overall percentage modal usage for the students.

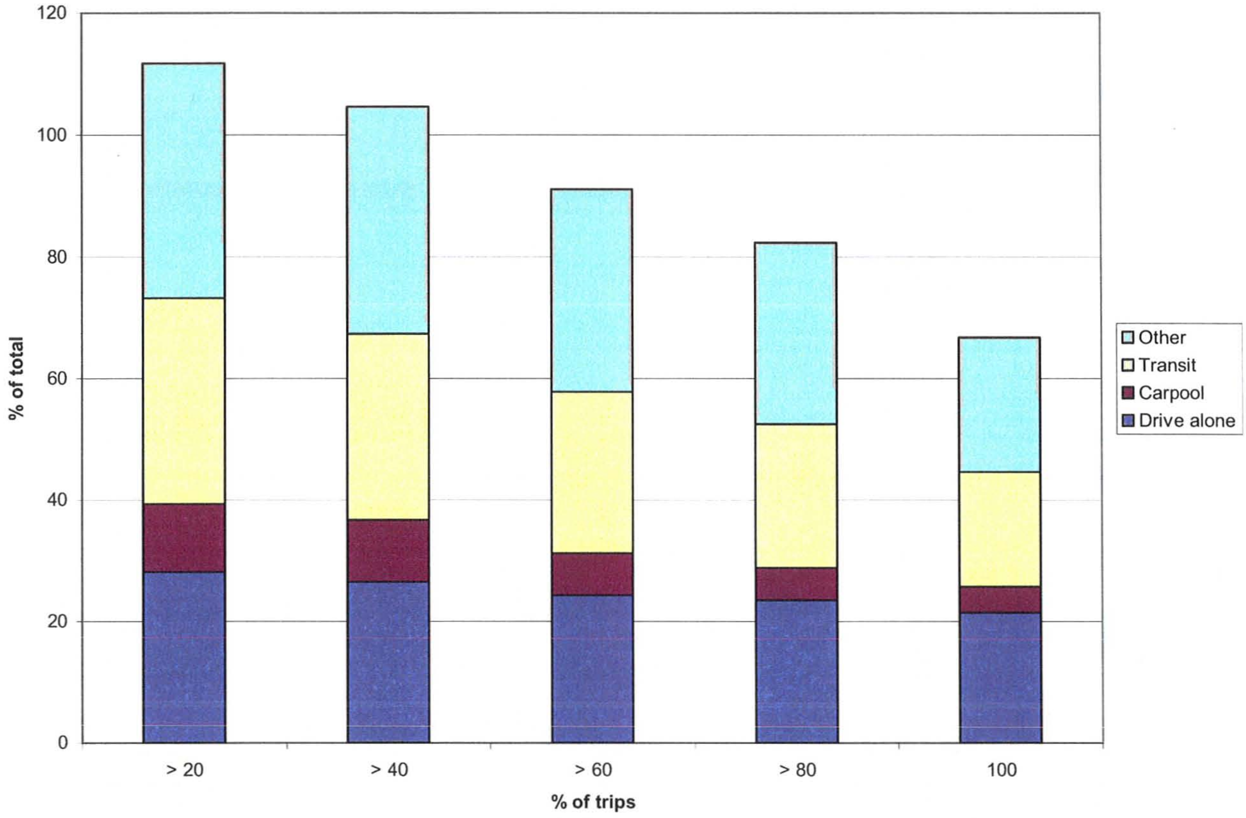

Figure 8: Mode Choice Usage vs. % of Total

Unlike the similar chart created from the staff data, Figure 8 shows that the dominant mode is that within the "Other" category which has the tallest bars, followed by "Transit", "Drive Alone", and "Carpool." This reflects the tendency for students to live within the immediate local area (i.e. within 4 or 5 KM) around the university, and a substantial amount of student housing is located within walking distance off campus. Figure 9, below, affirms this assertion.

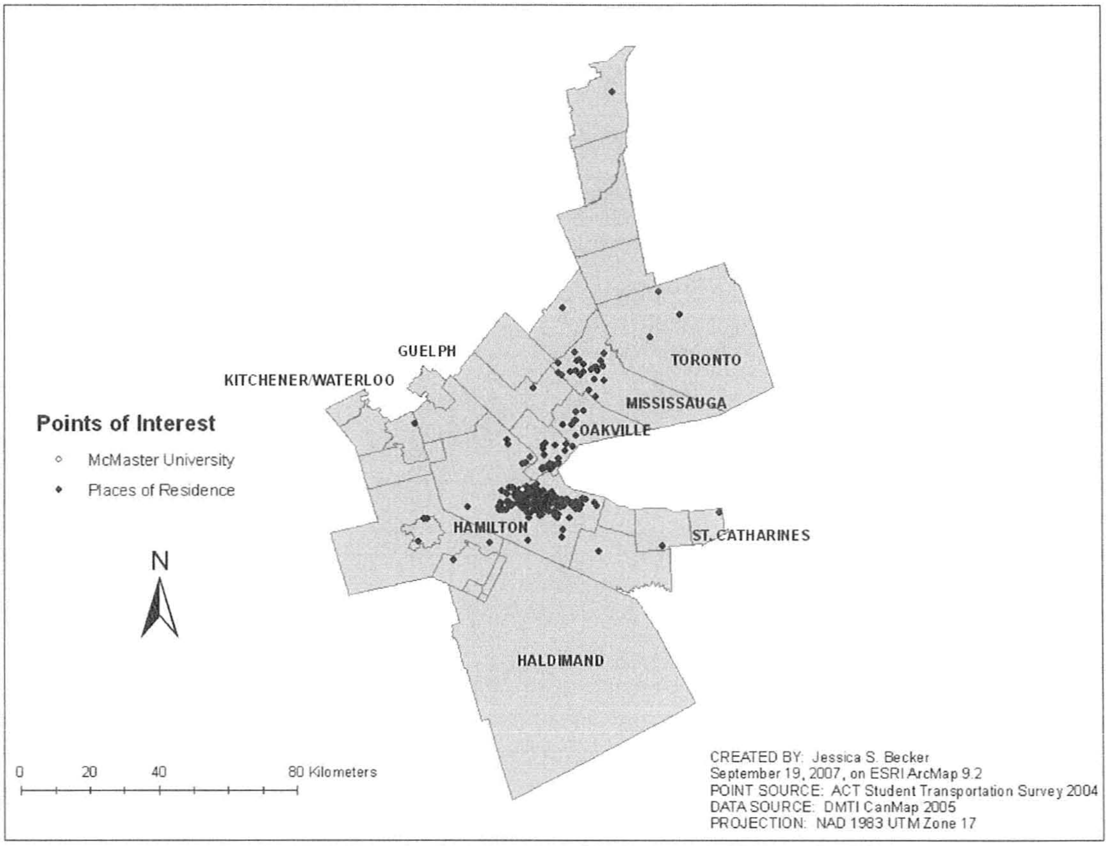

Figure 9: Spatial Representation of Student Places of Residence

From this Figure it can be seen that the assertion made above is correct. While the chart in Figure 8 does not identify the general spatial distribution of the sample, Figure 9 indicates that there is a high concentration of students living within the Hamilton CMA. However, even from this Figure it cannot be easily discerned how many students do live as close as within 4 and 5 KM of the university. Therefore, Figure 10 was created to give clearer insight into the actual numbers of students living within the distance thresholds summarized earlier in this chapter.

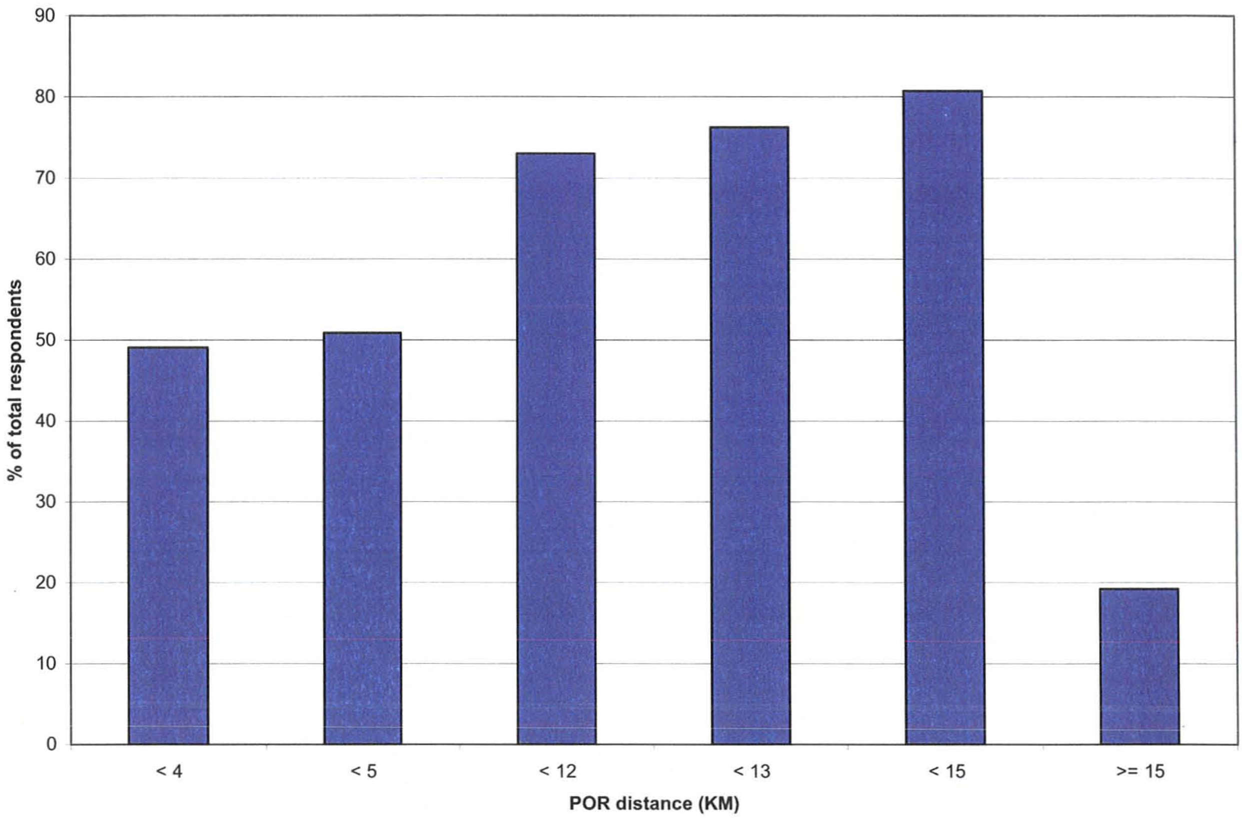

Figure 10: Student Place of Residence Distance vs. % of Total

As mentioned, Figure 10 was created to obtain a clearer picture of the exact numbers of students living within the various distance thresholds, and it can be seen that just over 80% of the student respondents are shown to live within 15 KM of the university. Furthermore, slightly over 50% of these live within 5 KM of the university, affirming the earlier statement regarding the concentration of students residing very close to the campus. This Figure also helps explain why the most popular mode choice is "Other", as living within shorter distances to the university better facilitates choosing to walk, bike, or the use of another non-motorized mode to travel to the campus. Finally, in comparison to the similar figure drawn for the staff (Figure 4), it can be seen that there are many more students living within 4 and 5 KM of the university. Not only is this explained by the high concentration of off-campus student housing within this area, as previously mentioned, it further demonstrates why students are more likely to choose alternate modes to travel to the campus: there are simply many more students physically living closer to the campus than staff.

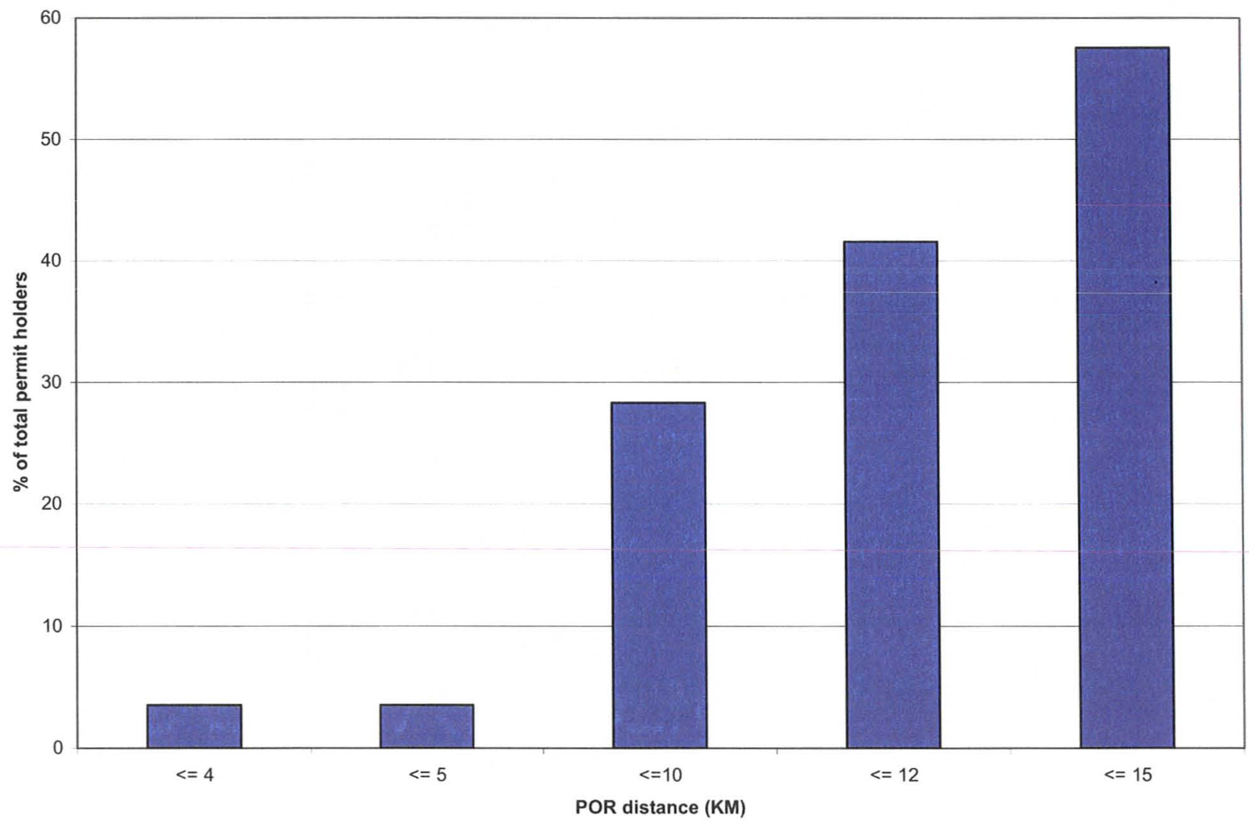

Figure 11: Student Place of Residence distance vs. % of Total Parking Permit Holders

A first glance indicates that the permit-purchasing behaviours of the students are much different than that of the staff. The students appear to be behaving in an expected manner, meaning that as the distance between their places of residence and the campus increases, they are more likely to be a parking permit holder. Less than 5% of the permit holders in this sample lived within 5 KM of the university, far less compared to the nearly 33% of staff living within the same distance who were also permit holders. However, similarly to the staff charts, the number of permit holders increases sharply between the 5 KM and 10 KM threshold. This again indicates that this is a result of the transit access to the campus from these distances becoming far more inconvenient due to route transfers, etc. In this case, it is a powerful observation such that even when presented with the opportunity to use the transit at no extra cost, even students will be less likely to choose to use transit due to the greater inconvenience it poses at these distances.

To investigate whether distance also had a bearing on the driving behaviours of the students, Figure 12 illustrates the places of residence distances against the percentage of student parking permit holders driving at least 3 out of 5 trips a week.

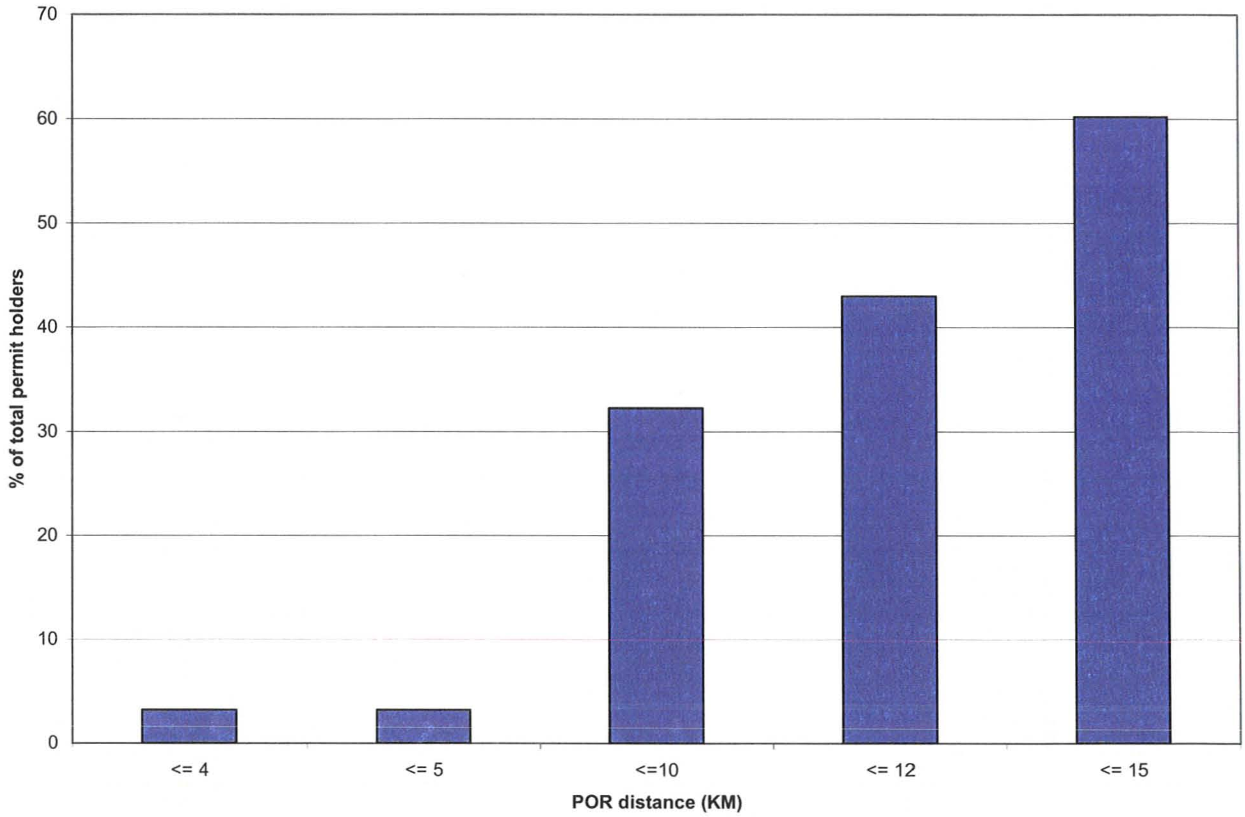

Figure 12: Place of Residence vs. % of Total Parking Permit Holders, Students choosing "Drive Alone" 60+% of Trips

The overall distribution shape of Figure 12 is similar to that of 11. This indicates that it may be more likely that students are initially purchasing parking permits based on distance, or convenience, and once the purchase is made they will drive regularly to the campus. Therefore, students are driving in order to get the full value out of the "unlimited" parking permit, which was similarly observed as a behaviour among permit-holding staff. This observation further implies that it may be possible to reduce the driving behaviours of the students by offering pre-paid parking options other than a monthly, unlimited permit. This suggestion is discussed in greater detail within Chapter 4 of this thesis.

Following the analysis of Figure 12, it was interesting to investigate the distribution of the student parking permit holders choosing to drive alone for at least 80% of all trips to the university.

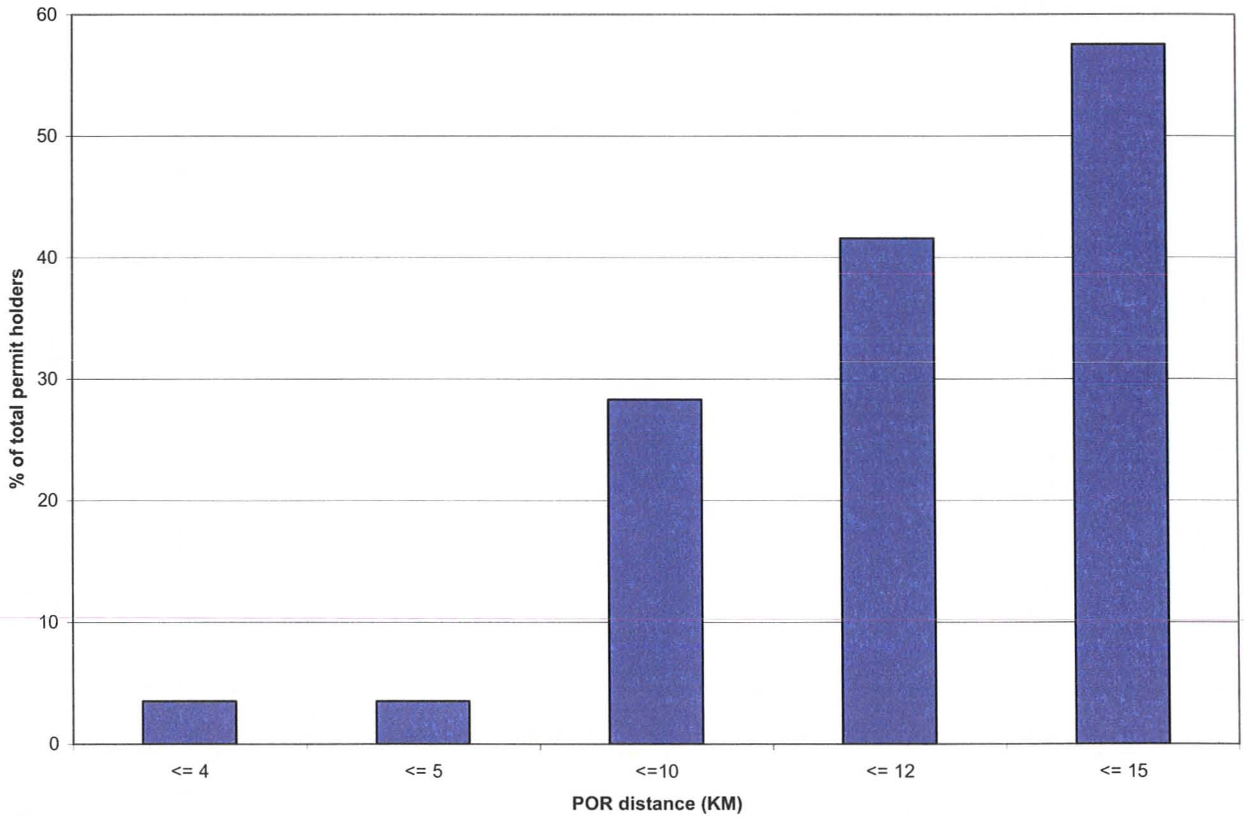

Figure 13: Place of Residence vs. % of Total Parking Permit Holders, Students choosing "Drive Alone" 80+% of Trips

At this point, this Figure also demonstrates the expected, established distribution pattern evident in Figures 11 and 12, though the percentages for the higher distance thresholds are slightly lower. As observed earlier, students appear to be driving regularly due to being permit holders, again a similar behaviour identified within the staff.

This analysis has shown that the students are more likely to be affected by distance than staff when considering the purchase of a parking permit. Unlike the staff, the majority of students who are parking permit holders live farther than 5 KM from the campus. Additionally, only 113 of the 493 students in the sample were permit holders, approximately 23%. This is in sharp contrast to the approximately 67% of the staff sample who identified as being permit holders. Since the most popular transportation mode among the students was "Other", it would appear that students will only choose to drive as a last resort if the distance to be covered is sufficiently large. Students have an unlimited public transit pass included with the cost of their tuition, which also facilitates the regular use of public transit within the 5 KM threshold discussed earlier in this chapter. From this analysis, it would appear that students choose the mode that is most convenient for them, to cover the distance between their residences and the campus. The students living closest appear least likely to be permit holders, and as such, to drive to the campus regularly. However, the students that are permit holders are driving on a regular basis. Since the majority of the students driving regularly live far enough for public transit to be a regular inconvenience, this makes sense. These students are possibly driving regularly out of convenience, rather than driving for driving's sake, the behaviour exhibited by the staff.

The hypothesis, then, that was tested within the modeling exercise was such: students living farther away from the campus will be more likely to drive, otherwise those living closer will choose alternate modes. The next sub-section will present the results and discussion that will demonstrate this hypothesis was shown to be acceptable within this context.

Model Results

As mentioned above, the modeling exercise set out to test the hypothesis drawn from the statistical analysis conducted as a preliminary step. Unlike the presentation of the staff results, the modeling exercise for the students resulted in only one model chosen (as opposed to two). The Master Variable List can be found within the previous chapter as Table 3.

Table 8: Transportation Mode Choice Model Results, Student

Variable Name	Model Results (p-value)
Drive Utility	
Constant	-4.986 (0.0000)
Access to Car as Driver: Reg.	2.414 (0.0000)
Parking Permit Holder	2.495 (0.0000)
Driving Time	0.0377 (0.0145)
Carpool Utility	
Constant	-3.835 (0.0000)
Access to Car as Passenger: Reg.	1.961 (0.0000)
Transit Utility	
Constant	-2.218 (0.0000)
Access to Car as Driver: Never	0.7379 (0.0039)
Other Utility	
Dist. to Campus	-0.3576 (0.0000)
n = 465	R^2 = 0.4703 L(*) = -341.4779 L(C) = -644.6269

Similar to the staff modeling results, it is quickly apparent that despite the creation and inclusion of many variables over the course of many trials, only a few are returned as significant. Also similar to the staff results, what were expected to be important variables (such as parking cost, transit time) did not return as significant in the final model. Despite this, the variables that are included in Table 8 are all significant at the 95% degree of confidence, and all parameters have the expected sign.

The students are also positively influenced by having access to a vehicle on a regular basis as a driver, as well as being permit holders, to drive alone to the campus. However, to further explain the behaviour, it can be seen that the driving time appears as positive and significant as well. This means that as the driving time between the campus and the student's place of residence increases, so does the probability that the student will drive alone. This variable can be understood as a proxy for distance, since an increased distance from the campus will evidently result in an increased driving time. Therefore, this model differs from the staff results such that distance does appear to affect the choice of driving alone in the case of the students.

Regarding the absence of the parking cost variable, students are only permitted to purchase permits for the outermost, and therefore most inexpensive, lots on the campus. Additionally, within the survey the students were given the opportunity to indicate, within the "Drive alone" section, if they drive to the campus but then park on a nearby side street and use transit or another means to complete the trip to the campus. Since this option was included on the survey, it shows that the university is aware of this phenomenon among parking behaviour of the students. Students who park off campus in this manner are not accruing any sort of parking charge, since those who choose this option will park sufficiently far from campus that they may park on the street all day for free. Therefore, a parking cost is a non-factor for these students, and since it did not return as a significant disutility within this model, it is possible that the majority of the students in this sample driving alone to the campus are opting to take advantage of the free on-street parking in the nearby neighbourhoods more often than purchasing parking permits to park on the campus. It is also possible that the negative constant associated with this mode is capturing the disutility of parking cost.

The remaining utilities indicate that students are choosing modes based on their personal situations. In the Carpool utility, the only independent variable that returned significant was the Access to a Car as a Passenger: Regularly, which had a positive coefficient associated with it. This indicates that an undergraduate student who has the opportunity to get a ride to campus on a regular basis will choose to travel to the campus in that manner. In a similar vein, within the Transit utility, its independent variable is that of Access to Car as a Driver: Never. This variable also is an indicator of the student's personal situation, and it means that if a student has no access to a vehicle, s/he will be more likely to choose to use transit. As mentioned, transit time did not return as a significant variable, and this may be due to the fact students are using this mode out of necessity, therefore the travel time that is associated with this mode is simply an "absorbed" disutility, and it is likely that this is captured within the constant for this alternative, which is negative. It may be important again to mention that a transit cost variable for the students was not considered or calculated, since the students have an unlimited transit pass included in the price of their tuition, and is a one-time cost. Therefore, any student using the local public transit is not incurring an out-of-pocket cost to use the service, simply by having paid tuition.

The final utility is that of Other, which includes the non-motorized modes of walking and biking. It is within this utility that the distance variable appears, and is negative and significant. This is the expected sign, since increasing the distance between a student's place of residence and the university campus will decrease the probability that the student will choose a non-motorized mode to travel to the campus. Therefore, the students who live the closest to the campus in its nearest neighbourhoods are the most likely to be choosing this mode to travel to the campus.

Student Results: Summary

The model results from the student data exude a number of variables that were expected to return as significant, and all with the expected signs on their parameters. Furthermore, these variables sufficiently explain the transportation modal choice behaviours of the students that is both observable, as well as meaningful. These results lead to the following conclusions: students who live sufficiently far from the University, have access to a vehicle as a driver, and are parking permit holders, are more likely to drive to the campus. The rest must behave as a result of their specific, individual situations. Those with the opportunity to carpool to the campus will do so. However, those without access to a vehicle must choose to ride transit. The remaining students who live close enough will walk, bike, or use some other non-motorized means to travel to the campus.

The lack of a parking cost disutility may be explained by the fact that students are observed to park off campus in the nearby neighbourhoods where they do not have to pay for parking. Therefore, while this raises the issue of congestion within the neighbourhoods in the surrounding area, it indicates that regarding the on-campus parking problem, the students do not appear to be the most active part of it. However, it may also indicate that the university should take responsibility to enforce that students are not clogging up the surrounding side streets, and to further encourage the use of alternatives such as carpooling, transit, etc.

Chapter Summary

In general, it would appear that distance to the campus does not factor in as a consideration for approximately one-third of the staff who are parking permit holders that live within 5 KM of the campus, and are driving to the campus alone on a regular basis. Both the statistical analysis, as well as the modeling exercise on the staff data indicated this was the case This means that there are other factors that lead these staff members to purchase the parking permit – immeasurable within this dataset, such as personal taste and preference factors. Past the 5 KM threshold it is slightly more apparent as to why these staff members are opting to bring their personal vehicles to the campus, if they have access to one. As discussed, it is past this threshold that it becomes required to transfer transit routes in order to complete a trip to the campus, and as a result the inconvenience of taking the transit is increased significantly. Requiring a transit transfer itself is inconvenient, but also means that total travel time is increased, as well as the access time to the second route that will take the commuter to the campus. This information, as well as this knowledge of the inconvenience of taking transit that increases with distance, can lead to a number of policy suggestions which will be discussed in the next section.

Regarding the student's travel behaviours, the model results were sufficient enough to adequately identify the factors leading to these behaviours without requiring further chart-type analyses. The most apparent conclusion to be drawn from those results, is that students behave as a result of their personal situations. Those with access to a vehicle, either as a driver or as a passenger, will be more likely to choose to travel to the campus by that mode. Those without this vehicular access must resort to transit. Finally, those that live close enough to walk, bike, or use another non-motorized mode, may choose to do so. Students also will avoid parking costs by parking sufficiently far away from the campus and completing their trips by walking, taking transit, etc. for the remainder of the trip. These results also bring up a number of policy suggestions, and they too are discussed in the next section.

This chapter has both presented, and discussed, the results obtained by the modeling of the staff and student data. It also presented and discussed the results of the chart-type analysis that followed the modeling of the staff data, due to the inadequate results obtained from the logit model. In doing so, this chapter has set up the information that will be used to create policy suggestions that will be argued and discussed in the next chapter.

Chapter 5: Recommendations

Introduction

The previous chapter presented and discussed the results of both the multinomial logit modeling, as well as descriptive data analysis conducted in the case of the staff data. The identification of the seemingly irrational driving behaviours of the staff required a second look into the literature, this time on the topic of Travel Demand Management (TDM) schemes. In doing so, not only was it found that the solution to the parking crunch situation at McMaster University is that of a well-developed TDM, but the most successful components of TDMs adopted in various other situations have been identified and are presented in a context that introduces relevant and possibly very successful solutions. This chapter will discuss the policy suggestions that should be considered for implementation at McMaster with accompanying literature references. It will also present some McMaster-specific solutions that have been inspired by the aforementioned TDM literature, a few of which could be employed outside of a large-scale TDM scheme.

General suggestions towards the improvement of the transportation behaviour survey tool will then be presented. Finally, the conclusions of the project will be discussed.

Travel Demand Management and McMaster University

A detailed discussion into the University's previous TDM measures has already been made within the Literature Review chapter. Rather than repeat what has already been presented in this thesis, this section both comment upon current strategies in-policy at McMaster, and present new suggestions with regards to increasing the effectiveness of TDM on campus. First, this section will discuss the current policy of increasing parking fees with little to no increase in the attractiveness or incentives of the other alternatives currently available to commute to the campus. Following that, successful incentives that have been implemented at other campuses, and businesses, that could be implemented at McMaster as well, will be discussed. The section will then identify how the ACT office can take a more active role in promoting alternative transit to the campus, and how such active approaches have been successful in other contexts. Finally, the last important factor to success, public input, will be emphasized with support from the literature.

Current Policy of Steadily Increasing Parking Fees

The most common solution that university campuses have adopted to attempt to decrease the parking demand on campus has been to simply increase the parking fees – both daily parking rates, as well as monthly permit parking rates. McMaster is no exception, and this was previously mentioned in the Literature Review chapter. This is also the simplest solution, which may lead to its overall popularity. Unfortunately, it has been known for quite some time that increasing parking fees as the sole means of TDM is ineffective (Bianco, 2000; Kuppam *et al*1998; Willson, 1997; Simpson, 1999; Washbrook *et al* 2004; Garling and Schuitema, 2007). In studying the effectiveness of TDMs in various situations and contexts, the overwhelmingly consistent conclusion is that simply increasing parking fees and hoping people will adopt an alternate means of transport is inherently flawed, and roundly unsuccessful in terms of gaining the desired modal shift. Depending upon the context, there are many reasons to explain the overall failure of such a policy. In many cases, the "allure" of the private car as a means of transportation is too strong to be offset by a higher parking fee (Garling and Schuitema, 2007). Some drivers do not recognize the increased parking fees as a response to a parking problem on the campus, and the intended effect is then completely lost, seen as a money-making scheme (Stewart and Pringle, 1997; Pona, 2007; Bamberg, 2006). In other cases, where the site permits, drivers will begin to park farther and farther from their destination to avoid a higher parking fee, or in some cases, any fee at all, and either walk or take transit for the remainder of the trip (Bianco, 2000; Arnott *et al* 1991), a phenomenon that has been observed as a parking behaviour primarily among the students at McMaster. Overall, specific reasons or factors leading to the failure of increased parking fees as the sole policy solution were not given or discussed within the majority of the studies cited above. However, many of these studies made a point of demonstrating that, when implemented along with greater incentives to carpool/rideshare, improving transit service or access to discounted fares, and other improvements to the attractiveness of alternative transportation, increasing the parking fees could be a very effective solution.

Strategies of Successful TDM schemes

Nearly as strong as the assertion that increasing parking fees alone is an insufficient method for curbing car use, is the finding that increasing parking fees, and concomitantly offering a number of incentives to use, or improving the attractiveness of alternate modes, is a successful approach to encouraging a modal shift (Bianco, 2000; Kuppam *et al* 1998; Garling and Schuitena, 2007; Willson, 1997; Simpson, 1999; Washbrook *et al*2004; Vuchic *et al*1998). This has been identified as true for many different contexts and situations, and if developed properly, a TDM with this focus should be met with modal shift success at McMaster as well.

McMaster has implemented a carpooling/rideshare matching programme, coordinated by the ACT office, as discussed in Chapter 2 of this paper. It is also very well serviced by the local public transit, supporting the thoroughfare of at least three different routes (four during the Fall and Winter semesters with the addition of the dedicated GO center – McMaster route). In a joint collaboration with GO transit, the university allowed for the opening of a GO transit hub on-campus to better facilitate the increased GO service to and from the university in early 2007. The installation of bike lockers and the general improvement of bicycle storage facilities across the campus indicates the administration has recognized the need to both upgrade and continue to improve its accommodation for those choosing that mode of transit. Therefore, it is apparent that McMaster has been quite willing to encourage the use of alternative transportation. This also demonstrates that the University is quite well-equipped to begin making these modes even more attractive and accessible to both its staff and students.

Currently, carpoolers who purchase a parking permit must pay the same fee for that permit as a "regular" parking permit. In this way, the reduced cost is only such that, presumably, the permit fee is split between the carpoolers. The incentives offered for carpoolers are a reserved parking spot close to the buildings, two free day passes if both carpoolers must drive alone, and a mixed set of coupons that in the past have included free taxi rides, or free gasoline vouchers. Regarding TDM schemes, the literature indicates that a greater switch to carpooling occurred when the carpool permit fee was offered as less expensive than the single-occupant vehicle parking permit, whether this fee is being subsidized or is offered at a true discount compared to the regular permit (Hansen *et al* 1998; Willson, 1997; Washbrook *et al* 2004). The most successful incentives included guaranteed ride programmes for those who, for one reason or another, are not able to carpool/rideshare (Berman and Ladow, 1997; Hansen *et al* 1998; Willson, 1997), as well as either a permit fee subsidy or discount, or a "cash back" incentive where the money saved by sharing the permit is refunded to the carpoolers at the end of the month (Willson, 1997). Therefore, while carpooling should continue to be encouraged at McMaster, and preferential parking spots should continue to be reserved, the addition of these greater cost-saving incentives will make the mode much more attractive, especially in comparison to the greatly increasing parking fees year to year. As a result, the administration may find that a greater number of reserved carpool-only spots may be required as the popularity of the programme increases. However, as the programme incentives stand now, it is more likely that those driving alone will find alternate places to park their vehicles rather than seek out a carpooling partner to avoid paying the higher fees.

The biggest modal incentive strategy must be focused on increasing the attractiveness of using public transit. Undergraduate and graduate students take advantage of transit due to their unlimited transit pass that is included as a one-time fee with their tuition. U-pass programmes such as this have been met with great success at many universities in North America, and such a programme should continue to be implemented at McMaster. However, no such programme is in place for the staff and faculty of the university, meaning that these individuals must pay full price, and often out of pocket, to use this mode. Until very recently, the price of an unlimited monthly transit pass was still more expensive than a monthly parking permit, with the exception of Zones 1 and 2. Adding to this the very limited area within which the transit service to the university can be used without the transfer of routes, the often over-crowded busses that leave transit users waiting for the next one to come by, and the common variables of discomfort associated with a public transit route, it is quite clear why over one-third of those driving to the campus on a regular basis are being drawn from the local, "highly serviced" area. Despite mode-specific inconveniences, there are a number of ways that the university could make transit more accessible to the staff. The first, and most important way, ties into TDM quite conveniently: facilitate a staff discount to use public transit. This can be implemented in a number of ways. The way in which it is ultimately instituted should be up for public input and chosen based on the stated preferences (greater discussion regarding the importance of public input in developing a TDM will be made later in this chapter).

One TDM scheme (Hansen, *et al*, 1998) involved the employer selling the transit tickets and passes to the staff directly, at a discount. The discounts were subsidized by parking revenues raised by the increased price of the "regular" parking permits. In this manner, staff and faculty had convenient access to less expensive transit fare options directly from the employer. An alternative to this could be to provide either a monthly transportation "allowance" for all staff and faculty, which would sufficiently pay for transit fully, but only part of a parking permit. An additional strategy could be in the form of a subsidy paid out at the end of the month if the staff member had used the transit for the majority of the trips taken during the month (such as, at least three out of five trips per week) (Willson, 1997). Other TDM schemes that had to address the issue of drawing staff and faculty from areas that had little or no access to transit found the use of a park 'n' ride and employer-sanctioned, dedicated route shuttle to be effective in deterring both staff and students from bringing their cars to park on the campus on a regular basis (Berman and Ladow, 1997; Bates *et al* 2000; Carter, 1996). The shuttle was either free and paid for by the employer, or partially subsidized by the employer and riders paid a small fee to use it. In keeping with creating incentives, this fee would be lower than the equivalent of a day of parking, but comparable to public transit. Therefore, by employing at least an employee discount on transit tickets, and taking strides to increase the convenience, reliability, and accessibility of mass transit (either by lobbying the city's transit commission or by establishing a university-mandated shuttle service), the university will be undertaking the minimum regarding encouraging the use of public transit that will be met with some success.

K-Means Cluster Analysis

To further demonstrate the possibility of establishing transit shuttle hubs for the staff, k-means cluster analysis was conducted on the staff data, specifically focusing on the points lying within the Hamilton CMA. K-means cluster analysis attempts to identify natural clusters within the data, but rather than searching for the clusters itself, the analyst provides the algorithm with the number of clusters to find. The algorithm then identifies the location of these clusters. Figures 14 and 15, below, are maps of Hamilton and Burlington with the points of origin for the staff living within these areas, the k-means cluster ellipse centroids (potential shuttle hub points), and the ellipses themselves measured one standard-deviation from those centroids, indicating the rough area from which the majority of those staff would be coming from to use those hubs. The reader must note that these analyses were conducted on the ACT data. Not only are these data a sample, but it is not fully clear whether or not these data are representative of the population, as discussed earlier in this thesis. Therefore, these maps and the subsequent discussion should be taken as an example of analyses that may be conducted, and how the results may be interpreted, if used to identify possible future transit hubs.

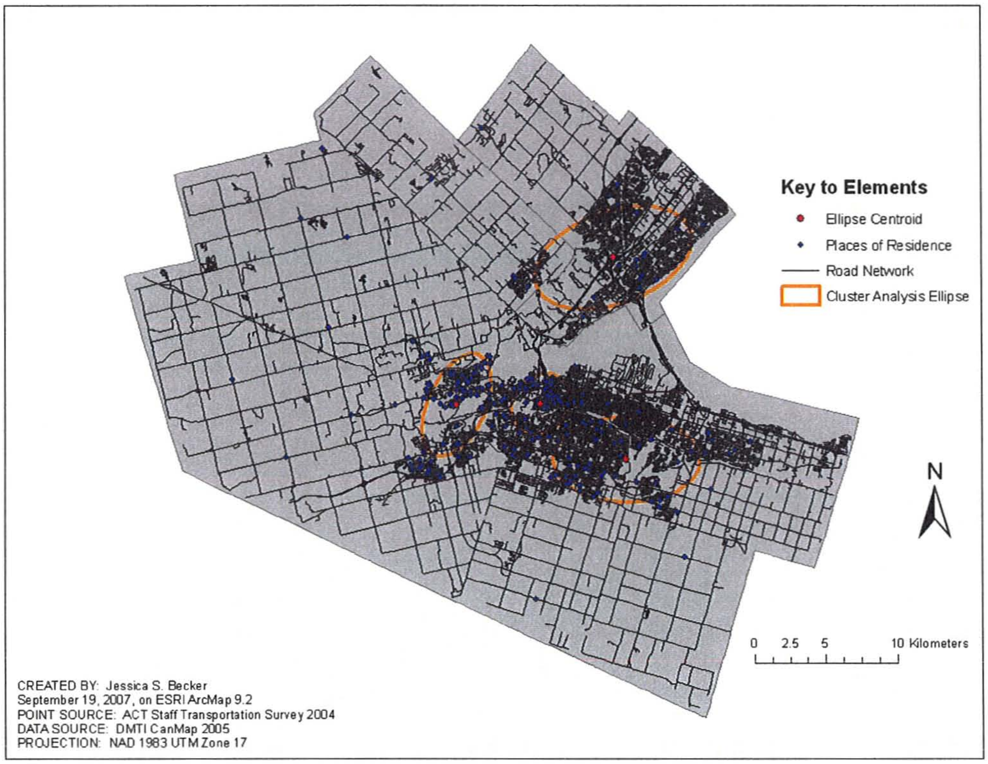

Figure 14: Suggested Shuttle Hub Locations from K-Means Clusters, 4 Clusters

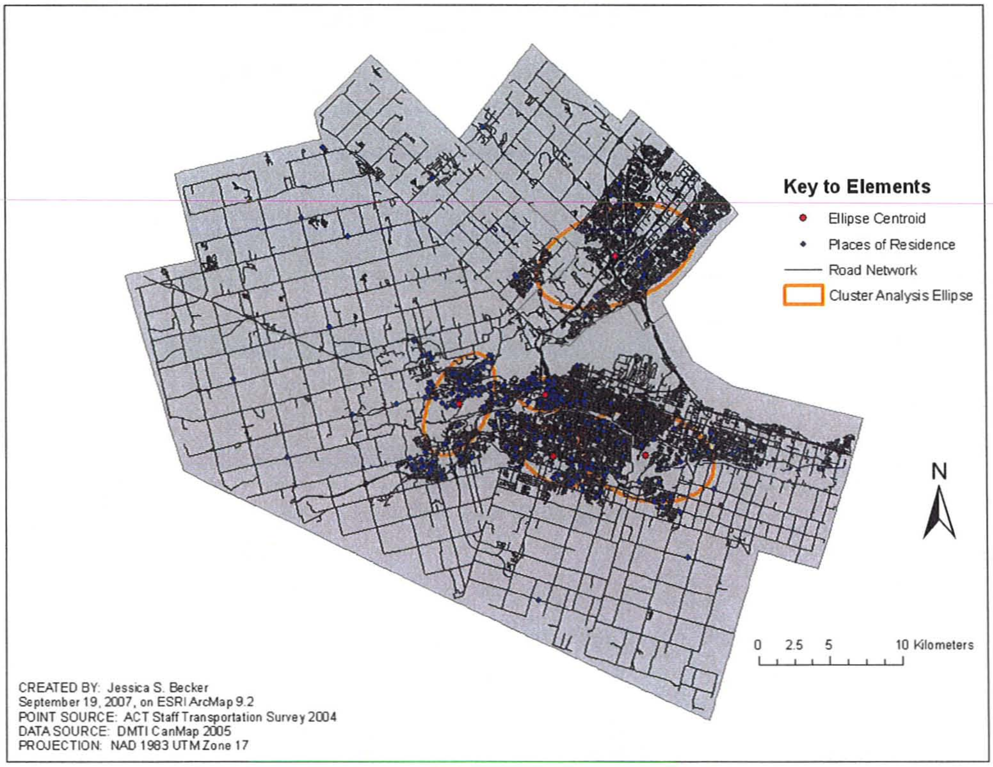

Figure 15: Suggested Shuttle Hub Locations from K-Means Clusters, 5 Clusters

By looking at both of the Figures, it is fairly clear that with the addition of one additional cluster to be calculated, the overall locations of the clusters do not change. The cluster ellipses in Burlington, east Hamilton, and Dundas remain in their same positions. However, having knowledge of the topography of Hamilton, Figure 15 makes more sense than Figure 14, as the centroid and ellipse shown to be in western Hamilton on Figure 14 is presumably servicing both that part of the "valley", as well as those residents on the escarpment, and this is not reasonable. Therefore, the addition of the hub on the southwest escarpment would make more sense. These are not meant to be taken as exact locations of hubs, but merely suggestions as to where it is most likely that residents would benefit the most from hubs due to their relative concentrations within those areas. From these figures, it can be seen that there are at least three locations where a direct shuttle bus pick-up point could be very effective in curbing the driving behaviours of the staff living within the local area.

Another major factor leading to the success of a TDM is the presence of an active committee that is involving itself in a direct way by approaching and informing the employees of their transit options, possible carpool partners within their area, and so on. McMaster has the ACT office at present, which is an invaluable resource for those who choose to out alternative transportation information and options. The ACT then provides personalized information for those individuals regarding transit routes, bike routes, as well as facilitate carpool partner matching and organize bike locker rentals. However, studies have found that this type of passive encouragement of alternative transportation fails in making an impact on the modal shift (Willson, 1997; Berman and Ladow, 1997;

Modarres, 1993; Stewart and Pringle, 1997; Bamburg 2006). This may be explained by both the highly-habitual nature of the modes being chosen on a regular basis (Bamberg, 2006; Cao and Mokhtarian, 2005), as well as the lack of a perceived parking problem (Stewart and Pringle, 1997). The results indicate that there is definite modal loyalty, meaning commuters are comfortable in their choices and making them on a regular basis. This loyalty will be very difficult to change if staff members are left to seek out alternative transportation information on their own. Regarding McMaster, the argument could be made that all staff are well aware of the transit that passes through the campus as the busses factor into the on-campus traffic. If the ACT were to become a more active presence on campus, all staff members would be approached and provided with personalized transit information, such that they could become more aware of all convenient transportation options within their areas. This would also allow for the opportunity to present staff with a risk-free transit trial voucher to help encourage them to try to use transit to the campus at least once, found as an effective habit-curbing action (Bamberg, 2006). It is important to note that all members of staff, including faculty and administrative officials would be approached in this manner. Willson (1997) indicates that participation from the "higher-ups" was a key factor in both the encouragement of staff to begin to use alternate transit, as well as to use it on a regular basis. In that example, the President of the company studied used the rideshare mode at least three times out of five times a week, and of course was eligible for the cash incentive that it promised.

Additional, specific suggestions regarding the increased ACT activity will be presented in the next sub-section. However, it should be stressed here that it is important for the alternative transportation information to be directly presented to the staff, rather than expecting the staff to seek the information out for themselves.

The last major factor to discuss is that of the importance of public input. A specific example of the usefulness of public input is found in Willson (1997), describing that the parking pricing schemes were both suggested and supported by the employees that they affected. Furthermore, to maximize the potential for participation, the TDM scheme must be designed so that there is personally significant time or financial gain. This can only occur if the TDM has been designed with the suggestions and preferences of those it will directly affect (Berman and Ladow, 1997). It is also possible that the staff will feel as though their thoughts, opinions, and preferences are being valued when they are being consulted about the TDM, and this may lead to greater participation, since there will be a better feeling of having had a say in how the policies were developed. Therefore, while the points discussed above have proven to be highly successful in other TDM policies implemented in various contexts, their ultimate success will depend upon whether or not these particular factors are even desired by the McMaster community to be provided to them. By allowing public input before TDM development, as well as at frequent intervals throughout its implementation, policy suggestions may arise that were not discussed here, such as a particular facet of the transit system that the staff would like to see changed. Since the TDM scheme must be developed for the particular situation and context of McMaster University, it must be acknowledged that public input is crucial for ensuring the development of a TDM that is both reasonable to expect participation levels to increase higher than they are currently, as well as to ensure that the TDM is continually evolving as per the suggestions and preferences of those it affects.

This section has presented a number of strategies employed in past, successful travel demand management schemes. They have also been presented with references from the literature within which their success have been documented. McMaster University already has the benefit of facilitating a number of transit routes to pass through the campus, bicycle storage facilities that include racks and lockers, a GO transit terminal, and an Alternative Commuting and Transportation office that keeps itself up to date on current transit schedules, as well as organizing the carpool programme on campus. Therefore, all of the strategies discussed above can be implemented within the framework that is already present, leading to minimal infrastructure change. However, it is also important to recognize that individually, these strategies are not enough to encourage a modal shift. The combination of many of strategies, implemented simultaneously, is the best path to ensuring TDM success. According to Berman and Ladow (1997), TDM schemes that employed many strategies at once could see between 30% and 40% reductions in car use.

Additional Recommendations Specifically for McMaster

The previous section noted the importance of developing a TDM scheme that specifically met the needs and preferences of the context within it would be implemented by employing many strategies at once. This is to ensure both the particular situation currently present can be exploited for its maximum convenience, as well as being able to address and accommodate the specific needs and preferences of those expected to participate. While this may be sufficiently addressed by a large-scale survey possibly conducted by the ACT on the staff at the university, there are a number of other things that could be done at McMaster with little additional administrative requirements. This section will discuss the suggestions of presenting permit applicants with transit and carpool information up front, providing transit information to all registered students, the use of greater incentives and rewards for those already choosing alternative transportation on a regular basis, the possibility of adding other options for pre-paid parking other than the "unlimited" monthly pass, and the strong discouragement of providing more parking space as a solution to the current congestion problems.

Recommendation 1: Discourage Single-Occupant Car Use Prior to Permit Assignment

At present, both staff and students wishing to obtain a monthly parking permit must apply for it, either in-person at the Parking and Security office on campus, or online through their website. To help encourage the adoption of an alternative transportation option prior to forming a driving habit, the parking office could provide all new permit applicants with personalized transit information and potential carpool partners up front at time of application. This can easily be implemented, since applicants must provide a home address as part of the application process. The transit and carpool partners information would be something that the ACT would be responsible for providing, and updating, on a regular basis, as it handles this information at present and would be well-equipped to do so in the future. This can be employed without violating the university's private information protection act, such that the applicants will be given the transit information based on the address they are providing at the time of application, and the carpool partner information will be provided "anonymously" until that applicant has expressed an interest in being put in contact with a potential carpooling partner. The important step is providing the information to the applicant, who may not even be aware of these possibilities at the time of application. This, coupled with the opportunity to purchase discounted transit fare tickets or passes, or a carpool permit for a significantly smaller cost than a "regular" permit could be a very powerful and successful way of starting new staff and students towards using alternative transportation prior to the forming of a driving habit.

Recommendation 2: Actively Provide Transit Information with a Trial Pass

In a similar vein of Suggestion 1, all new staff should be provided with an "alternative transportation options" orientation-type of package during job training or orientation, again assembled by the ACT office. This package would be an opportunity to provide the new staff with a transit trial voucher to encourage them to try the transit, and to inform them of the opportunity to purchase transit tickets or passes at a discounted rate from the university itself. This further facilitates the possibility that new staff will, at least, try alternative transportation prior to forming a driving habit. Students would also be provided with a similar package, but tailored to their specific situation of being able to use the local transit in an "unlimited" manner at no extra cost with their paid tuition, as well as how to obtain discount GO tickets and passes. They, too, would be given information about transit options or potential carpool partners within their area if they were to apply for a parking permit. This method of actively informing incoming staff and students about the opportunities to use alternative transportation, and its convenient accommodation on the campus, is another way that the McMaster administration could encourage the adoption of alternative transportation before driving habits are established.

Recommendation 3: Improved and Regular Recognition and Rewards

Also included within the "alternative transportations options" information package would be information about the incentives and rewards that are available to those who choose alternative transportation. Inherent in this strategy is the implication that the administration, through the ACT office, creates a scheme within which these commuters are regularly recognized for their contribution towards reducing car traffic on campus and the associated environmental impact. These recognitions and rewards should be on top of what will be offered as monthly incentives, and distributed on a regular basis. This could include a number of options, such as a draw for a free carpool permit or transit pass, a cash reward paid for by parking revenues, vouchers or gift certificates for the campus bookstore or Phoenix pub (again, paid for by parking revenues), or any other prize that could be the result of a suggestion on a survey. These draws could potentially occur on a monthly basis since they are not overly costly, and would also serve to encourage alternative commuters to continue using their transportation modes on an on-going basis.

Recognition also allows for the recipients' colleagues and coworkers to see that there are members among them that have become dedicated to using alternative transportation and have integrated it into their commuting routine. This could result in increased word-of-mouth encouragement and a sort of "viral marketing" that may lead to those that previously are not using alternative modes to strongly consider doing so, since they are able to interact so closely with someone who has made this commitment. This type of peer mentoring is a secondary effect of successful TDM schemes, and has very high potential within McMaster due to its many closely-knit offices and laboratory work environments.

Recommendation 4: Increased Number of Pre-Paid Parking Options

There are also a number of small changes that could be made to the parking permit policy that will compliment the new technology that will be installed over the next two years. Automated gates will remove the need for those parking on campus as a visitor to have to stop at a kiosk; instead, the driver will stop at the gate, take a ticket to display on the car's dashboard, park, and upon exit pay only for the amount of time s/he was parked. This is designed to encourage parking turnover and help generate revenue by resulting in an increased number of people having to pay for the parking rather than avoiding it and not always being caught. Those that purchase a parking permit in any form, regular or carpool, will be provided with transponders to mount within the car that will automatically open the gates without the driver being required to take a ticket. Since current carpoolers are entitled to a certain number of free parking vouchers per month, but only one transponder, they will be provided with tickets that can be inserted into the machine upon exit and not be required to pay out of pocket for having used the parking lot that day. These tickets should also be available in the form of a "pre-paid strip", much like how transit fare tickets are purchased. Other university campuses have found success in administering pre-paid parking vouchers in this way, since it means that those who would like to park occasionally are not forced to buy an "unlimited" month's worth to be guaranteed a spot or to pay the higher daily rate, which then leads to driving regularly such that the permit holder can get the perceived monetary value out of the purchase. This alternative to purchasing the "unlimited" monthly permit would further encourage more regular use of an alternative mode, and would especially be beneficial to graduate students who commute and are not required to be on campus on a daily basis. This may also discourage students from parking on the nearby side streets simply to avoid the daily deposit, if these students are only driving on an occasional or temporary basis.

Recommendation 5: Prohibit Increases to Parking Infrastructure and its Planning

Finally, it must be noted that the addition of further infrastructure is not recommended. With the completion of the new stadium and its underground parking facilities, the number of parking stalls on the campus will be elevated to that of what they were prior to the construction of the new residences and other facilities. Providing more parking will make it easier for those already driving regularly to campus to park, and also risks the strong possibility that those who do not already drive will begin doing so since there will be that increased space (Litman, 2006). Within the university's own Campus Master Plan, the mandate is to provide "less than average" parking facilities, and this mandate should be referred to if or when the administration begins to consider the construction of a parking facility. Chapter 2 identifies numerous studies indicating the failure of such strategies. There is sufficient parking space on the campus, the real parking "problem" stems from staff and visitors preferring to park as close as possible to the buildings, rather than having to use the shuttle bus and/or walking Zone 6 or 7. Therefore, there should be no consideration regarding the construction of a parking garage on the campus, especially if the focus that the university would like to take is to encourage alternative transportation by implementing a TDM scheme.

<u>Suggestions for Improving the ACT Survey Tool</u>

This section will discuss some general suggestions towards the improvement of the survey tool with the intention of improving the quality of data that could be obtained from the sample that is surveyed. One problem encountered with these data was that there was no real indicator of relative income of the participants. The staff were asked which payroll Roll they belonged to. Prior to changing the payroll system, all staff were grouped into a certain payroll bracket identified by a number. While certain levels of staff (such as faculty) were typically grouped within the same Roll bracket, a representative from Human Resources indicated that the Roll within which a staff member was paid could not indicate his/her relative income. Therefore, the possibility of using the Roll identified by the staff member as a proxy for income was impossible. To improve this, and thus provide a traditionally important variable within modal split analyses, the survey should not ask the staff member to identify the Roll s/he falls into, but rather to indicate a relative income amount as falls within a short list of given brackets. This would allow a much more meaningful incorporation of the income variable(s), and therefore, an improved indication of the possibility a certain staff member will be more likely to choose a certain mode.

A second issue that arose mostly within the student data was that of unusable records. Since students were surveyed in class, only a limited amount of time would have been provided for the administration and completion of the surveys. As such, students did not appear to be very well prepared to fill out the survey. Their lack of knowledge regarding the importance of filling out the survey carefully resulted in many records being rejected simply due to negligence on the travel behaviour question. As identified earlier within the thesis, many students either did not indicate any number of trips taken per week, or did not fill in their modal split. If students were educated regarding the purpose and importance of that question, it is possible that the response rate may increase significantly. As such, many would not know why they should fill out any such survey, its purpose, nor its importance, thus wasting their own time as well as that of the ACT.

A final suggestion is to allow a provision for the respondents to provide a relative travel time. While it is possible that respondents may not have any sort of accurate idea of their true travel times, allowing the respondents to provide an estimated driving or transit time would provide more meaningful information with which to conduct the modal split. This study required manual estimation of both driving and transit times. Driving times were estimated using data containing approximate driving times assuming a certain driving velocity, meaning the times were calculated under "ideal" conditions. On a day-to-day basis, it is possible that these estimated times would not be an accurate average. Regarding transit times, this was purely estimated using places of residence, local transit routes, and the study of many transit route schedules. Transit times vary considerably due to daily traffic and ridership, which is not fully accounted for within the transit route schedules. Therefore, the documented optimal transit trip is often not the typical experience for these reasons. By allowing respondents to indicate the "actual" transit time required to travel to the campus by bus, a more accurate deficiency in transit reliability may be identified, which will lead to more effective solutions to be developed and implemented.

To truly address the needs of the commuters traveling to the McMaster campus on a regular basis, the ACT surveys should attempt to incorporate these suggestions into their future endeavours. These suggestions will provide for more meaningful indicators of staff income, a better response rate from the students, and a more accurate identification of deficiencies in the transit service to and from campus. In this way, future analysis of data from these surveys can better inform any TDM currently implemented on how to tailor it towards addressing the needs of those who are affected by it.

Chapter Summary

This chapter has presented two sections. The first identified the key components of the most successful TDM schemes found by a close look within the literature. In doing so, it became apparent that McMaster already has the facilities and the resources to implement these components, it is simply a matter of commitment in terms of utilizing them as part of a large-scale TDM plan.

The second section discussed some recommendations to be undertaken in the short-term, prior to the implementation of a large-scale TDM scheme. This section identified some of the small ways that the current facilities and resources could be used to address parking demand at the present, and in ways that would not require extended policy review and yet still be a move in the right direction. While a large-scale TDM plan should be developed and implemented if parking demand is to be most successfully reduced, these additional, small changes can be easily integrated into current policy and begin to encourage the adoption of alternative transportation while the TDM plan is in development.

Based on the results discussed in Chapter 4, this chapter has identified and discussed the recommendations that should be undertaken if the university is enthusiastic for the development and implementation of a TDM scheme that will not only discourage single-occupant car use, but successfully encourage and reinforce choosing alternative transportation. Consistently within the literature discussed was the identification of the importance of implementing a number of different strategies simultaneously, as it also disclosed that individual strategies implemented alone are not strong enough to induce a successful modal shift. The most successful strategies were presented. One of the most important strategies is the inclusion of public input, both prior to the development of a TDM plan, and also over the course of its implementation to ensure the public not only feels empowered in its influence of the TDM scheme, but also to ensure its needs, ever changing, are being sufficiently addressed and accommodated. The chapter proceeded with a section identifying small policy changes that could be integrated at the present time, prior to the development and implementation of a large-scale TDM plan, such that the university may continue to make changes towards encouraging and rewarding alternative transportation behaviours. Finally, a group of suggestions for the improvement of the ACT transportation behaviour survey tool were discussed. These improvements would allow for more informed reports, as well as provide for better data with which studies, such as the one in this thesis, may be conducted.

Chapter 6: Thesis Conclusions

In 2007, communities, governments, and post-secondary education institutions are looking for ways to discourage single-occupant vehicle use and encourage the regular use of public transit and other alternate modes of transportation. This project, commissioned by the McMaster University administration, was asked to focus on the parking problem on the campus such that a solution from a geographer's perspective and approach may be presented. In order to effectively do so, it was important to step back from analyzing the parking facilities themselves, how they are run, and how to make their management more effective, and address the underlying behaviour that leads to requiring parking: commuters choosing to drive their private cars to campus. Chapter 2 demonstrated how parking, as a choice behaviour, has been well-documented and studied extensively by civil engineers attempting to grasp the motivations behind choosing to park closer or farther away from a driver's destination. It was also made apparent that many, if not all, universities and colleges in North America have struggled with a parking problem, such that McMaster is not unique in its situation. Finally, the chapter ended with an encouraging note that universities are recognizing that the encouragement of active transportation not only leads to better health of its students and employees, there was also an environmental benefit caused by the reduced emissions. Therefore, the overall context of the project was that while parking behaviour remains a popular topic of study, it does not address the underlying behaviour of driving, and this study was required to find its own way in attempting to identify the connection between driving and the parking problems on campus.

The investigation into the factors leading to the driving, as well as alternative transportation choice behaviours, of the staff and students employed the use of a multivariate logit model. This model has been used extensively in both past and recent studies due to its proven sufficiency in the estimation of the utilities of transportation mode choices. It allowed for the verification of the findings, discussed in detail, which arose during preliminary descriptive exploration of both the staff and student data.

The staff data indicated little influence of distance on the choice of transportation mode. Specifically, approximately one-third of the staff in the sample were permit holders and living within 5 KM of the university campus. Furthermore, this same 33% identified using the car to drive alone to the campus on a regular basis: at least 3 out of 5 trips a week. This analysis demonstrated that staff are driving from short distances for reasons other than distance, driving time, or transit service, as the transit service to the campus is most heavily concentrated and the most convenient at the threshold of that distance, findings which were mimicked within the model results. An increase in both the number of permit holders, and permit holders driving regularly is shown between the 5 and 10 KM threshold. This may be explained such that at the 5 KM threshold, a transit trip would require the transfer of at least one route, which increases travel time and access time, and therefore leads to a much greater inconvenience of taking transit at the greater distances from the campus.

Descriptive analysis of the student data showed that distance was a consideration in the acquisition of a parking permit. Students living within 5 KM of the university identified alternative modes as the most popular choice for the commute to campus. As found in the staff data, exceeding the 5 KM threshold identified a significant increase in the number of students in the sample who were parking permit holders. The model results from the student data reaffirmed these findings such that: those with access to a vehicle and a parking permit, and with a sufficiently high driving time, will drive alone; students able to carpool to campus will choose to do so; students with no access to a vehicle but live too far to walk or bike will take the transit; and those living very close to the university will walk, bike, or use some other non-motorized mode to make the trip.

These results allowed for a meaningful study of current travel demand management literature, as it is apparent that the driving behaviour of the staff is prevalent, and likely habitual. Many companies and campuses have attempted to curtail this regular driving habit with TDM, and the study of available literature allowed for the identification of the most important factors leading to TDM success. The key, and possibly most important finding, was that success is found when a number of strategies are employed simultaneously. The current strategy of increasing parking fees, while not improving or changing the attractiveness of the other modes available to campus (carpooling, transit, walking and biking), has been proven to be ineffective in curbing driving behaviour in the long-term. Furthermore, this strategy has not made an observable change to the driving behaviours on campus as the number of permit applications remains steady. The suggestions section detailed a number of strategies the university should strongly consider employing in order to develop and implement a TDM plan that will directly address the particular situation of commuting behaviour of the university community. This will also provide the greatest potential in terms of participation and subsequent reduced car use. A strategic combination of increasing parking fees, accompanied by discounted carpool permits and transit tickets and passes, the possibility of operating a number of shuttle bus park 'n' ride stops with direct transit to the university campus, increased recognition and regular rewarding of those adopting the alternative transportation, an increasingly active and direct role taken by ACT, and continual contact with the public for their input are all strategies supported by the literature regarding their success when implemented in various combinations.

Five recommendations that are McMaster-specific and easily integrated into current policy were presented and discussed. Detailed discussion and justification of these recommendations are found in Chapter 5, but their summaries are below.

Recommendation 1: Discourage Single-Occupant Car Use Prior to Permit Assignment

In keeping with the strategy of a more direct approach to providing staff and students information regarding transit options and encouraging carpool use, this recommendation entails providing permit applicants with personalized transit information, and potential carpool partners at the time of permit application, prior permit assignment. This will ensure that all applicants are provided with transit information the applicant may not have been aware of, and discourage the formation of a driving habit prior to one becoming established.

Recommendation 2: Actively Provide Transit Information with a Trial Pass

This recommendation stems from the results of a study identified and discussed within Chapter 5 in greater detail. While it is important to actively provide staff and students with personalized transit information, as the assumption that this information will be sought freely leads to failure in inducing a modal shift, it is equally important to provide a mechanism that will allow staff to use the transit at least once at no risk of incurring a cost. Students are provided with an unlimited local transit pass with paid tuition, and this recommendation does not hold for them because of this. In this way, staff are encouraged to try the transit at no cost to them, and may lead to more frequent transit use than at present. Coupled with providing transit tickets and passes at a reduced cost as part of the TDM plan, this recommendation has potential to become successful in inducing a modal shift.

Recommendation 3: Improved and Regular Recognition and Rewards

This recommendation addresses a significant lack in the current incentives being offered to those that have already adopted alternative commuting transportation behaviours. The ACT has the means to begin regular recognition and rewarding of those currently possessing carpool parking permits, and renting bike lockers, and should also allow self-nomination from those currently using transit, cycling, and other modes. This recognition may come in the form of a monthly draw for a substantial incentive prize, and the awarding of a certificate that may be displayed by the winner. In doing so, it encourages alternative commuters to continue in their chosen behaviours, and also will serve to encourage those who are not choosing alternative modes to strongly consider making a modal shift. Types of recognition and incentive prizes are discussed within Chapter 5.

Recommendation 4: Increased Number of Pre-Paid Parking Options

The automated technology to be installed over the next two years will easily facilitate this recommendation. The university should begin to offer other pre-paid parking options that is not just the purchase of an unlimited monthly parking pass. These options may include purchasing a "strip" of daily permit tickets, much like how transit fare tickets are purchased. Increasing the number of pre-paid parking options allows for those drivers that only require occasional use of their personal vehicles to use alternative modes on a more regular basis. In this way, the university would be accommodating these infrequent drivers in a much more meaningful way, encouraging alternative transit use, and also allow these occasional drivers to be eligible for the recognition and incentive prizes implemented by Recommendation 3.

Recommendation 5: Prohibit Increases to Parking Infrastructure and its Planning

This is the strongest and most encouraged recommendation. If the university does nothing else, it certainly must not plan for increased parking infrastructure. Chapter 1 identified numerous studies indicating the failure of this type of response to a high parking demand. Furthermore, this study has identified many recommendations not only for the development of a TDM scheme, but also a number of small policy changes that can be undertaken to curb the parking demand prior to a TDM plan implementation. It has also shown that providing more parking will not address the true problem underlying a parking crunch: the driving behaviour. The literature has indicated many types of strategies that, when implemented together, will lead to a successful modal shift and ultimately curb the parking demand on campus.

This project has identified the factors that lead to the various commuting behaviours chosen by the staff and the students of the university community. By careful analysis of the results, and comparison with TDM literature, this thesis has outlined a number of feasible strategies that can be adopted by the university to alleviate the parking problem. The solution is not to provide more parking, nor to continue to increase the parking fees with no other increases in the attractiveness or convenience of the other modes available. Instead, the integration of a number of publicly-supported strategies to be developed into a TDM and implemented at large that both discourages car use, and encourages alternative use in a highly attractive manner should be sought. This solution will require deep investment in many ways: the commitment to see it through; the increased staff the ACT will require to conduct large-scale surveys, as well as to provide and update personal transit and carpool partner information for all staff; the funding to provide the discounted carpool permits, and transit tickets and passes (or at least arrange such discounts with the transit commission), to hire the additional ACT staff, and to be able to provide the cash-based rewards to continue to encourage the use of alternative methods; and the time it will take to implement a TDM scheme of this magnitude fully. Adopting a TDM such as this will have numerous benefits both in terms of greatly increasing the use of alternative transportation to the campus, as well as the environmental effects of reducing the pollution from the car traffic, and solve the parking problem at the same time.

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APPENDIX

This appendix contains copies of the 2004 transportation surveys, conducted by the ACT. The surveys were compiled separately for the undergraduate students, and for the staff, and are presented in that order. Please note that the original surveys were double-sided, i.e. a single page only, but for the purposes of this thesis have been reproduced as single-sided.

MCMASTER UNIVERSITY STUDENT TRANSPORTATION SURVEY

ACT Office

The ACT Office (Alternative Commuting & Transportation) is conducting a survey on student transportation patterns in order to develop more effective and affordable transportation options for you here at McMaster.

Your participation in this survey is greatly appreciated!

Fill out this survey and get entered into a draw for one of ten **$20 Titles gift certificates.**

Complete this survey on-line at http://ACT.mcmaster.ca or fill out this copy and return it by *Friday, April 2, 2004* to:
~ *COMPASS Information Centre* in MUSC ~
~ *Parking & Transit Services Desk* in E.T. Clarke Centre ~
~ or to the friendly person who handed you the survey! ~

General Information

Name (optional): ________________ **Phone/E-mail** (optional - used for prize draw): ________________

1. Sex: □ M □ F

2. Age: □ under 20 □ 20-29 □ 30-39 □ 40-60 □ over 60

3. Enrolment Status: □ Full-time □ Part-Time

4. Faculty or Program

McMaster Programs Only

□ Arts& Science □ MBA
□ Business □ Medicine/Midwifery
□ Divinity College □ Science
□ Engineering □ Social Sciences
□ Health Sciences □ Continuing Education
□ Humanities □ Other ____________

Mohawk Programs Only

□ Practical Nursing
□ OTA/PTA
□ Pharmacy Tech
□ Cardio-vascular Tech
□ Personal Support Worker

Mo-Mac Programs

□ Collaborative BScN Nursing
□ Collaborative Radiation Sciences

5. Level of Study:

□ Undergraduate Year I □ Master's
□ Undergraduate Year II □ PhD
□ Undergraduate Year III □ Diploma
□ Undergraduate Year IV □ Certificate
□ Undergraduate Year V □ Other: ____________

6. Where have you been living during the 2003-4 school year? (select one)

□ On campus*

□ Off-campus: city ________________ <u>AND</u>

postal code <u>OR</u> street address

__________ ________________

7. Did you receive an HSR bus pass sticker to put on your student card?

□ Yes
□ No
□ Unsure

IF YES →

7 a) The fee for this bus pass sticker currently averages $8.13 a month. **If a fee increase was used to <u>improve</u> bus service to McMaster, would you be willing to pay $10.00 per month?**

□ Yes
□ No
□ Unsure

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* All references to "campus" or "McMaster" are to the Main campus located in Westdale.

ALL RESPONDENTS PLEASE TURN PAGE OVER...

Travel Behaviour

8. How many round trips to/from campus* do you typically make each week?
Mondays to Fridays ______ round trips
On weekends ______ round trips

9. Do you have a McMaster University Parking Permit?
□ Yes □ No

10. During the school year, how often do you have access to a car:
...as a driver? □ Never □ Occasionally □ Regularly
...as a passenger? □ Never □ Occasionally □ Regularly

11. On Mondays to Fridays during nice weather:

	Which of the following modes do you use to travel to or from McMaster*?	What % of trips is made by each of the modes you identified? *(should total 100%)*		
Drive alone	□ Park off-campus* + HSR	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Park off-campus* + walk	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Park in campus* lots (incl. 6&7)	□ 0% of trips	□ ___% of trips	□ 100% of trips
Carpool/ rideshare	□ Park off-campus* + HSR	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Park off-campus* + walk	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Park in campus* lots (incl. 6&7)	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Drop off on/near campus*	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Walk only	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Cycle only	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ HSR only	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ GO Transit only	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ GO Transit + HSR	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Other modes__________	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Other combinations________	□ 0% of trips	□ ___% of trips	□ 100% of trips

12. On weekends during nice weather:

	Which of the following modes do you use to travel to or from McMaster*?	What % of trips is made by each of the modes you identified? *(should total 100%)*		
Drive alone	□ Park off-campus* + HSR	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Park off-campus* + walk	□ 0%	□ ___% of trips	□ 100% of trips
	□ Park in campus* lots (incl. 6&7)	□ 0%	□ ___% of trips	□ 100% of trips
Carpool/ rideshare	□ Park off-campus* + HSR	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Park off-campus* + walk	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Park in campus* lots (incl. 6&7)	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Drop off on/near campus*	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Walk only	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Cycle only	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ HSR only	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ GO Transit only	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ GO Transit + HSR	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Other modes__________	□ 0% of trips	□ ___% of trips	□ 100% of trips
	□ Other combinations________	□ 0% of trips	□ ___% of trips	□ 100% of trips

13. Does your travel behaviour change during bad weather? □ Yes □ No
If Yes, please explain:

14. Further Comments:

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Feel free to contact us at 905-525-9140 ext. 24772 or ACT@mcmaster.ca

MCMASTER UNIVERSITY STAFF / FACULTY TRANSPORTATION SURVEY

ACT Office

The ACT Office (Alternative Commuting & Transportation) is conducting a survey of staff and faculty transportation patterns in order to develop more effective and affordable transportation options for you here at McMaster. Participation in this survey is confidential and participants will not be identified by name in any reports or publications that may result.

Your participation is greatly appreciated!

Complete this survey and get entered into a draw for one of ten ***$20 Titles*** **gift certificates.**

Complete this survey on-line at http://ACT.mcmaster.ca or return this copy by *Monday, May 31, 2004* to:

- *COMPASS Information Centre* in MUSC
- *Parking & Transit Services Desk* in E.T. Clarke Centre

Name (optional): ________________ **Phone/E-mail** (optional - used for prize draw): ____________________

1. **Sex:** □M □F

2. **Age:** □under 30 □30-39 □40-49 □50-59 □over 60

3. **Employment Status:** □Full-time □Part-Time □Retired □Emeritus

4. **Employment Type:** □Staff □Faculty □Grad Student

5. **Employer:** □McMaster □Mohawk □Other____________

6. ***Primary* work place:** □McMaster Main Campus (Westdale) □Downtown Centre □Frid Building □Henderson □Chedoke □St. Joseph's □Other______________

7. **Classification of employment (for McMaster employees only):**
   □Roll 1 □Roll 2 □Roll 3 □Roll 4 (TAs) □Roll 5 (Hospitality) □Other _________

8. **Were you enrolled in any academic courses at McMaster in the Sept'03-Apr'04 study period?**
   □Continuing Ed course(s)
   □Part-Time studies course(s)
   □None

9. **Where is your home?**
   City _________________ AND
   postal code OR street address
   _________ ____________________

10. **How often do you travel between the Main Campus in Westdale and the Downtown Centre?**
    □Daily □Once/week □Once/month □Rarely □Never

11. **If you ever ride the HSR for your commute to/from work, how do you usually pay your fare?**
    □monthly pass □bus tickets □cash

12. **Do you have a McMaster University Parking Permit?**
    □No □Zone 1 □Zone 2 □Zone 3 □Zone 4/5 □Zone 6/7 □Downtown □MUMC □other______

13. **During your work week, how often do you have access to a car:**
    as a driver? □Never □Occasionally □Regularly
    as a passenger? □Never □Occasionally □Regularly

page 1 of 2

ALL RESPONDENTS PLEASE TURN PAGE OVER...

14. How many round trips to/from your *primary* work place do you typically make each week?

Mondays to Fridays ______ round trips
On weekends ______ round trips

15. On Mondays to Fridays during nice weather:

Which of the following modes do you use to travel to or from your *primary* work place?	What % of trips is made by each of the modes you identified? (*should total 100%*)		
◻ Drive alone	◻ 0% of trips	◻ ___% of trips	◻ 100% of trips
◻ Carpool/Rideshare	◻ 0% of trips	◻ ___% of trips	◻ 100% of trips
◻ Get dropped off at/near workplace	◻ 0% of trips	◻ ___% of trips	◻ 100% of trips
◻ Walk only	◻ 0% of trips	◻ ___% of trips	◻ 100% of trips
◻ Cycle only	◻ 0% of trips	◻ ___% of trips	◻ 100% of trips
◻ HSR only	◻ 0% of trips	◻ ___% of trips	◻ 100% of trips
◻ GO Transit only	◻ 0% of trips	◻ ___% of trips	◻ 100% of trips
◻ GO Transit + HSR	◻ 0% of trips	◻ ___% of trips	◻ 100% of trips
◻ Other modes ____________	◻ 0% of trips	◻ ___% of trips	◻ 100% of trips
◻ Other combinations ____________	◻ 0% of trips	◻ ___% of trips	◻ 100% of trips
____________	◻ 0% of trips	◻ ___% of trips	◻ 100% of trips

16. Does your travel behaviour change during bad weather? ◻ Yes ◻ No
If Yes, please explain:

17. An adult HSR pass currently costs $65/month. The University is investigating a discounted employee transit pass program with the HSR. Such a program could enhance transit services and alleviate the parking crunch at McMaster.

a) Would you support an opt-in program where employees are each able to choose whether they want to pay for an HSR bus pass (at a discounted price of ~$50/month)?

◻ Strongly support ◻ Support ◻ Unsure ◻ Oppose ◻ Strongly oppose

b) Would you support a universal pass program where all McMaster employees would be required to pay for an HSR bus pass (at a much more deeply discounted price of ~$15/month)?

◻ Strongly support ◻ Support ◻ Unsure ◻ Oppose ◻ Strongly oppose

18a) During an average work week, how many off-campus stops/errands do you make:

	Travelling to work	During my work day	Travelling home from work
# of personal errands			
# of work-related errands			

b) What are your most frequent reasons for these stops/errands? (choose up to three)

Personal errands	Work-related errands
◻ pick-up/drop off children	◻ meetings
◻ personal appointments	◻ pick-ups/deliveries
◻ other ____________	◻ other ____________
◻ other ____________	◻ other ____________
◻ other ____________	◻ other ____________

18. Would your job description allow you to work from home at least one day per week?
◻ Yes ◻ No ◻ Unsure

19. Further Comments:

Feel free to contact us at 905-525-9140 ext. 24772 or ACT@mcmaster.ca