Morning Peak Period Travel Characteristics of a Residential Suburb in Cape Town during a School and Holiday period : What lessons can we learn ?

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously, in its entirety or in part, submitted it at any other university for a degree.

Signature : ……………………………………… Date : ……………………………

ABSTRACT

It is argued that an understanding of variability is central to the modelling of travel behaviour and the assessment of policy impacts and is not the peripheral issue that it has often been considered. There is a growing need to assess multi-day data to assess the distribution of user charges for road pricing, or patterns of public transport usage as well as improve the ability to identify mechanisms behind travel behaviour for modelling purposes.

Drawing on studies worldwide, in conjunction with a review of the literature, the thesis first examines the relevance for using multi-day data, then discusses the methodology and results of a five week survey undertaken specifically for this study, makes a comparison of the findings with that observed in other studies, and finally discusses issues relating to the application of the data and future research possibilities.

Previous studies have shown that behaviour which makes up the daily travel pattern can be highly repetitious in nature but that observing an individual's behaviour on a single day might not be representative of their routine travel and that this behaviour varies across demographic segments and driver gender.

This paper examines day-to-day travel behaviour variability of a residential area, Summer Greens, located in Cape Town (South Africa) using a travel dataset collected recently in November/December 2006. The survey technique employed was the recording of numberplates of all exiting vehicles from 06:00 to 10:00, weekdays from Monday to Friday over a period of five weeks. A total of 5677 vehicles undergoing 44 743 trips was observed and analysed.

This research replicates and extends previous work dealing with day-to-day variability in trip-making behaviour that was conducted with data collected by Del Mistro and Behrens (2006) in Buitengracht Street, Cape Town CBD, in July/August 2005. The present research extends the earlier work by including departure time variations as well as conducting the observations during both a school period (3 weeks) and consecutive holiday period (2 weeks). Further, the thesis presents a method to measure day-to-day variability using the available data surveyed.

This thesis finds a considerable difference in school and holiday traffic volumes as expected, but that despite this, certain identical travel behaviour patterns (such as vehicle appearance frequencies, following week repeat proportions etc.) is observed during both these periods. It was found that the peak hour for both school and holiday periods occurred during the same time period and greater traffic volume variability was found to occur on Fridays during the holiday period than in the school period. Traffic volumes across all weeks appeared to decrease from Monday to Wednesday and "bounce back" on Thursday and Friday consistent with the findings of another international study.

It was found that motorists exhibited more departure time freedom during the holiday period with average holiday departure times much later than during the school period. Departure times were also observed to gradually become later from Monday to Friday during both the school and holiday periods with Thursday and Friday departure times significantly different to the other weekdays.

The proportion of unique vehicles observed was found to increase with time of day and the resulting impact of this on the effectiveness of Variable Message Sign (VMS) applications is also discussed. The research concludes by applying the findings to determine the impact of a hypothetical congestion pricing scheme on traffic volumes.

SAMEVATTING

Die argument is dat ‘n begrip vir variasie sentraal staan tot die modellering van reisgedrag en die assessering van beleidsimiplikasies, en is dus nie net n nagedagte soos wat gereeld gedink word nie. Daar is ‘n toenemende behoefte om multi-dag data te analiseer om die verspreiding in gebruikerskostes te bestudeer vir die waardasie van paaie, of om verhoudings in publieke vervoergebruik uit te lig, asook, vir die verbetering van die vermoë om die meganismes agter reisgedrag te identifiseer vir modelleringsdoeleindes.

Die tesis bestudeer eerstens die relevansie van die gebruik van multi-dag data in samewerking met die literatuurstudie, gebaseer op studies wêreldwyd onderneem. Tweedens bespreek dit die metodologieë en resultate van ‘n vyf-week lange opname wat spesifiek vir hierdie studie onderneem is en tref vergelykings met die resultate verkry deur vorige studies. Dit bespreek dan die probleme wat voortspruit uit die toepassing van die data en ook toekomstige moontlikhede tot verdere navorsing.

Vorige studies het getoon dat die gedrag wat tydens daaglikse reispatrone voorkom van nature hoogs herhaaldelik is. Wanneer ‘n individu se gedrag observeer word op ‘n enkele dag is dit egter nie noodwendig verteenwoordigend van sy/haar roetine reisgedrag nie en dat hierdie gedrag afhanklik is van demografiese faktore en die geslag van die bestuurder.

Hierdie tesis bespreek die variasie in dag-tot-dag reisgedrag van ‘n residensiële gebied, Summer Greens, in Kaapstad (RSA) deur gebruik te maak van ‘n datastel wat onlangs saamgestel is (November/Desember 2006). Die data is ingesamel deur ‘n opname te doen van die nommerplate van alle uitgaande voertuie tussen 06:00 en 10:00, weeksdae van Maandag tot Vrydag, oor ‘n periode van vyf weke. A totale aantal voertuie van 5677 wat 44 743 ritte onderneem het, is waargeneem en ‘n analise is uitgevoer.

Die navorsing herhaal en brei uit op vorige werk wat die dag-tot-dag variasie in ritopwekking bestudeer. Del Mistro en Behrens (2006) het data bestudeer wat ingesamel is in Julie/Augustus 2005 in Buitengrachtstraat, in die Kaapse Middestad (RSA). Die huidige navorsing brei uit op hierdie werk deur die variasie in vertrektyd in te sluit asook om waarnemings te doen tydens die skoolperiode (3 weke) en die daaropvolgende vakansieperiode (2 weke). ‘n Metode word ook aangebied om die dag-tot-dag variasie te meet deur middel van die beskikbare data wat ingesamel is.

Hierdie tesis vind ‘n merkwaardige verskil in die skool en vakansie verkeersvolumes, soos verwag kan word, maar ten spyte daarvan bestaan daar sekere identiese reisgedragspatrone (byvoorbeeld die frekwensies waarteen ‘n voertuig voorkom, weeklikse herhaling van proporsies, ens.) gedurende beide hierdie periodes. Die bevinding is dat die spitsuur vir skool- en vakansieperiodes gedurende dieselfde tydsperiode plaasvind en dat verkeersvolumes groter variasie toon op Vrydae gedurende die vakansieperiode, as die skoolperiode. Dit wil blyk of verkeersvolumes gedurende al die weke afneem van Maandag tot Woensdag en dan “terug spring” op Donderdae en Vrydae. Hierdie bevinding is in ooreenstemming met resultate van ‘n ander internasionale studie.

Motoriste het ‘n neiging getoon tot groter vryheid in terme van vertrektye tydens die vakansieperiode, met die

gemiddelde vakansie vertrektye heelwat later as gedurende die skoolperiode. Vertrektye is ook gevind om geleidelik later te word van Maandag tot Vrydag gedurende beide die skool en vakansieperiodes, met Donderdag en Vrydag se vertrektye wat merkwaardig verskil van ander weeksdae.

Die verhouding uniek waargenome voertuie het volgens hierdie navorsing se bevindinge toegeneem met die tyd van die dag en die gevolglike impak hiervan op die effektiwiteit van sogenaamde “Vehicle Message Sign” toepassings word bespreek. Die navorsing sluit dan af deur die bevindinge toe te pas om die impak te bepaal wat ‘n hipotetiese kongestieprysskema op verkeersvolumes het.

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DISCLAIMER

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the information presented herein. The contents do not necessarily reflect the official views or policies of the University of Stellenbosch. This report does not constitute a standard, specification or regulation.

It is the intention of the Author to present this thesis as a paper at the South African Transport Conference (SATC), to be held at the Council of Scientific and Industrial Research (CSIR) in Pretoria in July 2008.

All ANOVA statistical testing conducted in this study has used the methodologies as specified on page 12.2 of "*Applied Statistics for Civil Engineers*" (Van As and Joubert, 1995).

ABBREVIATIONS

ADT	Average Daily Traffic
AM	Morning
ANOVA	Analysis of Variance for multiple variables
Ave	Average
CBD	Central Business District
CCTV	Closed Circuit Television
CMR	Cape Town Metropolitan Region
COCT	City of Cape Town
Cum.	Cumulative
DOW	Day of Week
Freq	Frequency
GPS	Global Positioning System
Hz	Hertz (Frequency)
ITP	Integrated Transport Plan
kbps	Kilobytes per second
Mb	Megabyte
M/bike	Motorbike
MBT	Minibus-taxi
min	minute
MP3	Compressed Audio File format

n Sample size

NHTS National Household Travel Survey

NMT Non-motorised transport

RDS Radio Data System

RSA Republic of South Africa

SEM Structural Equation Modelling

St Dev Standard Deviation

TDM Travel Demand Management

VMS Variable Message Signs

Vol Volume

Σvol Total Volume

vph Vehicles per hour

WAV Uncompressed Audio File format

w.r.t with respect to

%tile Percentile

GLOSSARY

Action Space A box plot of data showing the lower quartile (25%) and upper quartile (75%) and whisker lines extending from each end of the box to show the extent of the rest of the data.

Churn The variability in a traffic stream at the individual (intrapersonal) level

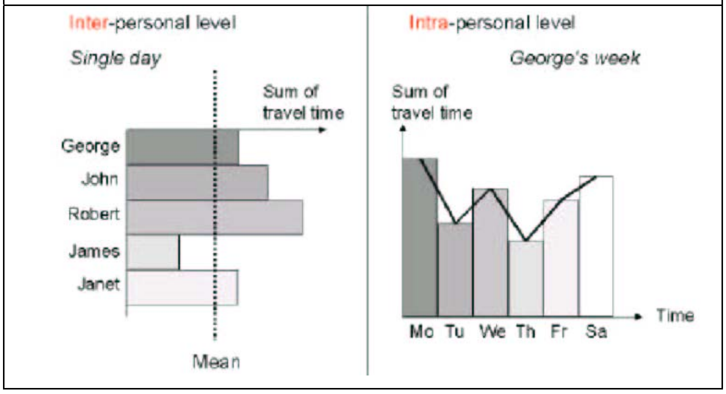
Heavies Heavy vehicles

Holiday Period Weeks 4 and 5 of the survey, conducted during a school holiday period.

Intrapersonal The variability of travel behaviour exhibited at the individual level. (Refer to Figure 1).

Interpersonal The variability of travel behaviour exhibited by several or group of persons. (Refer to Figure 1).

Figure 1 : Interpersonal and Intrapersonal levels of travel behaviour (Source : Schönfelder et al, 2002)



Macro A sequence of instructions written in Visual Basic (language) to operate in a Microsoft Excel environment.

Mobi*drive* A travel-diary based survey conducted in the cities of Halle/Saale and Karlsruhe in autumn 1999. A total of 317 persons over 6 years in 139 households participated in the main phase of the survey, after testing the survey instruments in a pre-test with a smaller sample in spring 1999 (44 persons). The paper-based instrument was supplemented by further survey elements covering the socio-demographic characteristics of the households and their members, the details of the households' car fleet and of the transit season tickets owned and personal values as wells as attitudes towards the different modes of transport (see for details König, Schlich, Aschwanden, Kaufmann and Axhausen, 2000; König, Schlich and Axhausen, 2000).

Returning vehicle A vehicle that was observed at least more than once during the entire five week survey period.

School Period Weeks 1 to 3 of the survey, conducted during a normal school going period.

Spurious match Number plates with similar or matching last three digits for different cars.

Taxi A minibus-taxi (MBT) retrofitted with 15 seats with no aisle and a sliding door.

Trip chaining A multi-purpose trip, eg. Home-School-Work trip.

Unique vehicle A vehicle that was observed only once during the entire five week survey period (or a “once-off” vehicle observation).

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1. BACKGROUND

1.1 Introduction

When one considers the congested citybound highways (eg. N1 towards Cape Town) occurring each morning in various cities around South Africa, it almost seems unreasonable to expect that motorists would be willing to endure such conditions on a daily basis. Certainly the peak hour volumes do not differ significantly on a day to day basis and hence the reason why transportation planners assume that travel patterns are stable i.e. have no variability, particularly when operating under capacity conditions. As a result, travel demand models are estimated on personal travel survey datasets that are collected over a one-day travel period only.

There is however an understanding amongst transport planners that Mondays and Fridays are non-typical days, but are classified as such purely on the basis of volume difference when compared to the other days of the working week.

Recent research conducted both locally and internationally indicates that these traffic streams, whilst stable at an aggregate macro (volume) level, change on a daily basis at a micro (or individual) level. This is because travel that is undertaken by an individual may be necessary to fulfil many activities (eg. personal business, shopping, social visits, medical/dental, etc.) that are not necessarily done on a daily basis. This variability in the traffic stream at the individual level has been referred to as “churn” (i.e. continuous change) in research by Chatterjee in 2001and by Del Mistro and Behrens in 2006.

“Churn” has significant implications for the effectiveness of Travel Demand Management (TDM) policy as these policies are targeted at individual motorists rather than aggregated individuals. There are many possible TDM techniques available to the practitioner as described in various literature sources, but one can conclude from these sources “*that their impact in changing travel demand has been limited, seldom altering aggregate demand patterns by more than single digit percentage point*” (Del Mistro and Behrens, 2006).

The purpose of this thesis is to present the findings on the extent of the daily variability and “churn” of vehicles during the morning peak period travelling on a residential distributor road exiting a residential suburb of Cape Town (Summer Greens), measured over a five week period during the school and holiday period in November and December 2006.

The results of the survey are then finally used to test a hypothetical TDM strategy at a micro level and assesses the calculated likely success of such a strategy in terms of overall volume reduction.

1.2 Relevance of the Study

Why is the measurement and modeling of day-to-day variability of travel behaviour important ?

Up until recently, transportation planning focused on the identification and relief of congestion on highway networks and relied on 4-step transportation models to predict traffic flows on roadway links and ultimately allow the practitioner to determine the additional number of lanes required to improve operational level of service on these roadways. The data requirements required to answer such capacity-expansion planning questions are modest and data from morning (AM) peak hour surveys has been considered sufficient and have also resulted in “snapshot” type models.

Due to lack of road space or funding resources or both, worldwide emphasis has shifted from capacity expansion to employing Travel Demand Management (TDM) techniques aimed at improving levels of service without additional costly infrastructure.

As a result of the manner in which the so-called “snapshot” transportation models have been developed, they are inherently unable to model travel pattern changes resulting from TDM strategies. This is because they are based on one-day data (regardless of the sample size) which "by their nature, does not adequately address questions about variations in behaviour over time". As a result, there has been a shift in the attention of transport research towards the dynamic processes in travel behaviour; learning and change on the one hand and rhythms and routines on the other.

Understanding of travel behaviour requires observation of self-report travel data over long duration. The survey reported in this project provides an alternative five-week data source, which contributes towards the understanding of travel behaviour at the origin end of a trip ie. from a residential suburb in Cape Town, South Africa. The data source presented in this thesis report has the added benefit of being conducted over both a school and holiday period during November / December 2006 allowing travel behaviour to be analysed and compared for these periods separately.

TDM strategies are normally coupled with traffic management services incorporating variable message signs (VMS) which would impact on more frequent drivers familiar with the road network. This impact has also been addressed in this study, and has been determined from the proportions of returning and unique vehicles making up the morning commuter traffic and hence help identify the optimum period for displaying messages.

1.3 Objectives of the Study

The specific primary objectives of the research project were to:

- Explore the daily morning commuter peak period variability in travel behaviour with respect to selected variables such as departure time, trip frequency and weekly occurrences.

- Explore the differences in daily morning commuter peak period variability in travel behaviour experienced in the school period versus the holiday period.

- Analyse day-to-day variability found in the numberplate-based dataset and compare the results against that reported in other literature and report on the comparison explaining why there are similarities or differences in the results.

- Analyse day-to-day appearance of unique vehicles found in the traffic stream and determine to what extent these proportions change over the survey time (ie. 06:00 to 10:00 AM) in order to determine the optimum time for VMS and/or RDS applications.

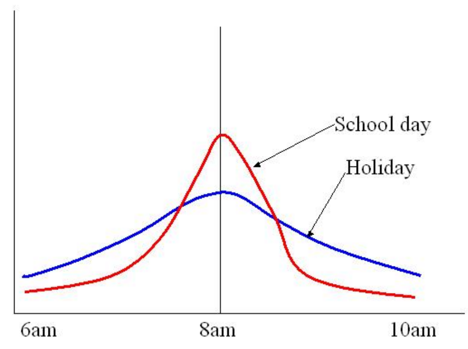
- Analyse day-to-day appearance of returning vehicles found in the traffic stream and determine the variation of departure times. The proportion of returning vehicles will give an indication of the likelihood of an individual's change in travel behaviour with the introduction of TDM measures.

- Determine the impact of a hypothetical TDM strategy applied to the research data by comparing pre and post TDM vehicle volumes.

As a secondary objective, it was initially hoped that vehicle occupancies identifying school children would be observed as part of the study, and thus enable more accurate conclusions regarding the impact of school-going family members on travel behaviour both during school terms and holiday periods.

The question needed to be asked to address this secondary objective is to test if additional trips (and magnitude thereof) are done specifically for school trips alone or is it done en-route to work. The general thinking is that during school days there is more traffic observed on the roads than during holiday periods, but that this is perhaps due to the peaking of traffic in the peak hour to drop off school children at 08:00 AM (school start time) with the volume of traffic in the AM peak period remaining more or less similar when compared to holiday traffic. This hypothesis is best described by referring to Figure 1.3 below. The hypothesis states that the vehicular volume under the red line equals the volume under the blue line indicating that commuters have more freedom of time to travel to work in the holiday period as they do not have the time constraint of a 08:00 school start time.

Figure 1.3 : School versus holiday period vehicular volume hypothesis



Pilot studies conducted revealed that the simultaneous survey of occupancies (including the identification of school children) was not possible and therefore abandoned. However, comment can be made with regard to the volume drop experienced from the school to holiday period during the survey period conducted.

1.4 Scope of the Study

The project scope included the following tasks:

- Conduct a literature review to identify research already undertaken and for data result comparison purposes.
- Identify a suitable study area to conduct the research survey.
- Conduct a numberplate survey over a three week school-going and a consecutive two week holiday time period using voice data recorders.
- Transcribe the dataset to an electronic format ready for analysis.
- Check dataset for errors and refine dataset.
- Explore variability in trip making characteristics.
- Compare numberplate-based survey results to other research on day-to-day variability in travel behaviour.
- Test the impact of a hypothetical TDM strategy applied to the research data by comparing pre and post TDM vehicle volumes.
- Prepare a thesis report summarizing the analysis and results.

As the survey data sample consists of vehicle numberplate details together with the associated time of observation and vehicle type only, it was not possible to determine trip purpose and so it is unfortunately not possible to determine the relationship between trip purpose and trip recurrence. For example it is possible for a vehicle that was observed every day of the week departing consistently between 07:30 and 08:00 to be mistaken as a commuter trip when in fact they are business trips (eg. collecting security guards at the end of an early morning shift).

1.5 Report Outline

Following the introductory chapter describing the objectives, scope and relevance of the study, an extensive literature review regarding variability of travel behaviour is presented in the next chapter.

The third chapter discusses the reasoning behind why the study area was selected together with demographic and economic characteristics of the selected study area. The fourth chapter describes results of pilot surveys undertaken leading to how raw field data was successfully obtained and describes sample size requirements. Problems encountered during the field survey stage are also described in this chapter.

Chapter 5 is dedicated to reporting day-to-day variability in travel behaviour found in the five-week dataset. This chapter examines morning commute variability in several different ways including trip frequencies, daily/weekly trip repetitiveness and departure time variability.

Chapter 6 provides a brief application and the implications of Travel Demand Management (TDM) on the data with Chapter 7 providing a summary of the conclusions made in the body of the report.

The eighth chapter is the concluding chapter that provides a discussion of possible future related research that can be undertaken.

2. LITERATURE REVIEW ON VARIABILITY OF TRAVEL BEHAVIOUR

2.1 Introduction

The previous chapter provided the objectives and relevance of the study and explained why multi-day travel survey data is useful for travel demand modeling. However to date, there has already been some significant study towards identifying day-to-day variability in travel behaviour from multi-day surveys thusfar. Table 2.1 summarises some of the more important travel behaviour surveys conducted. This section reviews local and international literature on the day-to-day variability in travel behaviour.

Table 2.1 : Summary of International Travel Behaviour Research

Survey Location	Year	Duration	Survey method (Sample size)	Authors / Date of publication
Uppsala (Sweden)	1971	35 days	Travel diary (n=149 persons)	Hanson and Huff (1988)
Reading (England)	1973	7 days	Travel diary	Pas and Koppelman (1987)
Leeds (UK)	1984	-	Questionnaires, Travel diary, Numberplates	Bonsall, Montgomery and Jones (1984)
Seattle, Washington (USA)	1989	3 days	Travel diary	Pas and Sundar (1995)
Southampton (UK), Cobden bridge & Winchester Rd	1994	21 days	Numberplates	Cherrett & McDonald (2002)
Southampton (UK), Bassett Ave & Winchester Rd	1996	10 days	Numberplates	Cherrett & McDonald (2002)
Halle/Saale and Karlsruhe (Mobi*drive* survey), Germany	1999	6 weeks	Travel diary (n=361 persons)	Axhausen, Zimmermann, Schönfelder, Rindsfüser and Haupt (2002), Schönfelder (2001), Zimmermann & Axhausen (2001)
Lexington, Kentucky (USA)	1997	7 days	GPS monitoring (n=100 households)	Pendyala (2003) Zhou and Golledge (2000)
Atlanta, Georgia (USA)	2004	1 week	GPS monitoring (n =56 drivers)	Li, Guensler, Ogle and Wang (2004)
Cape Town CBD, South Africa	2005	3 weeks	Numberplates (n=17361 vehicles)	Del Mistro and Behrens (2006)

According to Pendyala (2003), there are two sources of day-to-day variability in travel behaviour. First, day-to-day variability occurs because people's needs and desires vary from day-to-day. For example, there may be no need to undertake a trip in the holiday period to drop off school children. Second, behaviour varies from day-to-day because of feedback from the transportation system. Thus, a person may choose a different route and/or departure time for a work trip on Fridays if they encountered severe congestion the same time and day in the previous week.

The earliest multi-day travel behaviour research analysis was conducted by Hanson and Huff (1988) on the 1971 Uppsala (Sweden) household travel survey data. The Uppsala survey obtained information on all out-of-home travel - activity behaviour using self administered travel diaries for a 35-day period. Hanson and Huff used a representative sample of 149 individuals who completed diaries for the entire 35-day period to examine the day-to-day and week-to-week variability in travel behaviour.

Their research concluded that work trips are repeated on a day-to-day or week-to-week basis when examined in isolation of the overall daily activity-travel pattern. However, when the overall daily activity-travel pattern is examined in its entirety, they found that a one-day pattern is not representative of a persons routine travel. They concluded that behaviours which make up the daily travel pattern can be highly repetitious in nature but that observing an individual's behaviour on a single day might not be representative of their routine travel.

The research conducted by Pas and Koppelman (1987) utilizing the seven-day activity data collected in 1973 in Reading, England and using the three-day travel diary data collected in 1989 in Seattle concluded that greater levels of precision can be obtained from multi-day data than from a one day dataset.

They also found that the level of intrapersonal variability (between individuals) varied significantly across demographic segments and found for example, that females exhibit higher levels of intrapersonal variability than males, possibly due to the roles traditionally played by females in households. In their study, Pas and Koppelman concluded that "*there are high levels of intrapersonal variability in daily travel behaviour, and that such variability differs across population groups".*

Pas and Sundar (1995) found considerable day-to-day variability in the trip frequency, trip chaining, and daily travel time of the sampled persons using the three-day travel dataset collected during 1989 in Seattle, Washington (U.S.A.).

The evidence thus challenges the existence of a typical travel day representative of the daily or weekly activity-travel patterns exhibited by individuals and that day-to-day variability in travel behaviour exists and is substantial. It must be noted that each of the studies presented in the literature review in the following sections apply to a particular socio-economic and demographic population segment not consistent with all the studies reviewed.

2.2 Literature Review on Variability of Travel Behaviour

<u>Departure time variability</u>

In the research conducted by Pendyala (2003) on the GPS based data conducted in Lexington, Kentucky (USA) over seven days, it was found that departure time had the most significant variability using the F-statistic test at the 95% confidence level. This was expected as average trip departure times for Saturday and Sunday was 10:02 AM and 08:13 AM respectively compared to the 7-day average of 10:45 AM.

Pendyala also grouped all individual departure times and classified all departure times within ± 20% of the median to be the same departure period. The median was used to eliminate the effects of outliers. The 4-day sample revealed that 25% of all departure times were considered within ± 20% of the median. The 5-day sample revealed that only 7.1% of all departure times were considered within ± 20% of the median confirming that the extent of intra-personal (within-person) variability increases as the period of observation increases.

Day of the Week variability

In the research conducted by Pendyala (2003) on the GPS based data conducted in Lexington, Kentucky over five days from Monday to Friday, it was found that Thursday was different to the other weekdays in terms of number of trips, travel times and travel distances. It was also found that Fridays had lower trips rates than other days but had similar travel times and distances as the other weekdays.

Analysis of the Mobi*drive* data conducted by Schönfelder (2001), using the concept of "Action Space" plots to represent travel behaviour data, identified an extensive urban space band on Fridays relative to narrower bands observed for the rest of the working week, indicating greater travel behaviour variability on this day.

Research conducted by Zhou and Golledge (2000) on the Lexington, Kentucky dataset measured activity travel behaviour using time series plots with specific focus on variability amongst the seven different days of the week. The time plots of daily peak trip counts indicated a gradual decreasing traffic volume from Monday to Wednesday with volumes "bouncing" back on Thursdays and Fridays. This was attributed to declining working efficiency as time passes from Monday and "picks" up again with the approach of the weekends, indicating a possible psychological factor that may be affecting people's "go-to-work" behaviour. The day with the highest traffic count was observed to be Thursday with Saturday the lowest count.

Their research also confirmed that even amongst weekdays, when the routine of work constrains activities, different travel behaviours emerge, but more so during the noon, early afternoon and evening time slots.

Further research on the Mobi*drive* data by Simma and Axhausen (2001) used Structural Equation Modeling (SEM) to model relationships between transport variables. They postulated that Monday influences all other days in the week with decreasing influence during the course of the week. The results of the SEM analysis revealed that direct effects do exist particularly between Monday and Tuesday, Monday and Saturday and the following Monday. The SEM model also proved that the previous days travel behaviour plays an important role in the behaviour of the next day.

Impact of School trips

In a paper by Lesley (2002), it is mentioned that one in eight (12.5%) of all UK journeys made are to or from school. This paper was specifically written to identify the predicted travel mode to school as a result of a proposed new school and recommended some interventions to reduce the impact of new vehicular trips.

In a specific survey conducted in West Wallasey (UK), all modes of travel were recorded in a road side survey, undertaken on a school day and on an equivalent school holiday. The results showed that the volume differences were significant when tested with the Chi-square test at the 95% confidence level. In the morning peak hour, car trips reduced from 1212 to 659 vehicles per hour (or 45.6%) which provides an indication of the impact of school traffic on road networks.

The report concludes that the way children travel to school has changed significantly over the last twenty years with car ownership increasing and a decreased interest in cycling due to safety reasons and motivated the use of NMT methods of travelling to school by appropriate design and encouragement of the parents.

Unique (Once-off), Daily Returning Vehicle Occurrence and Frequency of departure time intervals

Research by Cherrett and McDonald, (2002) on a numberplate survey conducted in 1994 and 1996 at two sites in Southampton (UK), (refer to Table 2.1) found that the percentage of returning vehicles (non unique) that appeared on more than one day formed 80% of the traffic before 08:15 but only 60% between the 08:45 to 09:00 peak period. Table 2.2.1 shows the average percentage of unique vehicles per daily time slice observed at the Winchester Road and Bassett Avenue surveys.

Table 2.2.1: Percentage Unique and Returning vehicles observed in the 1996 Winchester Rd/Bassett Ave surveys (Source : Cherret and McDonald)

Time Slice	% Unique vehicles	% Returning Vehicles
07:45 – 08:00	20%	80%
08:00 – 08:15	20%	80%
08:15 – 08:30	25%	75%
08:30 – 08:45	35%	65%
08:45 – 09:00	40%	60%

Table 2.2.2 shows the overall proportion of day-to-day returning vehicles of all the surveys conducted.

Table 2.2.2 : Proportion of Daily Returning Vehicles observed in the 1994 & 1996 Cobden Bridge, Winchester Rd & Bassett Ave surveys (Source : Cherret and McDonald)

Survey	% of returning vehicles	% of returning vehicles appearing within ± 5min of previous day's time
Cobden Bridge (1994)	36.7%	67.1%
Winchester Rd (1994)	24.8%	67.6%
Bassett Ave (1996)	49%	61.9%
Winchester Rd (1996)	48.9%	65.7%
	Average	65.0%

The table shows that 49% of the (Bassett Ave) vehicles in the 1996 survey were returning vehicles of which approximately 62% returned within ± 5 minutes of the previous day's departure time. On average, for all four surveys, 65% of returning vehicles appeared within ± 5 minutes of the previous day's departure time which could be considered part of a habitual behaviour pattern.

A numberplate study conducted by Bonsall, Montgomery and Jones (1984) around Leeds (UK), revealed a 50% day-on-day reappearance of returning vehicles which closely matches the Cherret and McDonald 1996 Basset Avenue (49%) and Winchester Road (48.9%) data results.

A number plate study conducted by Del Mistro and Behrens (2006) on Buitengracht Street, a major arterial to the CBD of Cape Town (South Africa) from Monday to Friday over the two weeks between 25 July and 5 August and then a week later from 15 to 19 August 2005 between 07:30 and 09:00, revealed that, over a three week survey period, an average of 52% (with a standard deviation of 1.2%) of vehicles observed on the first day, were also observed on the next day, again closely matching the results of Cherret and McDonald and Bonsall et al.

Departure times and Median Switch

A study by Li, Guensler, Ogle and Wang (2004) investigated departure time variability in Atlanta, Georgia (USA) in terms of a “median switch”. A median switch is used to study the time deviation from motorists usual travel behaviour. A motorist is said to “switch” when the absolute difference between departure time and the median of all the departure times is greater than a certain test criteria (t_c), which could be 5 minutes (300 seconds) or 10 minutes (600 seconds) for example. The median was selected to avoid the influence of outliers.

So, if the median is represented by m_i and departure time in seconds by d_t, then a switch occurs when :

$$\left|d_t - m_i\right| \geq t_c$$

Note that all variables require the use of a continual clock time starting at midnight with, for example, 08:00 AM equalling 28 800 seconds.

Figure 2.2.1 shows a graphic representation of the “median switch” definition. The figure shows the observation times (d_{t1} to d_{t4}) over four consecutive days. For the first three days, the observed departure times do not trigger a “median switch” event whilst the last departure does.

Figure 2.2.1 : Graphic representation of “Median Switch”

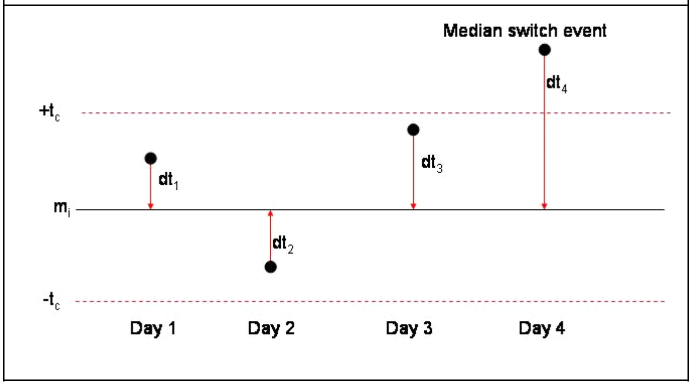


Table 2.2.3 shows the results of the “median switch” survey conducted on the Atlanta, Georgia sample of 56 vehicles equipped with GPS devices.

Table 2.2.3 : Departure time switching of a sample of 280 journeys (Source : Li, Guensler, Ogle & Wang, 2004)

Criteria	**5 min switch criteria**	**10 min switch criteria**	**30 min switch criteria**
No. of “Median switches”	148 out of 280 trips	116 out of 280 trips	54 out of 280 trips
% of total journeys that “Median switched”	53%	41%	19%

The results concluded that considerable variability exists in departure time decisions. Even at the 30min switch criteria, it was found that almost 20% of the 280 commute journeys switched. The authors noted that the results must be considered in the context of the small sample size and restricted to a certain geographic area. It should also be noted that the 53% “5-min switch criteria” cannot be compared to the average 65% “% of returning vehicles appearing within ± 5 min of the previous days time” observed by Cherrett and McDonald, (2002), on the basis of the switch definition.

In a survey conducted over one month in Brussels (Belgium) by De Palma, Fontan and Khattak (2004), afternoon commuter work departure times were surveyed instead of the usual morning home departure times. Statistical evidence of the results of this survey indicate that work related factors such as tolerance of employers towards leaving work early, flexi-time and occupation type (scientific and executive professionals) were associated with higher departure time variability. Such a conclusion would seem applicable to morning departure time variability as well.

Weekly Returning Vehicle Occurrence

The previous section dealt with the re-appearance of vehicles on a day-to-day basis. The study by Del Mistro and Behrens (2006) investigated the following week repeat defined as when a motorist makes a trip on the same day in the following week. Table 2.2.4 shows the results of the three week survey. The percentage value indicated in the "Average" column in the table is the average percentage of repeating vehicles found in weeks 1 and 2, weeks 2 and 3 and weeks 1 and 3.

Table 2.2.4 : Percentage of vehicles observed on the same day of the following week (Source : Del Mistro and Behrens, 2006)

Observed frequency of vehicles per week*	Average	Standard Deviation
0	71.2%	1.02%
1	12.7%	0.38%
2	5.9%	0.35%
3	4.5%	0.40%
4	3.3%	0.25%
5	2.4%	0.10%

* Note that this is not trips/week. This parameter measures the observed number of days in the week a vehicle is matched (irrespective of the number of trips observed on a particular day).

Frequency of vehicles per week

The study conducted by Del Mistro and Behrens (2006) revealed that almost 47% of all observed individual vehicles appeared only once; (thereby supporting the average of between 23% and 50% calculated by the Cherrett and McDonald (2002) studies, and that less than 10% appeared on all five days in each week. Table 2.2.5 shows the results of the average frequency of observed vehicles for the three week period. Note that the standard deviation for all vehicle appearances is less than 1% indicating consistent values for each of the individual weeks.

Table 2.2.5 : Appearance of vehicles per week (Source : Del Mistro and Behrens, 2006)

Appearance of vehicles per week*	Average (Week 1-3)	Standard Deviation (Week 1-3)
1	46.9%	0.80%
2	19.3%	0.75%
3	13.3%	0.55%
4	10.9%	0.46%
5	9.6%	0.78%

* Note that this is not trips/week. This parameter measures the observed number of days in the week a vehicle is matched (irrespective of the number of trips observed on a particular day).

From the table, it can be seen than less than 35% were observed (at least once) for three or more times per week. The figure could in fact be higher due to the fact that certain trips could have been recorded before 07:30 or after 09:00 or be part of the 5% missed plates or 20% spurious matches reported in the study. Also, the location of the study, although situated on an arterial, did not prevent motorists from using alternative routes and so results may overestimate the proportions of less frequently observed vehicles.

Another way of looking at this data is the percentage of trips made by vehicles with respect to frequency of appearance. Table 2.2.5 only measured vehicle appearance per week and not number of trips per week. For example, a motorist observed once in that week may have actually undertaken three trips that day. Table 2.2.6 provides a better means of explanation by indicating vehicle observations recorded (of one hypothetical vehicle) over four time intervals over one week.

Table 2.2.6 : Explanation of Vehicle Appearance and Proportion of trips per week for a vehicle

Time Interval	Monday	Tuesday	Wednesday	Thursday	Friday	Total
1	x	x	x	-	-	3
2	-	x	-	-	-	1
3	x	x	-	-	-	2
4	x	x	-	-	-	2
Minimum	1	1	1	0	0	**3**
Sum	3	4	1	0	0	**8**

x : indicates time period within which vehicle was observed

From Table 2.2.6, it can be seen that the vehicle made three daily appearances per week (based on the total weekly minimum count of observations) whilst the total proportion of trips made is eight trips per week (based on the total sum count of observations). In other words, the vehicle in the table which appeared on three separate days per week, can be associated with undertaking a total of eight trips over that week.

Table 2.2.7 shows the same data but looking at the degree of variability from the point of view of the percentage of trips associated with the frequency of vehicle appearance.

Table 2.2.7 : Percentage of trips made by vehicles w.r.t Frequency of Appearance (Source : Del Mistro and Behrens, 2006)

Appearance of vehicles per week*	Average (Week 1-3)	Standard Deviation (Week 1-3)
1	21.6%	0.59%
2	17.8%	0.85%
3	18.5%	0.58%
4	20.1%	0.95%
5	22.0%	1.61%

* Note that this is not trips/week. This parameter measures observed number of days in the week a vehicle is matched (irrespective of the number of trips observed on a particular day).

A comparison between Table 2.2.5 and Table 2.2.7 shows that although only 9.6% of vehicles were seen (appeared) at least once everyday in the week, they constituted 22% of the total trips made in the observation period, as per the definition explained in Table 2.2.5. Del Mistro and Behrens (2006) went on to conclude that if one defined the term "habitual" to include travellers making three or more trips per week, then "habitual travellers" could be said to account for 61,6% of all trips.

Measuring variability

Until now, no mention has been made as to how travel variability can be measured. How more variable is one dataset from that of another? The major obstacle in addressing this issue is the absence of a commonly accepted similarity measurement technique.

In research by Schlich (2001a), several methods of measuring variability is assessed and critically discussed. Some of the variability indices assessed included :

R_j : Overall repetition measure which measures an overall repetition index for single trips but has the disadvantage that it cannot measure trip repetition for more than one day.

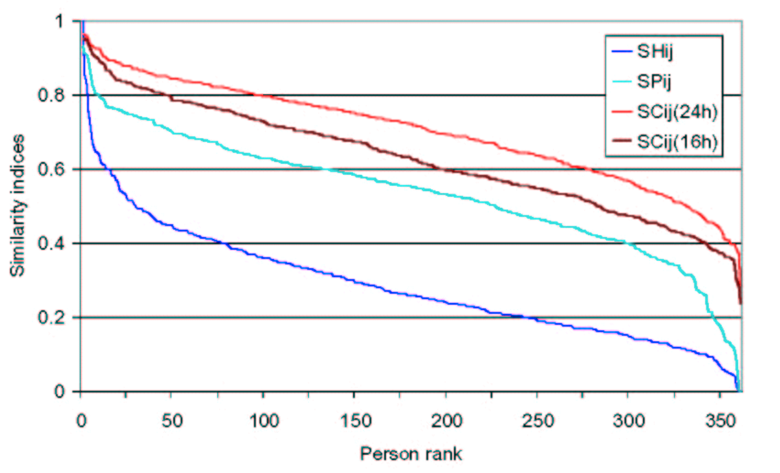
SH_{ij} : Similarity index Hanson, which takes into account different attributes as well as the number of daily trips. The disadvantage of this measurement index method is that it can only take two attributes into consideration.

SP_{ij} : Similarity index Pas, which compares two daily travel activity patterns by describing each trip in the pattern by one primary variable and a set of secondary variables, thus allowing more than two attributes to be taken into account.

SC_{ij} : Similarity index Clarke/Jones which compares trip similarity based on a time budget rather than on trips. This index method is exclusively based on times of performed activities and ignores attributes like traffic mode and can be conducted over a 16 hour SC_{ij}(16h) or 24 hour SC_{ij}(24h) period, or any other selected time period.

Schlich used these index measurement techniques and applied them to the 361 person Mobi*drive* dataset. The results (refer to Figure 2.2.2) show that the measures differ significantly from each other and concluded that day to day travel behaviour is more variable if measured with trip based methods (ie. R_j, SH_{ij} and SP_{ij}) than using time budget methods (ie. SC_{ij}(16h) or SC_{ij}(24h)). Note that a similarity index value of one indicates identical activity patterns and a value of zero indicating no matches. The SCij(24h) shows more identical patterns than the SC_{ij}(16h) index due to the "sleep period" included in the 24 hour period.

Figure 2.2.2 : Comparison of similarity indices for all persons by rank : Mobi*drive* dataset (Source : Schlich, 2001a)



In a follow up study, Schlich (2001b) used the sequence alignment method on the Mobi*drive* dataset to classify travel behaviour. The sequence alignment method compares two separate sequence of events (eg. trip purposes of day one trips with day two trips) and attempts to equalise them using different operations such as substitutions, insertions or deletions, each operation carrying a certain score. For example, compare the following trips of a motorist over two separate days :

Day 1 : H-W-H
Day 2 : H-W-S-L-H

where H = Home, W = Work, L=Leisure and S = Shopping trips

Using the sequence alignment method, either a deletion of “S” and “L” on the second day or an insertion of “S” and “L” on the first day would equalise the sequence of the two days. If substitutions score two points and deletions and insertions one point each, then in the example above, the sequence comparison of the two days score two points. The smallest sum of the operations needed to match the sequences is called the Levensthein distance. In the sample above, the Levensthein distance thus equals two.

Using the Mobi*drive* dataset, Schlich found that the average Levensthein distance from one working day to other working days is not constant indicating that weekday behaviour is not totally repetitious and that constraints such as working times are perhaps not as strictly adhered to as previously thought.

This chapter has provided a literature review of relevant studies that have been carried out elsewhere including the analysis techniques used. It should be noted that other relevant literature is referenced in the body of this thesis.

3. STUDY AREA SELECTION AND CHARACTERISTICS

3.1 Introduction

The idea of specifically selecting a study area for this project only materialised after an initial investigation at the start of this study. At the initial stage of the study, it was the intention to observe traffic variability (or “churn”) for a period of five weeks on the N1 freeway leading into the Cape Town CBD with no consideration or need for a study area. With this idea in mind and in an attempt to automate the number plate data collection process as much as possible at this stage, a pilot study was conducted on the N1 (city bound lanes) in June 2006 at the Ysterplaat station pedestrian bridge (just outside Cape Town) using home digital video recording equipment.

The pilot study entailed erecting the camera on a tripod directly over the three city bound lanes on the pedestrian overpass during the morning peak hour and recording for a short period of five minutes for video review later. The results of the video recording revealed that whilst individual vehicles could certainly be counted and classified (ie. lights, heavies , MBT’s, buses etc.) within the traffic stream, the resolution of the footage together with vehicle speeds, made it impossible to read the individual number plates. In addition, maximum camera battery life would only last for half an hour. This type of survey would require two high definition cameras operating alternatively to ensure video footage overlap during battery changes.

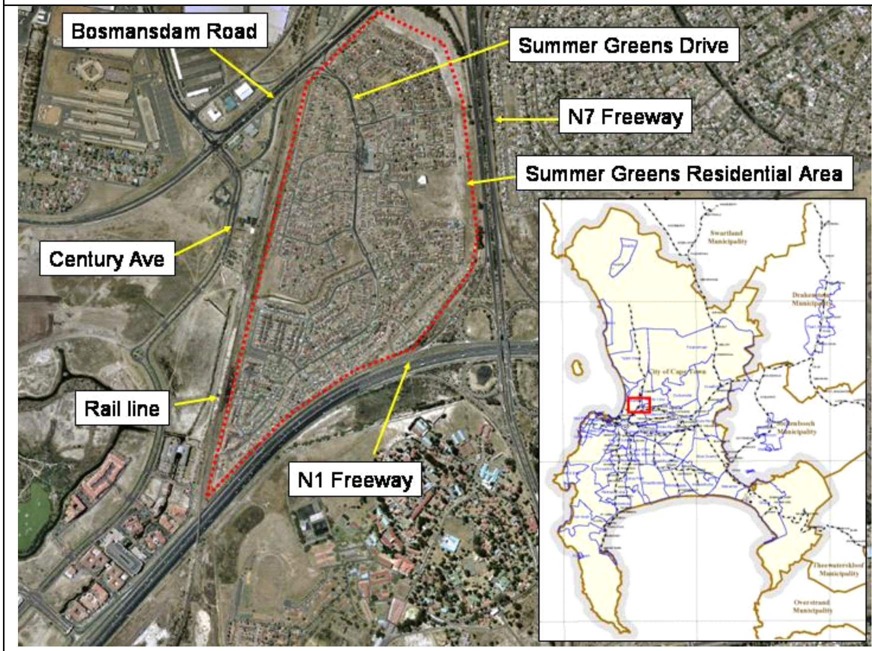
The idea to utilise video footage to record number plates was therefore abandoned in favour of more manageable manual observation of vehicle numberplates utilising only a single lane of a carriageway. The idea of selecting a study area to manually monitor vehicle movements exiting a residential area thus originated.

3.2 Study Area Selection

In order to minimise field enumerator resources required for this project thesis, it was necessary to select a residential area that had few alternative access exit routes. After rejecting several potential study areas on the basis of multiple access routes, the residential suburb of Summer Greens located to the north east of Cape Town was identified as ideally suited for this project (refer to Figure 3.2 for a location and study area).

The suburb is bordered by the N7 freeway to the east, the N1 freeway to the south, the Chempet/Atlantis railway line to the west and Bosmansdam Road to the North. The suburb is thus isolated and has only one access road (viz. Summer Greens Drive) servicing this area, which connects directly to Century Avenue with a “Left-in” only connection from Bosmansdam Road.

Figure 3.2 : Location of Summer Greens Study Area



This means that all residents leaving the area are forced to use Summer Greens Drive, providing the ideal opportunity to study commuter patterns for all outbound vehicles during the morning peak period.

Table 3.2 lists the six possible aspects, identified by Cherrett and McDonald (2002), that can be varied when undertaking a trip. The table also shows how the careful selection of the study area (Summer Greens) has allowed the trip data to be restricted to only three measurable aspects viz. No's 1, 5 and 6.

Table 3.2 : Applicable trip aspects measured and method surveyed

No.	Aspects	Applicability	Method
1	The time of making the trip	Yes	Time of observation
2	The route taken	Only 1 possible route	Not applicable
3	The origin of the trip	Summer Greens	Not applicable
4	The destination of the trip	Unknown	Not applicable
5	Transport mode; including car sharing	Yes	Mode classification
6	Whether the trip is made at all	Yes	Number plate analysis

3.3 Demographic Charateristics

Demographic data for the study area of Summer Greens was obtained from the Census 2001 dataset (2001).

Population Group :

Table 3.3.1 presents the Census results of the race group demographics of both the local, Summer Greens (n=4,445 persons) and Cape Metropolitan Region (CMR) area (n=2,893,250 persons). The table shows that the Summer Greens area can be considered almost uniformly multi-cultural with an even distribution across all race groups (except the Indian/Asian group).

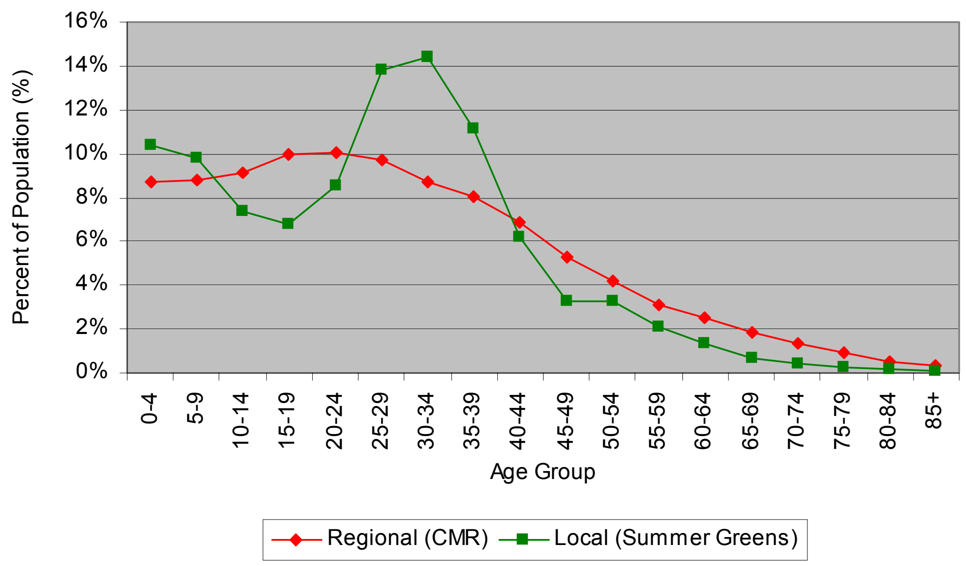
Table 3.3.1 : Comparison of Regional and Local Race Group demographics (Source : Census 2001)				
Context	**Black African**	**Coloured**	**Indian/Asian**	**White**
Regional (CMR)	31.7%	48.1%	1.4%	18.8%
Local (Summer Greens)	22.9%	37.8%	4.0%	35.4%

Of interest worth mentioning here is the findings of the latest research by Venter (2007) indicating that even when taking household income into account and all other factors, that black African households are on average less likely to have car access than other households, suggesting the existence of a cultural/legacy effect, independent of income.

Age Group :

Figure 3.3 shows the Census Age group distribution of Summer Greens (n=4,445 persons) when compared to the CMR (n=2,893,250 persons).

Figure 3.3 : Comparison of Regional and Local Age Group demographics (Source : Census 2001)



The graph shows a marked increase in the "25 to 39 year old" age group proportion of the local Summer Greens area when compared to the CMR data profile. This indicates the tendency of this residential area to accommodate the younger person possibly either entering the job market or starting a family having relocated from other areas.

The findings of Venter (2007) indicate that people in car-access households most likely to use public transport are in their late teens or early twenties, and female. The graph indicates that the proportion of this population group (ie. "13 to 25 year old" age group) residing in Summer Greens is significantly lower than the CMR average, suggesting an overall lower public transport dependency for this area.

Gender :

According to Census data (n=4,445 persons), the Summer Greens Male:Female proportion is 48,3%:51,7%. The findings of Venter (2007) indicate that women are more car deprived than men suggesting that the male breadwinner normally gets precedence in using the car. Unfortunately, it was not possible to identify the gender of the driver in the survey conducted for this project to correlate this finding.

Highest Education :

Table 3.3.2 shows the highest education achieved for the age group 20 years and older for the Summer Greens area according to Census data (n=2,939 persons).

Table 3.3.2 : Highest Education Achieved (Summer Greens area : Population over 20 yrs old only) (Source : Census 2001)

Education level	Proportion (%)
No Schooling	1.6%
Some Primary school	1.7%
Complete Primary school	1.1%
Some Secondary school	29.8%
Std 10/Grade 12	45.3%
Higher	20.3%
Total	100%

The table indicates that 65.6% of the Summer Greens population over the age of 20 has either completed a formal high school education or has a post schooling education.

Employment Status and Occupation:

Table 3.3.3 shows the employment status for the entire Summer Greens population (n=4,445 persons).

Table 3.3.3 : Summer Greens Employment Status (n=4,445 persons) (Source : Census 2001)

Employment status	Proportion of Summer Greens population
Employed	51.8%
Unemployed	4.3%
Student	6.4%
Housewife	2.8%
Retired/pensioner	2.1%
School	29.1%
Other	3.7%
Total	100%

The table shows that most persons (87.2%) are either employed, attend school or are students who necessarily require transport outside the residential area. The types of occupation are shown in Table 3.3.4.

Table 3.3.4 : Summer Greens Occupation types (n=4,445 persons) (Source : Census 2001)		
Employment status	**Classification**	**Proportion of Summer Greens population**
Managers, Officials	White Collar workers	6.2%
Professionals		7.4%
Technicians		7.8%
Clerks	Blue Collar workers	11.8%
Shop/service workers		7.2%
Fishery workers		0.1%
Craft/Trade workers		4.1%
Plant/Machine operators		2.1%
Elementary occupations		2.5%
Undetermined		3.1%
Not Economically active		47.9%
Total		100%

Of the 52.1% of the Summer Greens population economically active, approximately 21% are white collar professionals (ie. managers/professionals/technicians) whilst the remaining 31% are blue collar workers (ie. either daily 9-to-5 workers or shift workers).

3.4 Travel Characteristics

Travel characteristics for the study area of Summer Greens was obtained from both the Census 2001 and the National Household Travel Survey (NHTS) 2003 datasets.

The National Household Travel Survey (NHTS), was undertaken in 2003 and collected demographic, travel, accessibility, and perception data from 52 376 households nationally. The first national travel survey of its kind in South Africa, it produced a rich dataset for a statistically representative sample of households across the entire country.

Mode of Travel

Table 3.4 shows the results of the modal use by residents of Summer Greens (n=3,059 persons) using Census data. The sample excludes NMT modes such as walking and cycling (n=1,388 persons).

Table 3.4 : Summer Greens Travel Mode and Vehicle Proportions (n=3,059 persons) (Source : Census 2001)					
	Motorbike	**Car**	**MBT**	**Bus**	**Total**
Persons	24	2210	490	335	3059
% Persons	0.8%	72.2%	16.0%	11.0%	100%
Occupancy*	1	1.3	10	43.9	-
No vehicles	24	1700	49	8	1780.6
% Vehicles	1.3%	95.5%	2.8%	0.4%	100%

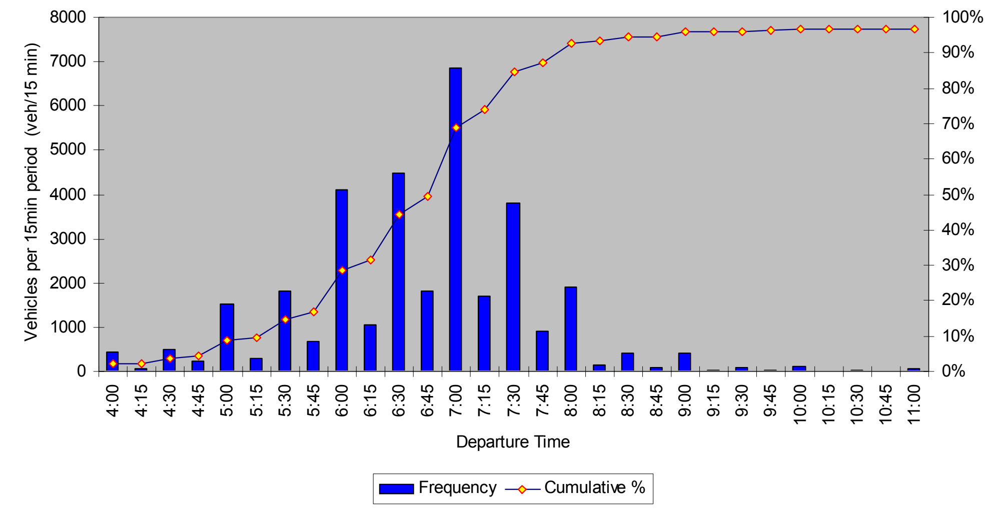
* : assumed

In order to calculate vehicle volumes, vehicle person occupancies as indicated in the table were assumed. The table shows a high 72.2% car dependency, which compares well with the national 70% average (Venter, 2007). When person travel mode is translated to vehicle volumes, the impact of a 72% person car dependency translates to cars being 95.5% of the vehicular traffic.

Departure Times

Figure 3.4 shows the results of the National NHTS travel departure times for all nine provinces and three hundred and forty two Travel Analysis Zones (TAZ's). The departure times indicated are for all the data records and includes all modes of transport including walking and/or cycling and includes both rural and urban environments.

Figure 3.4 : National travel departure times (n=35,032 persons) (Source : NHTS 2003)



The graph shows the tendency to bias the verbal responses to the closest ½ hour of probable true departure time. Whilst departure time characteristics have been determined from analysis of the NHTS data, recorded via questionnaires, such methods of data collection are subject to criticisms that people lie or falsely recall information about times of travel (Zhou and Golledge, 1999) and, as shown in the NHTS data, biased responses such as rounding of trip times to selected time intervals is evident.

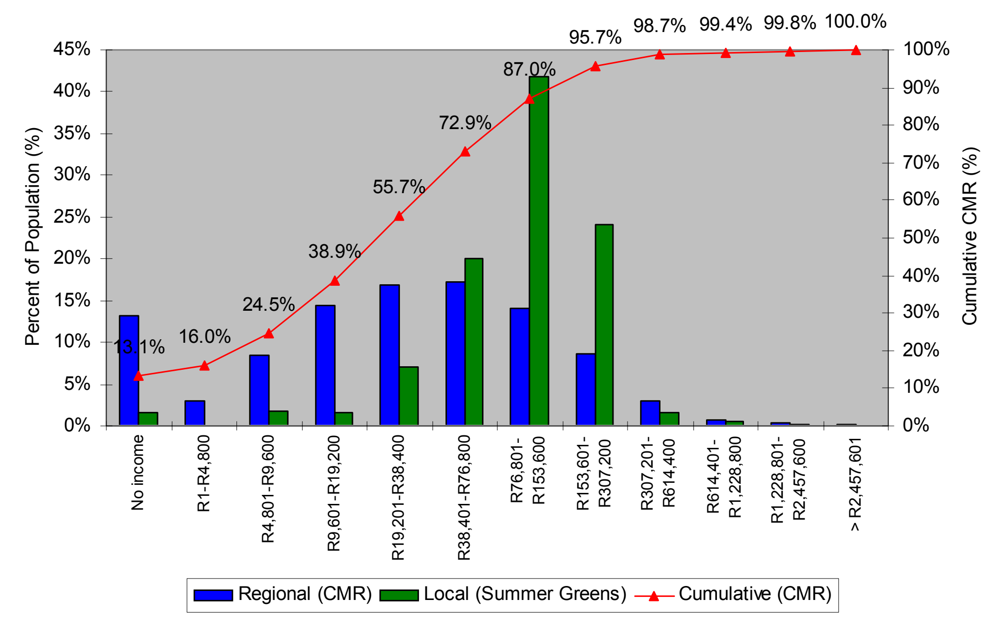
3.5 Census Household Income and car ownership

The 2001 Census data was used to obtain annual household income results. Figure 3.5 compares the proportions of annual household income of the entire Cape Town Metropolitan Region (CMR) with that of the local Summer Greens household income profile.

In the context of the broader CMR, 86% of Summer Greens residents (ie. those falling into the R38 401 to R307 200 bracket) fall within the 73 to 95% percentile of CMR income earners. In other words, 86% of Summer Greens households fall within the top 5 to 27% of all household earners in the CMR. During the survey data collection stage, it was evident that most private vehicles observed were in fact newer models, suggesting higher affordability levels.

There is a strong relationship between household income and car ownership (Venter, 2007). The NHTS (2003) data indicates that the majority of households earning more than R36 000 per month have "access" to a car (ie. households who are not necessarily car owners but have access to vehicles such as neighbours or family owners). In the context of Summer Greens area, approximately 88% of the Census sample earn more than R36 000 per annum and thus have potential car access

Figure 3.5 : Local (n=4,445 persons) and Regional (n=2,893,250 persons) Annual Household Income Levels (Source : Census 2001)



According to the results of research conducted by Mokonyama and Venter (2005), South African household car ownership starts to increase substantially (ie. where the average number of cars owned by households in the population starts to exceed one) at monthly household incomes of R6 000 (or R72 000 per annum). In the context of Summer Greens, approximately 68% of the Census sample earn more than R72 000 per annum and are thus potential vehicle owners. This figure correlates well with Table 3.4, which showed that 72.2% are indeed car dependant users.

4. DATA COLLECTION

4.1 Intoduction

This section covers the development of the survey methodology, the execution of the pilot surveys and results, the problems experienced, the revised methodology used on the basis of the pilot study experience, sample requirement rates and an assessment of the data quality in terms of survey observation rates and useable data and survey fatigue.

Before any surveys were in fact conducted, the first area of concern was with potential errors in the eventual recorded data, with the size of these errors being largely dependant on the method used to acquire the data. Writing down the number or license plates as they are observed potentially reduces the number of transcription steps involved but is only appropriate for low to moderate flows of vehicles. Dictation techniques are able to accommodate a higher volume of traffic but this does involve the possibility of an additional transcription stage.

For higher volume roads, the option of only recording a partial number plate is also available, although this will lead to the possibility of the analyst being unable to match all vehicle plates precisely and is therefore not utilised in any of the surveys in this project. For all surveys conducted in this study (both pilot and actual), the entire number plate was observed thus eliminating spurious matches.

4.2 Preliminary Investigations

Once the study area was selected, a preliminary volume count was conducted on Thursday, 20 July 2006, from 06:00 to 12:00. The primary objective of this weekday pilot count was to determine the AM peak period and peak hour volume that could normally be characterised as commuter travel. Secondary objectives included the assessment of other travel data collected such as vehicle occupancy, mode types, directional split etc.

Simultaneous volume counts were conducted for lane movements “A” (Bosmansdam Road entry), “B” (Century Avenue entry) and “C” (Summer Greens Drive exit). Figure 4.2.1 shows the location and direction of the lane movements surveyed.

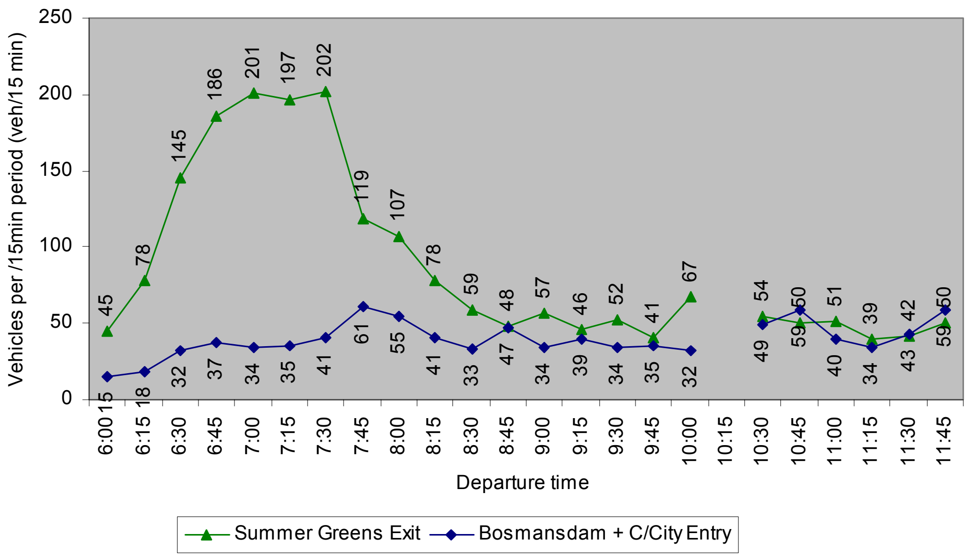
All modes of transport were observed including the NMT modes, cycling and walking. Where possible vehicle occupancies were also observed for the 6-hour period. Vehicles modes observed were classified as either :

C : Private car	T : Minibus-taxi
P : Pedestrian	B : Bus
L : Light commercial vehicle	CY : Cyclist
H : Heavy commercial vehicle	M : Motorbike

Figure 4.2.1 : Lane movements where Pilot Volume Counts were undertaken.

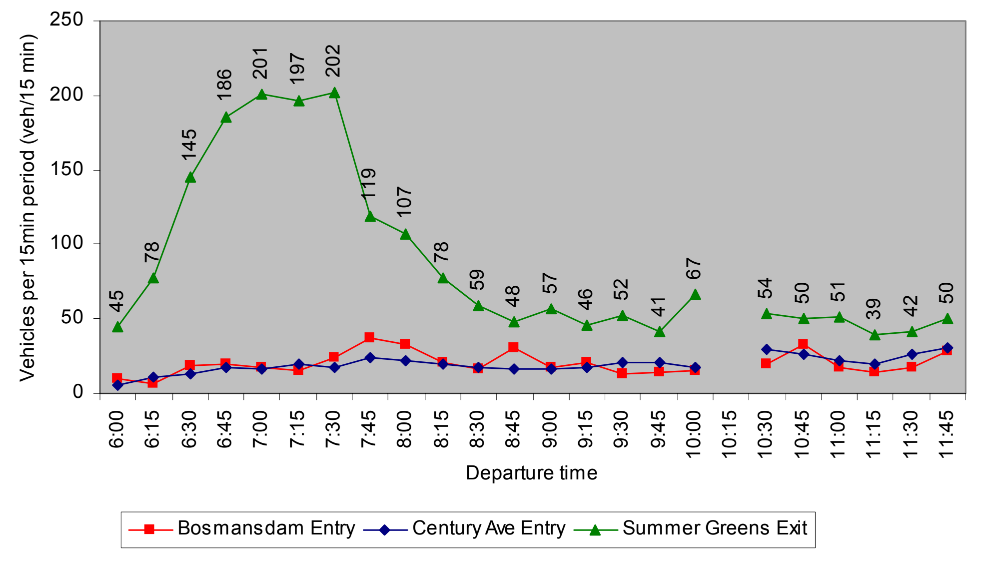
Figures 4.2.2 and 4.2.3 shows the 15-minute interval counts of all vehicles counted (excluding NMT). Note that no data was recorded during the 10:15 to 10:30 time period.

Figure 4.2.2 : Vehicular volumes (excluding NMT) per 15 min period



The graph in Figure 4.2.2 shows the 15-min counts of the three individual movements whilst the graph in Figure 4.2.3 shows the same graph with combined movements represented as either exiting or entering movements only. The data reveals a distinct dominance of the exit movement during the morning peak hour period between 06:45 an 07:45. The exit: entry directional split during this peak hour is 85:15.

Figure 4.2.3 : Exiting and Entering Vehicular volumes (excluding NMT) per 15 min period



Between 08:30 and 09:00, the dominant movement is still the exit movement but now reduces to a 60:40 directional split. After 10:30, it becomes apparent from the graph that the exit and entry volumes are similar with a directional split of approximately 50:50. Whilst occupancies were observed where possible, the results are not presented here due to possible lack of accuracy issues.

The pilot survey however provided a good indication of the traffic volumes expected to be observed and recorded during the actual travel survey intended for this research project. To ensure that the full commuter portion of exiting traffic would be observed, the period from 06:00 to 10:00 was thus selected for the purposes of the travel survey.

4.3 Methodology

Traditional means of measuring day-to-day variability in travel behaviour has been by utilising "one day travel diaries" and more recently with the use of GPS devices. Conducting multiday personal travel diary surveys have typically low response rates, are biased towards more important or longer trips and the participant usually exhibits survey fatigue with poorer recording occurring with longer time durations of survey (Pendyala, 2003). On this basis, the diary method of travel behaviour observation was not selected for this research project.

Recent technological advances of both in and out-of vehicle technology has allowed more sophisticated vehicle identification techniques to be used including transponders, cell phones and dedicated GPS location devices. The use of Global Positioning System (GPS) devices to be installed in vehicles and has the added benefit of capturing route choice, path, and speed information that is typically very difficult to collect in traditional personal recall surveys. The disadvantage of such a system is the cost involved in acquiring GPS units and hence limited sample size when compared to the study area population and was thus not used for this project.

Outside the vehicle, modern camera CCTV technology is able to isolate and read a vehicle's registration details. Usually this newer technology is capable of uniquely identifying a vehicle, but in two separate tests conducted in Southampton, England, (Cherret and McDonald, 2002), numberplate recognition accuracy levels were reported to be only 77% and 65%. The limited availability of this equipment and its associated success in South Africa is still in it's infancy and has thus not been used in this research project.

In collaboration with the City of Cape Town (COCT), it was decided to install a loop counter on the exit lane of Summer Greens Drive together with a camera (mounted on a street light pole) to count traffic over the five week period. The objective of this exercise from the COCT perspective was to test the camera counting software against the loop counts. The manual count conducted during the numberplate survey provided a third dataset for comparison. The results of this exercise however never materialised due to problems with data retrieval from both the loop and camera devices.

Other possible measurement techniques are by direct interviews, driver log diaries or number plate observations. Results from a survey conducted by Bonsall, Montgomery and Jones (1984) revealed that the day-on-day reappearance of vehicles was 80% from the direct interview method, 74% from driver logs and 50% from number plate data and concluded that the former two techniques over-estimated the constancy of reappearance.

A recent travel study conducted in the Cape Town CBD by Del Mistro and Behrens (2006) was done by observing and recording vehicular numberplates entering the city between 07:30 and 09:00 daily, over a three week period. Some common problems encountered with this study and associated with numberplate surveys in general, are as follows :

1. Survey times are dependant on time of the year as it is impossible to read numberplates in the dark during the winter months. The study by Del Mistro and Behrens was conducted in the August winter months restricting numberplates to be read from only 07:30 onwards, which meant that the data analysis needed to account for the vehicles that were not recorded before 07:30 that might have been recorded on the previous day. From the Summer Greens pilot volume count, it would be necessary to count before 07:30 to capture the full commuter proportion and minimise this problem.

2. Recording of vehicle numberplates could be difficult with multiple lanes, rainy weather and vehicle speeds.

3. Where possible, the entire numberplate should be recorded to avoid "spurious" matches ie. where vehicles are matched based on incomplete or partial numberplate recordings. In the study by Del Mistro and Behrens, only the last four digits of the numberplates were observed which resulted in a 20% numberplate sample duplication.

4. There is also a maximum capacity that a single person can observe and record numberplates. This capacity is largely dependant on recording method (write or verbal), number of persons observing,

weather conditions or season, light conditions, traffic volumes, traffic speeds, reading of partial of full plates and the requirement to observe other characteristics of the vehicle being observed (eg. mode type, occupancy etc.). Due to the relatively large volumes (2300 to 2600 vehicles in 90 minutes), almost 5% of the total numberplate sample in the study by Del Mistro and Behrens was missed.

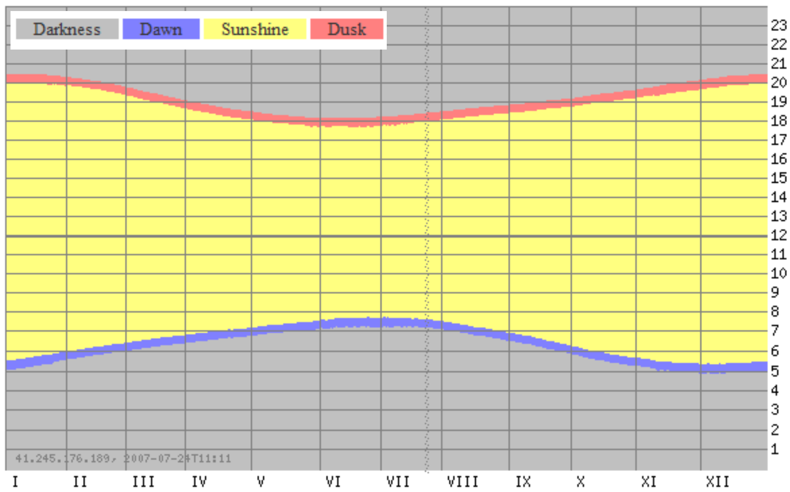
5. The location of the study, although located on an arterial, did not prevent motorists from using an alternative route and so results may overestimate the proportions of “Unique” or “Once-off” vehicles.

Resulting from the Bonsall et al (interview and travel log) survey findings and in order to compare the travel characteristics of the Del Mistro et al data with that of Summer Greens, it was decided to obtain travel data using the same methodology, viz, via vehicle numberplate recording but with the following changes made to the survey data collection methodology.

Time of the Year :

It was decided to conduct the survey during the summer months during November and December in order to get maximum daylight benefit (refer to Figure 4.3 for Cape Town daylight hours). From the graph, sunrise in the July during winter season is at 07:43am. In August, sunrise is at 07:14am and in October it is 05:54am. It was observed on 25 July 2006 that it was not possible to read front numberplates in hours of darkness against the contrast of vehicle headlights. In addition, darkness further reduces the ability to monitor other features such as vehicle occupancies, driver gender etc. It was also considered impractical to read back numberplates as not all vehicles have their back plate illumination in working order.

Figure 4.3 : Cape Town Sunrise and Sunset times for the whole year (Source : Gaisma.com)



Location of observation point

Although it was decided to observe numberplates of exiting vehicles along Summer Greens Drive, it was not possible to pre-plan the optimum observation point on this section of the route. To this end, it was decided to conduct a pilot study at several points to assist in this regard. This is discussed in more detail in the following section.

<u>Numberplate observation</u>

The exercise of matching successive observations of individual vehicles within a traffic network is a “classical” transportation engineering problem. The first area of concern is with errors in the recorded data, and the size of these errors is dependant on the method used to acquire the data (Clark, 2001).

Writing down the number plates as they are observed reduces the number of transcription steps involved but is only appropriate for use in decent weather conditions and with a low to moderate flow of vehicles. Dictation techniques are able to accommodate a higher volume of traffic but this does involve the possibility of an additional transcription stage. For high volume roads, the option of only recording a partial number plate is also available, although this will lead to “spurious matches” ie. the possibility of multiple vehicles being associated with a certain partial plate.

The pilot volume count undertaken on 20 July 2006 allowed an assessment of the likely volumes required to be observed. The AM peak hour volume for the exit lane during the pilot study amounted to 786 vehicles per hour, which occurred between 06:45 and 07:45. According to Bonsall et al. (1984) study, it is has been shown that a single enumerator can record vehicle numberplates for volumes of up to 1200 vehicles per hour. More recently however, according to Cherrett and McDonald (2002), it was determined that a single enumerator can only accurately record vehicle numberplates for volumes of up to 700 vehicles per hour. The actual peak Summer Greens volume at 839vph, which occurred on Wednesday, 22 November 2006, was found to be close to the capacity recording limit of our enumerator. It is mentioned however that the majority of the plates consisted of reading a maximum of six numbers only whilst the Cherrett and McDonald study is based on UK plates that consisted of a combination of four letters and three numbers which may be considered more onerous to verbally record. Note that the survey for the Summer Greens area included the identification of other vehicle/travel characteristics as well (eg. Mode of travel).

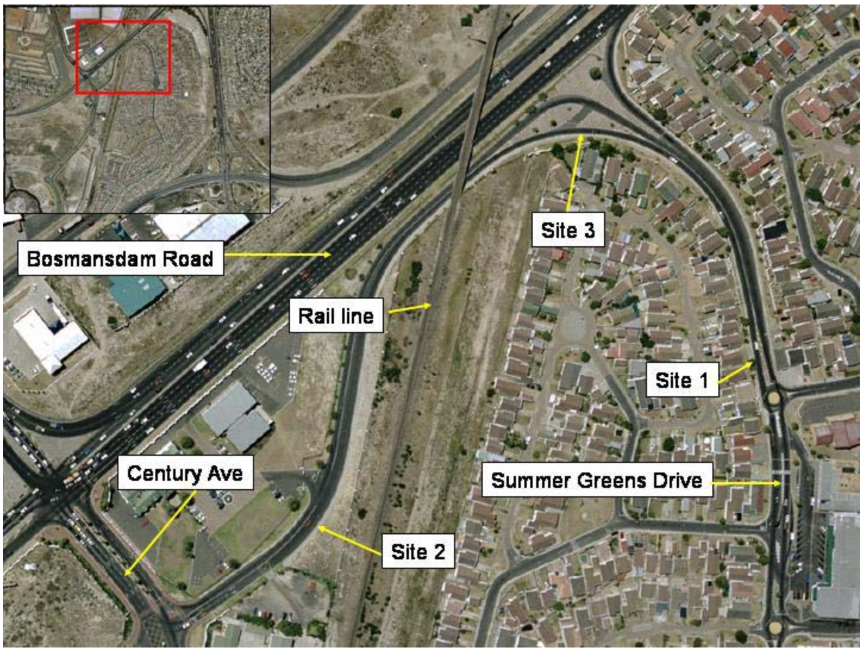
In order to eliminate the likelihood of “spurious” matches that accompany the reading of partial plates (Cherrett and McDonald, 2002), it was decided to observe and record the full numberplate including all number prefix lettering and special custom numberplates.

4.4 Pilot Surveys and Study

Once the numberplate survey methodology and the time of the year had been selected to suit the daylight requirements, Monday, 16th October 2006 was chosen as the first day of the survey. In preparation for this, a mock pilot study was conducted on Friday, 13 October 2006 between 06:00 and 10:00 to identify and address any unforeseen issues which could arise.

The location for the mock study was conducted at “Site 1” (refer to Figure 4.4.1 for the location of the various observation station sites) and was based on the theory that motorists would be negotiating the mini-traffic circle travelling northbound on Summer Greens Drive and hence would be travelling at relatively low speeds ideal for numberplate recording.

Figure 4.4.1 : Location of the various Survey Observation Sites



The methodology employed during the mock survey entailed the use of two students, one reading the complete observed numberplate whilst the second person would be manually writing the data to paper. Once the mock study was completed, and despite missing a few vehicles as expected (it was hoped to achieve less than a 5% "miss" rate, or an "observation" rate better than 95%), it appeared that the full survey could continue.

The same two students then continued with the survey as planned on the 16th,17th and 18th October 2006 without any changes made to the survey technique. However, after only three days of observations, survey fatigue set in and the motivation for the students to proceed with the manual writing technique fell rapidly and the students refused to continue with the survey. It also transpired during the data capture stage that the "observation rate" for the four completed surveys (inclusive of the mock study conducted on the 13th October) was considered unacceptable, varying from 85% to 92%.

Apart from this, certain other problems emerged during the three survey days including the fact that the road verge at the Site 1 location could not accommodate a parked car for the enumerators to observe from, requiring them to be outside in the elements for the entire four hour survey period. Secondly, there were many pedestrians on this route affecting visibility at times and also queries from local traffic police interrupted the survey recording periodically.

On the basis of the poor recording rate achieved, it was decided to abandon the manual (pen and paper) survey method and opt for using analogue tape recorder/s, which allows for a reduced survey staff requirement from two to one. To permit a single enumerator to observe from within the shelter of a car, it was decided to shift the observation location to Site 2 affording more road verge for parking.

An analogue survey was personally conducted on Monday, 23 October 2006 from 06:00 to 10:00 at survey Site 2. During this survey, vehicle occupancies and the presence of school children in the vehicles were additional observations attempted. Whilst this was possible for lower volumes, it became impossible to observe during higher volumes and the recording of this information was thus abandoned. The "observation" rate for the entire four hour period using this method improved to 96.1% but the survey technique was however still not without problems.

Firstly, the analogue tape recorders only allowed recording of 30 minutes per tape, which meant that two such devices were needed to ensure that no vehicles were missed in the recording during tape reloading. Secondly, although observations were conducted in the comfort of a car, the road carriageway width at Site 2 is wide enough to accommodate two vehicles and so overtaking vehicles within the lane could not be observed by a single enumerator. Thirdly, the site was located too close to the Century Drive intersection which, during the peak hour, resulted in queue lengths developing past the observation point in rows of two vehicles making it impossible to observe all the vehicles.

Finally the playback quality of the audio was of such poor quality making accurate transcribing difficult. The microphone tended to pick up static hiss and a series of cumbersome conversion processes was necessary to convert the analogue recording to digital format, which could be stored and played back on computer for transcribing purposes.

Table 4.4.1 tabulates the sample details and "observation" rates achieved at all the pilot studies undertaken for this project thesis.

Table 4.4.1 : Pilot study sample details and "Observation" rates achieved

No	Date	Total Trip Sample	Vehicular trips missed*	"Observation" Rate	% Missed
1	Fri, 13 Oct 2006	1580	172	89.1%	10.9%
2	Mon, 16 Oct 2006	1704	243	85.7%	14.3%
3	Tue, 17 Oct 2006	1720	225	86.9%	13.1%
4	Wed, 18 Oct 2006	1748	134	92.3%	7.7%
5	Mon, 23 Oct 2006	1776	70	96.1%	3.9%
5	Tue, 24 Oct 2006	Data not analysed, Investigation only			
7	Tues, 7 Nov 2006	Data not analysed, Investigation only			

* Including motorbikes

In an attempt to avoid the queuing problem and double rows of traffic encountered at Site 2 and to achieve an even better "observation" rate, it was decided to conduct a further pilot study at Site 3 on Tuesday, 24 October 2006 from 06:00 to 08:00 only using the analogue voice recorder. The benefits of this observation station was the narrow road, permitting only one vehicle at a time to pass, as well as a pedestrian speed hump, just upstream of the observation point, which slowed vehicles down to approximately 20km/h, which greatly assisted in the numberplate observations. It was concluded from this pilot study that this observation site would be the ideal location. Despite lower speeds, the vehicle volumes encountered did not allow for in-vehicle observations such as occupancies. Certainly, such observations could be undertaken but at the expense of a significantly lower numberplate "observation" rates.

The final pilot study was personally conducted at Site 3 on Tuesday, 7 November 2006 during the busiest period ending at 09:00am. For the first time, this survey introduced a digital MP3 recording device (shown to scale in Figure 4.4.2), which allowed for a maximum of 6 to 7 hours of non-stop recording time with a 7 hour battery life. The benefits of such a versatile device allowed the time of observations to be recorded automatically without the need to announce it as the saved audio (wav) file can be played back on any Windows Media Player (v 10.00.00.4036), which shows time lapse of the recording.

Figure 4.4.2 : MP3 device used for recording purposes

The MP3 device has a 256 Mb onboard memory capacity, which allowed for a significantly higher quality audio file (recording rate set at 0.011 Mb/sec or 22050 Hz wav format) than the analogue device and virtually eliminated background hiss. The four-hour digital file also occupied far less computer space ie. 156 Mb per file compared to the analogue file.

Table 4.4.2 summarises the details of all the pilot studies undertaken for this project.

Table 4.4.2. : Pilot Study Survey dates and locations

No	Date	Station	Survey Method	Time	Enumerator/s
1	Thur, 20 July 2006	-	Volume count	6 –12am	G. Venter
2	Fri, 13 Oct 2006	1	Manual	6 – 10am	M. Ralehoko / K. Khaketla
3	Mon, 16 Oct 2006	1	Manual	6 – 10am	M. Ralehoko / K. Khaketla
4	Tue, 17 Oct 2006	1	Manual	6 – 10am	M. Ralehoko / K. Khaketla
5	Wed, 18 Oct 2006	1	Manual	6 – 10am	M. Ralehoko / K. Khaketla
6	Mon, 23 Oct 2006	2	Analogue	6 – 10am	L. Hermant
7	Tue, 24 Oct 2006	3	Analogue	6 – 8am	C. Schmidt
8	Tues, 7 Nov 2006	3	Digital (MP3)	8 – 9am	L. Hermant

The successful identification of an observation station, recording device and methodology resulting from the eight pilot studies provided an acceptable level of confidence to proceed with the five week survey.

In summary it was concluded that, with the preliminary survey process undertaken thus far, that one should never underestimate the value of pilot studies to identify problems. In fact, in this project, although a series of pilot studies were undertaken, not all the problems were identified and certain problems emerged in the actual five-week survey itself, discussed in more detail in the following sections.

4.5 Survey Sample Requirements

According to Pas and Koppelman (1987), the one basic condition in analysing intrapersonal variability is to observe behaviour over as long a period as possible. This is the only way to cover as much as possible out of the spectrum of all activities a person performs and to avoid biases in forecasts as far as possible.

Due to the large variability found in the Del Mistro et al survey (Del Mistro and Behrens, 2006), the number of weeks over which the Summer Greens survey would have to be conducted to find the average might need to be quite large.

The Mobi*drive* travel behaviour survey is at present unique in terms of the length of the reported period and completeness of available data items.

It is the result of a six week travel diary implemented in the context of the research project Mobi*drive*. Funded by the German Federal Ministry for Education and Research, in autumn 1999 in the cities Karlsruhe and Halle/Salle, altogether 361 persons were interviewed. The project consortium consisted of the PTV AG (Karlsruhe), the Institut für Stadtbauwesen at RWTH Aachen and the Institute of Transport, Traffic, Highway and Railway Engineering (IVT) at ETH Zurich. Research by Schlich (2001a) provides a description of identifying variability, sampling procedures, and a recommended observation period. Altogether, the interviewed persons reported 52273 trips on 14360 person days.

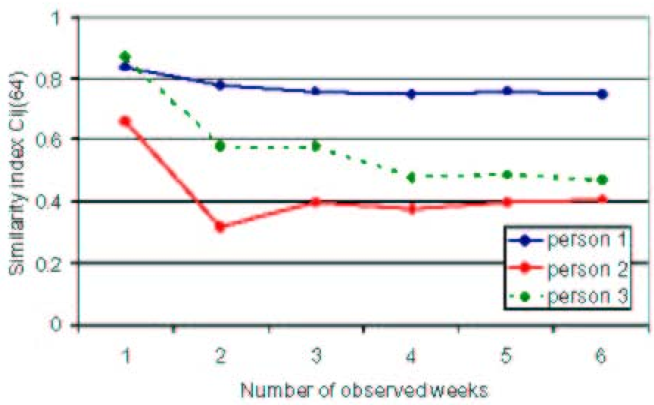
There is however one other comparable survey example, which covers a period of five weeks - the Upsalla survey. This survey was conducted in 1971 and is the basis of a series of publications by Hanson and collaborators concerning the stability of travel behaviour (e.g. Hanson and Huff 1982, 1986 and 1988; Hanson and Burnett 1981 and 1982; Huff and Hanson 1986 and 1990). Besides the Upsalla survey, there are several other travel behaviour surveys covering periods of one or two weeks previously mentioned in the literature review (Chapter 2). However, due to their comparatively short duration, those surveys permitted only limited calculations.

Recent technological advances and interest in GPS based tracking of vehicles has resulted in a number of initiatives which has allowed for long term recording of car-based travel. However, these surveys are still in it's infancy and multi-week surveys have yet to be conducted using this technology. A current example of a GPS based survey is the six day study conducted in Lexington, Kentucky (Pendyala, 2003) where 100 household vehicles were tracked.

But we come back to the question : "How long does the survey observation period have to be ?" This question is addressed by comparing the measured variability of activities of three randomly chosen persons for different time periods using the Mobi*drive* data (Schlich, 2001a). The reported time period covers one to six weeks.

The measurement according to Jones and Clark shows different results for three people over different time periods as shown in Figure 4.5. A similarity index of 1 denotes no variability whilst a value of 0 reflects maximum variability in travel behaviour.

Figure 4.5 : Average similarity of daily activity patterns for different observation periods according to Jones and Clarke (1988)



The stability in activities is highest for person 1, who is retired. For all persons the total amount of variability is increasing with the increasing duration of the observation. The longer the observed period is, the higher the number of different performed activities and thus the smaller the variability index. Another interesting trend is the strong decline of the index when moving from a one to a two week survey period.

The measurements conducted by Schlich confirmed the tendency of decreasing stability with increasing observation period and show stability after two weeks. Even if a longer period is observed, the resulting index is nearly the same. With this in mind, Schlich recommends that empirical surveys about travel behaviour research should cover a period of at least two weeks. (Schlich and Axhausen, 2003).

The two week survey period then formed the minimum duration for the Summer Greens survey conducted during the holiday period whilst three weeks was selected for the normal school going period in order to provide a comparative time period with the survey by Del Mistro et al, also conducted over three weeks. The overall survey was thus conducted over a period of five consecutive weeks. It should however be noted that considerable survey fatigue set in towards the end of the fifth week and it would be recommended to use two pairs of enumerators if possible to alternate survey weeks to reduce this problem.

4.6 Data Description

The objective of the dataset was to obtain a recording of vehicular numberplates on a daily basis with a corresponding time at which the particular observation took place. A printout of the first 100 data records is included in Appendix 1 and a full electronic version of the data is included in the enclosed CD. The data fields that were directly inputted at the transcribing phase was the “Registration Plate”, “Special”, “Vehicle Type” and “Data No” fields as well as the time fields “HH”, “MM” and “SS”. All the other fields were inputted at the data checking phase which included “Period”, “Day of Week”, “Record Time”, “Actual Time” etc. Vehicle types identified were classified as either one of the following :

C : Car, Bakkie	P : Police vehicle
B : Bus	T : Minibus-Taxi vehicle
H : Heavy vehicle	M : Motorbike
HR : Heavy Refuse vehicle	

No NMT movement was recorded. The “Record Time” was derived from the inputted “HH:MM:SS” time and indicates elapsed time once recording has started and normally ended after 14 800 seconds (or 4 hours). In order to perform calculations with observed vehicle times, the “Record Time” was based on a 86 400 second clock starting at 0h00 (0s) and ending at 24h00 (86 400s). The “Actual Time” of an observation was then calculated, also based on 86 400s clock, by means of comparing the “Record Time” observed at 10h00 exactly and by adjusting the remaining dataset record times to the true time accordingly.

No times were specifically recorded during the surveys, but by the announcing of numberplates, the recording of the time in “hh:mm:ss” format was automatically made and identified during audio playback on a Windows Media player which shows elapsed time in this format.

To save transcribing time, the letter prefix of all local “CA” plates was excluded and only non-CA plates were recorded. Details with regard to the analysis of the data collected is described later in Chapter 5.

4.7 Problems Encountered with Data Collection

The physical location of the observation point at Station 3 was approximately 1.0m downstream of the pedestrian crossing speed hump (refer to Figure 4.7.1). This is because the speedhump automatically produced vehicle headways making it easier to read plates after the bump, not before.

Figure 4.7.1 : Photograph showing location of observation vehicle at Site 3

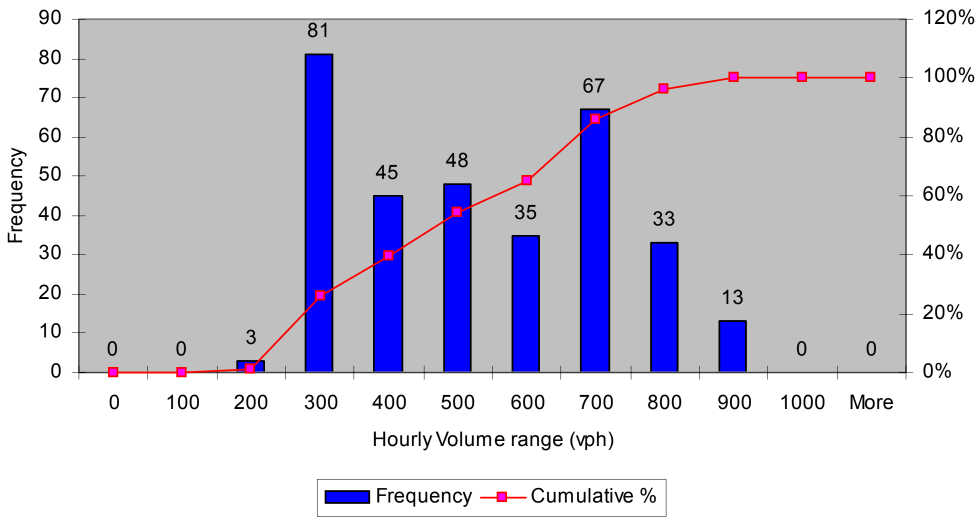
Some of the errors observed during the data collection process are as follows :

1. There was initially great interest by Metro Police and Traffic policemen who made it difficult to converse with and observe plates simultaneously. On the Friday morning of the first week of surveying (17 November 2006), two police constables almost jeopardised the survey as they claimed the survey car was parked illegally in the road verge and wanted it removed. Fortunately, the survey proceeded. A visit to the Milnerton police station was done and formal permission to conduct the survey was obtained from Capt. C. Charles and no further police enquires were then reported. However, it was decided from this point on, that two enumerators would be required to survey, one to read out plates and the other to cross-check numberplates. The second enumerator would also be responsible to field questions from the public, thus not interfering with or jeopardising the survey. To desensitise the local community as to the presence of the enumerators and survey operations, an article was placed in the local newspaper. The article was published in the Thursday, 30 November 2006 edition of Table Talk and is included in Appendix 2. The Councillor of Ward 56, which includes Summer Greens, Mr. Jacob Ridder, was also personally contacted to inform him of the survey.

2. Whenever a vehicle was observed to have the front numberplate missing, it was decided not to read the back plate as this would interfere with normal pattern of reading plates and potentially miss other vehicles. In these situations, it was decided to identify the car by its colour, make and type, which was hoped would be easy to identify and tag for matching purposes in the eventual dataset. Whilst this is sound in theory, in practice, the entire dataset of vehicles with missing front number plates had to be removed from the dataset as the colour variation per vehicle differed amongst the various enumerators. In addition, certain enumerators could not identify the vehicle make correctly and had even more difficulty identifying the model type. As survey fatigue set in, model type was eventually not even called out. This resulted in multiple false vehicle matches, based on vehicle colour and make alone, which led to the eventual exclusion of this data from the dataset.

3. As indicated in Section 4.6, a study by Cherrett and McDonald (2002) indicated an observation capacity of 700 vph for accurate identification of UK-based numberplates. Figure 4.7.2 shows a histogram of the hourly count volumes from 06:00 to 10:00 for the entire 25-day survey period. Note that the volume range shown in the figure shows the upper bin range only ie. 900 represents the 800-900 bin range. The graph shows that only 46 (14.15%), of all the 325 possible peak hour combinations observed (made up of 15 minute intervals), had associated volumes greater than 700 vph. Fortunately, the enumerators selected to undertake the survey had the required vocal ability and so were able to easily cope with these busiest periods. The "observation rate" achieved for the survey period is described later in Chapter 5. The enumerators did tend to read the numberplates at a fast rate even in the low volume periods making it difficult to transcribe. Also, since the "CA" part of the plate was not read out, the occurrence of two or more similar marked vehicles would be confusing to the transcriber if not differentiated as the recording playback would repeat a long series of numbers. It was suggested that enumerators should announce the word "NEXT" in between reading plates to differentiate between "CA"–plated vehicles to eradicate this problem.

Figure 4.7.2 : Survey hourly volume count histogram (06:00 – 10:00)



4.8 Data Transcribing Processes and Problems

Once the enumerator/s had completed the morning's observation, it was necessary to immediately download the data off the MP3 player's in order to release memory capacity for the following survey day as each 4-hour survey session utilised approximately 156 to 160 Mb, leaving only 99Mb (or 39%) of spare capacity in the device.

The MP3 player recorded audio to a 22 050 Hz "wav" file format, which although is able to be played back on Windows Media Player (v 10.00.00.4036), it did not allow playback at variable speeds. The variable playback speed control allows the users to slow down playback rates by up to a half (x 0.5) or double the playback speed (x 2.0) of the original recording. The slowing down of playback rates proved immensely valuable in the transcribing of numberplates during busy periods and when identifying numberplates from problematic dialogue.

Unfortunately, the "wav" file, when directly downloaded from the MP3 player did not allow variable control and needed to be converted to a "A-Law", 8000 Hz, 64 kbps, mono "wav" file format which reduced the file size to between 113 and 118 Mb without compromising the audio quality. Goldwave v5.16 audio computer software (available off the internet) was used for this conversion process. The "A-Law" file format then allowed for variable speed playback.

The data for each day was entered into a separate MS-Excel spreadsheet. In order for accurate vehicle matches to be made with the data, it was necessary that the data be typed in uniformly into the spreadsheet and a template for this purpose was prepared for use by the data typist. An example of the datasheet is included in Appendix 1. The following criteria and/or protocol was maintained in the data transcribing process:

1. To save typing time, no prefix lettering was typed in for Cape Town registered cars. For example, "CA 234-223" was typed in the appropriate column as "234223". The full plate was required for all "non CA"

registered vehicles and special plated vehicles.

2. For Gauteng, Eastern Cape and Northern Cape, only the three numbers and province was required to be typed in, eg. CLD 095 GP was typed in as 095GP.

3. For special plates and government plates, the entire plate was to be typed in without spaces, eg. ZINZAN – WP would be typed in as ZINZAN-WP.

4. All comments made by the enumerator was to be made in the appropriate "comments" column. Comments would include reporting on towing vehicles, weather, police vehicles etc. as well as to serve as a communication from data typist to analyst eg. "Unsure if CFR or CBR".

5. In certain instances, it was not possible for the enumerator to read the entire plate due to obstruction by towbars, broken or dirty plates etc. In such cases, the partial plate would be recorded as far as possible and unidentified numbers be recorded as period points eg. CA 231…".

6. If a vehicle plate was missed, it was to be recorded as such in order to determine overall volumes and calculate the "observation" rate.

7. For vehicles with missing front plates, the type, make and colour of the vehicle was to be typed in the appropriate column for possible matching during data analysis.

8. If the plate recording was unclear, or a possibility of two options existed (eg. 48 or 408), then the best option was to be typed in the plate column and the second best option typed in the comment section with "unsure" typed in. This then flagged this data point for error checking later, which possibly required listening to the second backup recorded file to confirm the number.

In terms of time frames, the completed 25-day, 4-hour survey sample undertaken from 13 November to 15 December 2006 took 39 days to transcribe and was completed on 11 January 2007. After this followed an intensive error checking process whereby all the recordings were replayed and checked for errors. As part of this process, the time of observation was also captured. The true observed time periods were calculated "backwards" from the recording end time of the "wav" file as enumerators tended to closely watch the 10:00am end time. Enumerators were requested to start recording the moment they arrived on site with the result that starting times varied from 05:45 to 06:00 which they sometimes failed to mention. The error checking process was however time consuming and took 73 days from 18 December 2006 to 27 March 2007 to complete. Some of the errors observed during the transcribing process or in the transcribed data are as follows :

1. Problematic numeral combinations observed were the two numbers "8" with the "0" pronounced as "ou". For example "48" occasionally sounded like "408". As soon as this was observed, the enumerators were requested to pronounce "0" as "zero" to rule out confusion. This unfortunately did not become a habit.

2. The letters “M” and “N” was virtually impossible to differentiate eg. Sometimes “MD” would erroneously be recorded as “ND” representing a Durban numberplate.

3. The spelling of the special plates was occasionally not typed in consistently. Eg. “MR T–WP” would be typed in as “MISTAT-WP” elsewhere in the data record and this would need to be corrected.

4. Occasionally, the enumerators spoke too close to the MP3 microphone, creating “hiss”. Fortunately this occurred only once and was rectified. The MP3 microphone is extremely sensitive and it is possible to record without the need to hold the device in your hand. During the survey, the device was placed on the dashboard (drivers side) of the observers’ vehicle.

5. On certain occasions, enumerators found it difficult to decide if a kombi-type vehicle was in fact a MBT or not.

6. Heavy vehicles, particularly buses, produced interference in the recording when passing. Open windows worsened this problem which would then introduce additional interference on windy days.

7. Although it did not occur frequently, enumerators either laughed or yawned simultaneously during number plate reading making it difficult to discern numberplates.

8. During the error checking stage, it became time consuming to match typing errors such as “CB143-222” and “CD143-222” as the letters and numerals were not separated. Future attempts to enter such data should aim to separate the letter and number fields into separate spreadsheet columns.

The data transcribing was extremely time consuming and it would be recommended in future surveys that enumerators try and read out plates as slow as possible. This allows the recording to be played back at a faster rate and thus reduce the transcribing time requirements. Although this was mentioned to the enumerators after two weeks, it was neither practiced nor adhered to.

Due to inability to control the interference from heavy vehicles, door slamming, etc., it was decided to purchase a second MP3 player and use it as a recording backup. The device was placed at a different location in the car (dashboard – passenger side) which proved valuable in error checking.

5. DATA ANALYSIS

5.1 Data Characteristics

A total of 44 743 vehicle number plates (or trips) was observed for the raw dataset (viz. Dataset version 1) recorded for the duration of the five week survey period. Table 5.1.1 shows the modal distribution of all trips observed for dataset version 1.

Table 5.1.1 : Modal Distribution of raw data over 4-hour survey period (Dataset version 1)

Date	Day	Bus	Heavy	M/bike	MBT	Car	Σvol	Weather	Ave Σvol per day
13 Nov 2006	Mon	14	17	15	31	1714	1791	Sun	
14 Nov 2006	Tue	14	16	15	30	1688	1763	O/cast	
15 Nov 2006	Wed	12	21	10	36	1706	1785	O/cast	
16 Nov 2006	Thu	14	18	11	30	1742	1815	Sun	
17 Nov 2006	Fri	19	12	13	33	1776	1853	Sun	
20 Nov 2006	Mon	14	14	13	23	1734	1798	O/cast	
21 Nov 2006	Tue	14	14	11	29	1740	1808	Rain	
22 Nov 2006	Wed	13	15	17	36	1774	1855	Sun	1824
23 Nov 2006	Thu	13	17	14	28	1776	1848	Sun	
24 Nov 2006	Fri	13	18	13	28	1771	1843	Rain	
27 Nov 2006	Mon	15	8	15	32	1720	1790	Sun	
28 Nov 2006	Tue	13	12	15	31	1756	1827	Sun	
29 Nov 2006	Wed	13	8	13	31	1738	1803	Sun	
30 Nov 2006	Thu	15	12	17	25	1817	1886	Sun	
1 Dec 2006	Fri	12	16	14	36	1822	1900	Sun	
4 Dec 2006	*Mon*	*10*	*19*	*13*	*32*	*1678*	*1752*	*Sun*	
5 Dec 2006	*Tue*	*10*	*15*	*15*	*30*	*1664*	*1734*	*Sun*	
6 Dec 2006	*Wed*	*10*	*7*	*14*	*29*	*1668*	*1728*	*Sun*	
7 Dec 2006	*Thu*	*11*	*12*	*11*	*34*	*1660*	*1728*	*Rain*	
8 Dec 2006	*Fri*	*10*	*13*	*13*	*30*	*1703*	*1769*	*Sun*	*1738*
11 Dec 2006	*Mon*	*10*	*12*	*12*	*35*	*1663*	*1732*	*Sun*	
12 Dec 2006	*Tue*	*10*	*10*	*11*	*31*	*1671*	*1733*	*Sun*	
13 Dec 2006	*Wed*	*10*	*24*	*15*	*35*	*1632*	*1716*	*Sun*	
14 Dec 2006	*Thu*	*10*	*10*	*7*	*31*	*1647*	*1705*	*Rain*	
15 Dec 2006	*Fri*	*10*	*22*	*13*	*32*	*1704*	*1781*	*Sun*	
Total		309	362	330	778	42964	44743		
Total (%)		0.7%	0.8%	0.7%	1.7%	96.0%	100%		
Total (%) Census*		0.4%	n/a	1.3%	2.8%	95.5%	100%		

* Census 2001 data from Table 3.4 of this report. Figures in italics represent data within the holiday period

The modal distribution data shows a close match with those of the Census data. Figure 5.1.1 shows a graphical representation of the modal distribution of vehicles observed during the 4-hour day over the 5-week survey period.

Figure 5.1.1 : Modal distribution of observed vehicles (Dataset version 1)

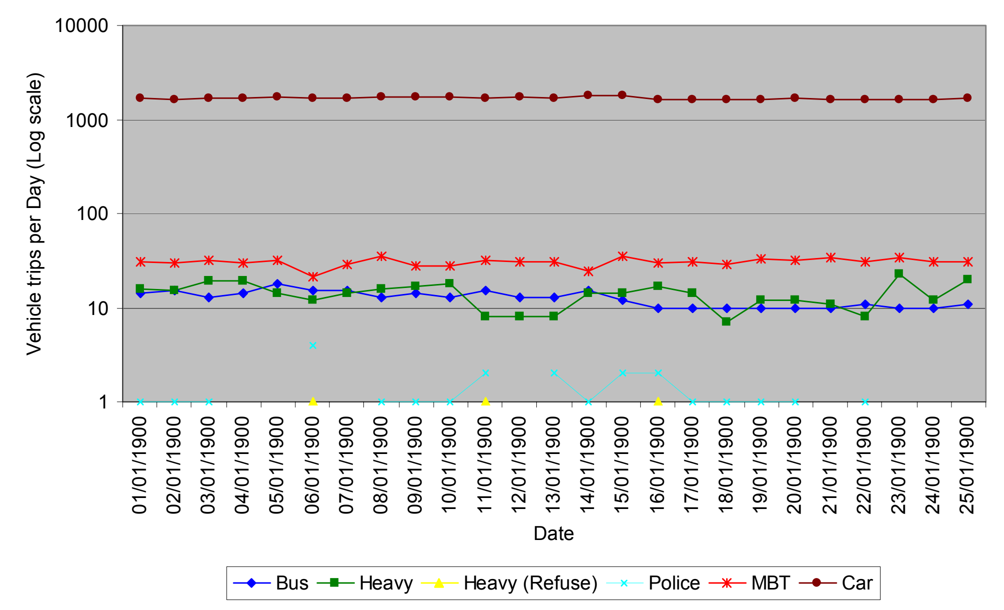
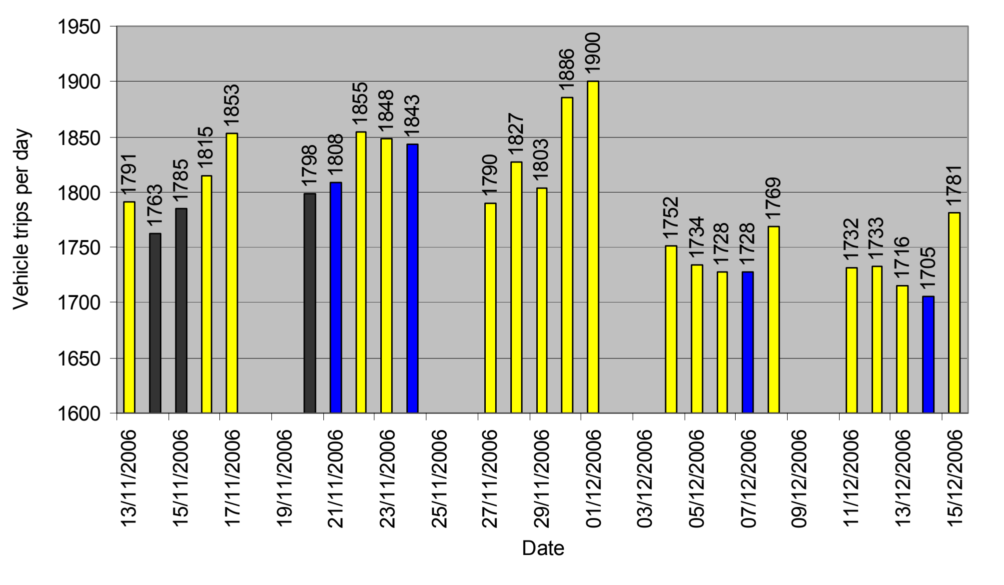


Table 5.1.1 shows a high overall 96% private car usage. As expected, there is an average 4.7% drop in average trip volumes from 1824 vehicles to 1738 vehicles per 4-hour period between the school and holiday period. Figure 5.1.2 shows a graphical representation of the total observed trips per 4-hour day of Dataset 1 over the 5-week survey period. Note that the yellow bars represent "sun" days, blue bars represent "rain" days and grey bars represent "overcast" days, providing a record of prevailing weather conditions experienced on the day.

Figure 5.1.2 : Total trips observed per day and daily weather pattern (Dataset version 1)

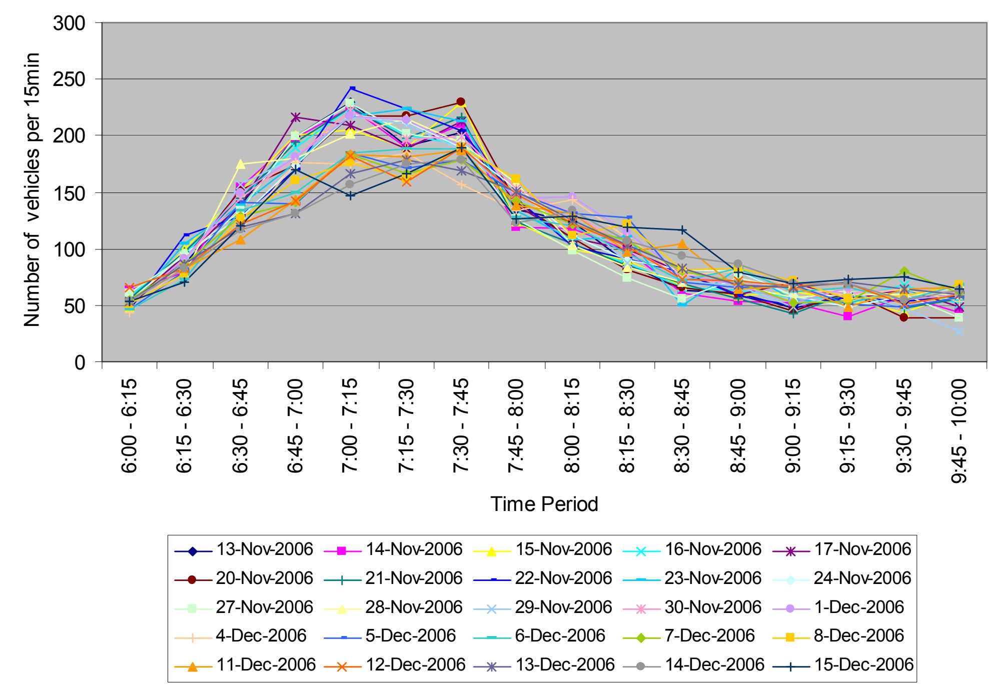


The graph shows the typical total daily flow patterns experienced over the four hour period and seems to indicate slightly higher volumes on Mondays and Fridays. The graph also shows associated weather conditions which did not seem to adversely affect the volume pattern significantly. Interestingly, rain days did not affect the volume pattern in the Summer Greens survey in any way and according to the graph, appears to have somewhat reduced volumes on these days. There is a general public perception that rain significantly impacts or increases traffic volumes and it is hypothesised here that the perceived "increase in traffic" is not an actual increase in vehicular trips but results from increased delays due to collisions, signal outages etc. typically experienced on such days which, with resulting congestion, make it appear to be higher volume days. This hypothesis would however need to be appropriately evaluated in further research.

Table 5.1.2 shows the total 15-minute trips observed over the four hour survey period. Note that from 17 November 2006, enumerators were instructed to commence with observations the moment they were in position and hence the reason for a small number of observations in the 05:45 to 06:00 time period.

Figure 5.1.3 shows a graphical representation of the total observed trips per 15-minute time period for Dataset 1 during the 4-hour day over the 5-week survey period.

Figure 5.1.3 : Total trips observed per 15-min period (Dataset version 1)



From the figure, the traffic volumes per 15 minute period fall within a consistent envelope. However, there is a split in the envelope and two separate patterns are evident in the 6:45 to 7:45 time period resulting from the close groupings of the school period counts that show higher volumes when compared to that of the holiday period showing a slightly lower volume pattern.

5.2 Shortcomings of Data and Data Refinement

Dataset version 1, consisting of 44 743 recorded observations is considered a raw (unrefined) dataset which required a further two refinement processes to arrive at the final Dataset version 3 with 43 579 recorded observations. Refinements made to Dataset version 1 to obtain version 2 data are now discussed:

Table 5.1.2 : Trips observed per 15-min time interval (Dataset version 1)

Date	Day	5:45-6:00	6:00-6:15	6:15-6:30	6:30-6:45	6:45-7:00	7:00-7:15	7:15-7:30	7:30-7:45	7:45-8:00	8:00-8:15	8:15-8:30	8:30-8:45	8:45-9:00	9:00-9:15	9:15-9:30	9:30-9:45	9:45-10:00	10:00-10:15	Total
13/11	Mon	1	55	87	139	199	230	191	203	135	124	87	63	61	47	57	54	58	n/a	**1791**
14/11	Tue	1	63	79	154	198	225	190	210	119	118	98	61	53	52	40	58	44	n/a	**1763**
15/11	Wed	n/a	49	99	151	200	205	190	229	124	99	90	67	58	62	55	44	62	1	**1785**
16/11	Thur	n/a	58	95	144	190	225	201	192	158	102	88	66	63	57	57	68	51	n/a	**1815**
17/11	Fri	20	51	93	138	216	209	188	213	139	109	100	79	60	71	55	64	48	n/a	**1853**
20/11	Mon	27	50	91	152	174	217	218	229	141	109	81	65	59	45	62	39	39	n/a	**1798**
21/11	Tue	33	56	97	144	194	225	198	216	124	104	85	69	56	43	61	47	56	n/a	**1808**
22/11	Wed	34	46	112	129	170	242	223	204	144	102	91	79	58	50	57	53	61	n/a	**1855**
23/11	Thur	15	49	105	139	176	217	223	213	134	108	110	50	83	55	52	63	55	1	**1848**
24/11	Fri	24	53	96	127	174	219	213	190	153	112	90	81	80	58	49	58	65	1	**1843**
27/11	Mon	26	61	94	133	199	228	202	196	126	98	74	56	74	63	62	59	39	n/a	**1790**
28/11	Tue	16	51	78	175	180	202	215	193	158	103	84	70	67	57	59	60	59	n/a	**1827**
29/11	Wed	22	53	87	157	181	217	210	187	147	132	87	72	67	48	62	47	27	n/a	**1803**
30/11	Thur	22	51	91	144	181	222	197	199	153	131	102	74	69	64	61	64	61	n/a	**1886**
1/12	Fri	24	51	91	149	181	217	214	191	144	146	114	78	68	52	66	55	59	n/a	**1900**
4/12	*Mon*	*28*	*44*	*87*	*116*	*176*	*175*	*185*	*157*	*134*	*143*	*109*	*76*	*80*	*67*	*58*	*64*	*53*	*n/a*	***1752***
5/12	*Tue*	*23*	*46*	*80*	*141*	*140*	*185*	*171*	*179*	*149*	*131*	*127*	*71*	*66*	*68*	*51*	*49*	*57*	*n/a*	***1734***
6/12	*Wed*	*19*	*46*	*73*	*133*	*149*	*185*	*188*	*188*	*127*	*120*	*96*	*72*	*82*	*62*	*65*	*55*	*68*	*n/a*	***1728***
7/12	*Thur*	*21*	*55*	*86*	*129*	*141*	*183*	*166*	*178*	*142*	*122*	*107*	*80*	*71*	*52*	*54*	*80*	*61*	*n/a*	***1728***
8/12	*Fri*	*14*	*51*	*78*	*126*	*160*	*176*	*162*	*190*	*161*	*112*	*121*	*81*	*83*	*72*	*56*	*58*	*68*	*n/a*	***1769***
11/12	*Mon*	*13*	*53*	*83*	*108*	*143*	*184*	*181*	*187*	*139*	*131*	*97*	*104*	*64*	*67*	*49*	*64*	*65*	*n/a*	***1732***
12/12	*Tue*	*27*	*66*	*83*	*121*	*142*	*182*	*159*	*189*	*148*	*123*	*102*	*73*	*72*	*67*	*69*	*51*	*59*	*n/a*	***1733***
13/12	*Wed*	*23*	*54*	*86*	*119*	*131*	*166*	*179*	*169*	*151*	*125*	*103*	*83*	*68*	*65*	*70*	*64*	*60*	*n/a*	***1716***
14/12	*Thur*	*13*	*53*	*82*	*116*	*131*	*157*	*175*	*178*	*123*	*134*	*107*	*94*	*86*	*69*	*69*	*55*	*63*	*n/a*	***1705***
15/12	*Fri*	*13*	*54*	*70*	*120*	*170*	*147*	*166*	*190*	*126*	*129*	*119*	*117*	*79*	*69*	*73*	*75*	*64*	*n/a*	***1781***
Totals		**459**	**1319**	**2203**	**3404**	**4296**	**5040**	**4805**	**4870**	**3499**	**2967**	**2469**	**1881**	**1727**	**1482**	**1469**	**1448**	**1402**	**3**	**44743**

Note : Figures in italics represent the school holiday period.

<u>Contractor vehicles :</u>

During the survey period, the Bosmansdam pedestrian bridge had recently been completed and a landscape contractor was adding the finishing touches to the landscaping around the structure. This resulted in eight repeated sightings of contractor vehicles during the first three weeks.

<u>Personal vehicle :</u>

On two occasions due to unannounced visits, the vehicle number plate of the author was erroneously transcribed into the data, which had to be removed from the Dataset version 1 record.

<u>Duplicate vehicle :</u>

On one occasion, a duplication of a number plate was erroneously transcribed into the version 1 dataset which was also removed.

Table 5.2.1 shows a summary of the makeup of Dataset version 1 and the occurrences of the Contractor, Personal and Duplicate plates eliminated from Dataset version 1.

Table 5.2.1 : Dataset Version 1 makeup

Date	Day	Contractor Plates	Personal Plates	Duplicate Plates	ΣDataset version 1 trips	ΣDataset version 2 trips
13 Nov 2006	Mon	-	-	-	**1791**	1791
14 Nov 2006	Tue	-	-	-	**1763**	1763
15 Nov 2006	Wed	1	-	-	**1785**	1784
16 Nov 2006	Thu	1	-	-	**1815**	1814
17 Nov 2006	Fri	1	-	-	**1853**	1852
20 Nov 2006	Mon	-	-	-	**1798**	1798
21 Nov 2006	Tue	-	1	-	**1808**	1807
22 Nov 2006	Wed	-	-	-	**1855**	1855
23 Nov 2006	Thu	-	-	-	**1848**	1848
24 Nov 2006	Fri	-	-	-	**1843**	1843
27 Nov 2006	Mon	1	-	-	**1790**	1789
28 Nov 2006	Tue	3	-	1	**1827**	1823
29 Nov 2006	Wed	1	-	-	**1803**	1802
30 Nov 2006	Thu	-	1	-	**1886**	1885
1 Dec 2006	Fri	-	-	-	**1900**	1900
4 Dec 2006	*Mon*	-	-	-	***1752***	*1752*
5 Dec 2006	*Tue*	-	-	-	***1734***	*1734*
6 Dec 2006	*Wed*	-	-	-	***1728***	*1728*
7 Dec 2006	*Thu*	-	-	-	***1728***	*1728*
8 Dec 2006	*Fri*	-	-	-	***1769***	*1769*
11 Dec 2006	*Mon*	-	-	-	***1732***	*1732*
12 Dec 2006	*Tue*	-	-	-	***1733***	*1733*
13 Dec 2006	*Wed*	-	-	-	***1716***	*1716*
14 Dec 2006	*Thu*	-	-	-	***1705***	*1705*
15 Dec 2006	*Fri*	-	-	-	***1781***	*1781*
Total		**8**	**2**	**1**	**44732**	**44743**
Total (%)		**0.018%**	**0.004%**	**0.002%**	**99.975%**	**100.0%**

The removal of the eleven records from Dataset version 1 resulted in a version 2 dataset. This dataset however required further refinement for the following reasons :

Partial plate:

Unfortunately, a single data record had to be removed as an inconclusive partial plate was recorded in the dataset. Several partial plates were observed in the survey but these could be matched with other observations based on the amount of information provided.

Missed plates :

A total of three vehicle numberplates were not observed (missed) for unknown reasons.

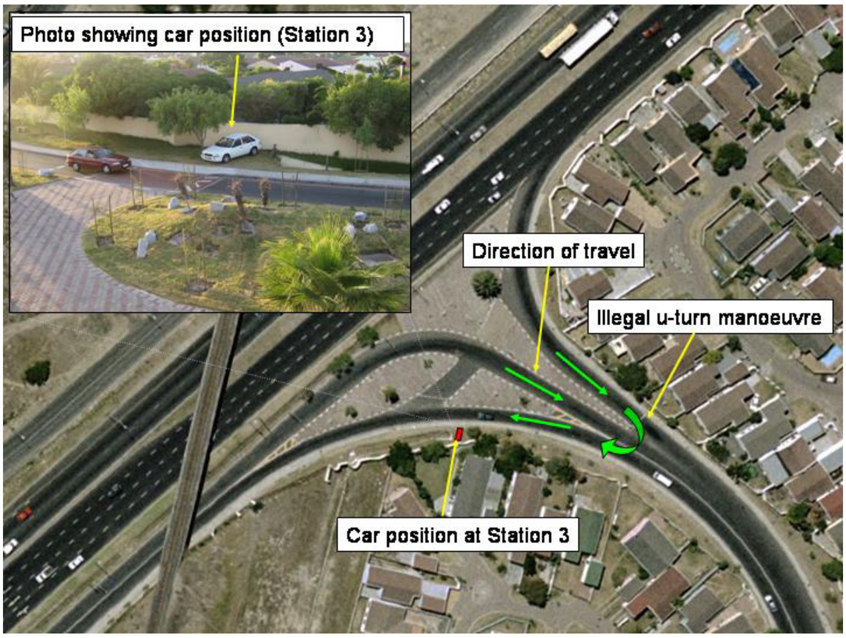
Missing plates :

A large proportion of vehicles were observed without a front numberplate and so could not be used in the analysis process. It was originally thought to identify such vehicles by car model, type and colour, but variations and omissions of any of these three criteria made data matching difficult and introduced guesswork. A total of 808 vehicle trips (or 1.8%) of the total Dataset version 2 sample were trips made with vehicles without front numberplates. These vehicles were thus removed from the dataset.

U-turners :

One of the concerns observed during the survey, was the occurrence of motorists undertaking illegal “u-turn” manoeuvres at the entrance to Summer Greens (refer to Figure 5.2.1) despite clear road signage indicating this restriction.

Figure 5.2.1 : Location of illegal “U-turn” manoeuvre



Although this was observed for 279 trips (or 0.624% of the sample) and noted as a concern, it was decided not to remove these vehicles from the dataset. It is assumed that motorists would perform these u-turn manoeuvres to avoid the traffic signals and congestion at the Bosmansdam Road/ Century Avenue intersection en route to the Century City shopping centre and/or office complex.

Wrong direction :

A further vehicle had to be removed from the dataset as the numberplate could not be observed as the motorist exited the suburb using the incoming lane.

Motorbikes:

Whilst motorbike numberplates were not specifically recorded, the occurrence of this mode was recorded for modal distribution purposes. As such, the data could not be used for travel behaviour analysis and was removed.

Table 5.2.2 shows a summary of the makeup of Dataset version 2 and the occurrences of Partial, Missed, No plates and U-turn plates.

Table 5.2.2 : Dataset Version 2 makeup

Date	Day	Partial Plate*	Missed Plate*	No Plate*	No Plate & U-turn*	Wrong Side	U-turn Plates	Motorbikes + Captured Plates	ΣDataset version 2 trips
13 Nov 2006	Mon			31	1		11	1748	**1791**
14 Nov 2006	Tue			37			5	1721	**1763**
15 Nov 2006	Wed			34			7	1743	**1784**
16 Nov 2006	Thu			37			8	1769	**1814**
17 Nov 2006	Fri			35	2		14	1801	**1852**
20 Nov 2006	Mon			35			12	1751	**1798**
21 Nov 2006	Tue		1	35			16	1755	**1807**
22 Nov 2006	Wed		1	33	1		16	1804	**1855**
23 Nov 2006	Thu		1	27			14	1806	**1848**
24 Nov 2006	Fri			31		1	9	1802	**1843**
27 Nov 2006	Mon			29			4	1756	**1789**
28 Nov 2006	Tue			39			8	1776	**1823**
29 Nov 2006	Wed			34			13	1755	**1802**
30 Nov 2006	Thu			37			6	1842	**1885**
1 Dec 2006	Fri			38			17	1845	**1900**
4 Dec 2006	*Mon*			*25*			*11*	*1716*	***1752***
5 Dec 2006	*Tue*			*30*			*4*	*1700*	***1734***
6 Dec 2006	*Wed*			*36*			*6*	*1686*	***1728***
7 Dec 2006	*Thu*			*26*	*1*		*15*	*1686*	***1728***
8 Dec 2006	*Fri*			*29*			*17*	*1723*	***1769***
11 Dec 2006	*Mon*			*31*			*5*	*1696*	***1732***
12 Dec 2006	*Tue*			*31*			*8*	*1694*	***1733***
13 Dec 2006	*Wed*	*1*		*31*	*1*		*8*	*1675*	***1716***
14 Dec 2006	*Thu*			*28*			*7*	*1670*	***1705***
15 Dec 2006	*Fri*			*29*	*3*		*29*	*1720*	***1781***
Total		**1**	**3**	**808**	**9**	**1**	**270**	**43640**	**44732**
Total (%)		**0.002%**	**0.007%**	**1.806%**	**0.020%**	**0.002%**	**0.604%**	**97.559%**	**100.0%**

From this table, it can be seen that the average percentage of unreadable plates is 1.835% constituting the plate classifications indicated with an asterisk (*). This compares well with the 1 to 3.3% of unreadable plates recorded by Cherret and McDonald (2002) in their four surveys conducted in Southampton (United Kingdom). The data record fields identified with an asterisk, including the vehicle driving on the wrong side, was deleted from the version 2 dataset.

Table 5.2.3 shows the total sample of recorded motorbikes, including those motorcyclists who chose to execute u-turns.

Table 5.2.3 : Motorbike record of Dataset Version 2

Date	Day	U-turn Plates	Motorbikes	Total
13 Nov 2006	Mon	-	15	**15**
14 Nov 2006	Tue	-	15	**15**
15 Nov 2006	Wed	-	10	**10**
16 Nov 2006	Thu	-	11	**11**
17 Nov 2006	Fri	-	13	**13**
20 Nov 2006	Mon	-	13	**13**
21 Nov 2006	Tue	-	11	**11**
22 Nov 2006	Wed	-	17	**17**
23 Nov 2006	Thu	-	15	**15**
24 Nov 2006	Fri	-	13	**13**
27 Nov 2006	Mon	-	15	**15**
28 Nov 2006	Tue	-	15	**15**
29 Nov 2006	Wed	-	13	**13**
30 Nov 2006	Thu	1	16	**17**
1 Dec 2006	Fri	1	13	**14**
4 Dec 2006	*Mon*	*-*	*13*	***13***
5 Dec 2006	*Tue*	*1*	*14*	***15***
6 Dec 2006	*Wed*	*1*	*13*	***14***
7 Dec 2006	*Thu*	*2*	*9*	***11***
8 Dec 2006	*Fri*	*2*	*11*	***13***
11 Dec 2006	*Mon*	*-*	*12*	***12***
12 Dec 2006	*Tue*	*1*	*10*	***11***
13 Dec 2006	*Wed*	*1*	*14*	***15***
14 Dec 2006	*Thu*	*1*	*6*	***7***
15 Dec 2006	*Fri*	*1*	*12*	***13***
Total		**12**	**319**	**331**
Total (%)		**3.625%**	**96.375%**	**100.0%**

A total of 331 motorbike data records was thus removed from the version 2 dataset.

Table 5.2.4 summarises the data refinement process from Dataset version1 to Dataset version 3.

Table 5.2.4 : Summary of Refinement process (Version 1 to Version 3)		
Dataset version / Action	**Records**	**Percentage**
Raw data records (Version 1)	44743	100%
minus 2 x Personal vehicle	2	-
minus 8 x contractor vehicle	8	-
minus 1 x duplicate plate	1	-
Dataset Version 2	44732	99.98%
minus 3 x missed vehicles	3	-
minus 808 x no plates	808	-
minus 9 x no plates/u-turners	9	-
minus 331 x motorbikes	331	-
minus 1 x incomplete plate	1	-
minus 1 x vehicle on wrong side	1	-
Dataset Version 3	43579	97.4%

The table shows that a total of 2.6% of the collected data (or 1164 data records) is unusable. This two step refinement process resulted in Dataset version 3 with a total of 43 579 recorded trips which is the basis of all further analysis in this thesis report.

Table 5.2.5 shows the final version 3 dataset used in further analysis in this thesis report.

From the table, there is an average difference of 80 vehicle trips between the average 4-hour observed trip volume counted during the school period versus the holiday period. This constitutes an average 4.5% drop in trip volume over the daily 4-hour survey period.

<u>Duplicate Plates :</u>

It was also found that different vehicles had duplicate (identical) plates. Table 5.2.6 shows the distribution of Dataset version 3 into individual vehicle counts and trips.

Table 5.2.6 : Total vehicles and trips (Dataset version 3)							
Description	**Bus**	**Heavy**	**Heavy (Refuse)**	**Police**	**MBT**	**Car**	**Total**
Total individual vehicles	119	142	1	2	110	5309	**5683**
Total trips	314	348	3	24	765	42125	**43579**

Following the refinement process, it was found that there were 5677 individual vehicles in the version 3 dataset and not 5683 as the table above indicates. Thus there was an unexplained shortfall of 6 vehicles. However, after careful scrutiny of the data, it was found that there were six duplicate plates accounting for the shortfall.

Table 5.2.5 : Dataset Version 3 makeup and Characteristics

Date	Day	U-turn Plates	Captured Plates	Total No Trips (Dataset)	No. Vehicles per day	No. veh doing > 1 trip	Trips/veh	Ave Trips/veh	Ave No. veh doing > 1 trip	Total No. Trips/week	Total No. Veh/week	Total No. Trips/Veh	Ave Trips
13 Nov 2006	Mon	11	1733	1744	1601	143	1.09						
14 Nov 2006	Tue	5	1706	1711	1587	124	1.08						
15 Nov 2006	Wed	7	1733	1740	1602	138	1.09			8763	8063	1.09	
16 Nov 2006	Thu	8	1758	1766	1613	153	1.09						
17 Nov 2006	Fri	14	1788	1802	1660	142	1.09						
20 Nov 2006	Mon	12	1738	1750	1608	142	1.09						
21 Nov 2006	Tue	16	1744	1760	1636	124	1.08						
22 Nov 2006	Wed	16	1787	1803	1671	132	1.08	1.084	137	8916	8246	1.08	1775
23 Nov 2006	Thu	14	1791	1805	1671	134	1.08						
24 Nov 2006	Fri	9	1789	1798	1660	138	1.08						
27 Nov 2006	Mon	4	1741	1745	1602	143	1.09						
28 Nov 2006	Tue	8	1761	1769	1653	116	1.07						
29 Nov 2006	Wed	13	1742	1755	1639	116	1.07			8948	8261	1.08	
30 Nov 2006	Thu	5	1826	1831	1678	153	1.09						
1 Dec 2006	Fri	16	1832	1848	1689	159	1.09						
4 Dec 2006	*Mon*	*11*	*1703*	*1714*	*1603*	*111*	*1.07*						
5 Dec 2006	*Tue*	*3*	*1686*	*1689*	*1576*	*113*	*1.07*						
6 Dec 2006	*Wed*	*5*	*1673*	*1678*	*1566*	*112*	*1.07*			*8498*	*7920*	*1.07*	
7 Dec 2006	*Thu*	*13*	*1677*	*1690*	*1579*	*111*	*1.07*						
8 Dec 2006	*Fri*	*15*	*1712*	*1727*	*1596*	*131*	*1.08*						
11 Dec 2006	*Mon*	*5*	*1684*	*1689*	*1580*	*109*	*1.07*	*1.072*	*113*				*1695*
12 Dec 2006	*Tue*	*7*	*1684*	*1691*	*1571*	*120*	*1.08*						
13 Dec 2006	*Wed*	*7*	*1661*	*1668*	*1571*	*97*	*1.06*			*8454*	*7900*	*1.07*	
14 Dec 2006	*Thu*	*6*	*1664*	*1670*	*1561*	*109*	*1.07*						
15 Dec 2006	*Fri*	*28*	*1708*	*1736*	*1617*	*119*	*1.07*						
Total		**258**	**43321**	**43579**		**43579**							
Total (%)		**0.592%**	**99.408%**	**100%**									

Table 5.2.7 shows the occurrence and modes of the duplicate plates.

Table 5.2.7 : Duplicate Plate Occurrence and Mode		
Number Plate	**Duplicate plate #1**	**Duplicate plate #2**
CA 287799	1 x Bus	1 x Car
CA 299935	1 x Heavy	21 x Car
CA 380288	1 x Heavy	1 x Car
CA 598609	1 x Taxi	8 x Car
076GP	1 x Heavy	1 x Car
269GP	1 x Bus	12 x Heavy

The table shows that for numberplate "CA 299935", there was one heavy vehicle which was matched with twenty one private car records with the same numberplate details. Duplicate plates could only be detected if this occurred across modes as duplicate plates within modes would not be detected due to the survey technique used. Unfortunately, this shortcoming in the data was identified only very late in the study and was thus ignored due to it's insignificant value (0.11% of the 5683 individual vehicles).

Table 5.2.8 provides a summary of other observed activities which may influence the data analysis:

Table 5.2.8 : Observations made during the survey period and possible implications to the analysis		
Date	**Observation**	**Possible impact on analysis**
15 Nov 2006	Last day of exams for most Matrics (History).	Uncertain
20 Nov 2006	Car with flat tyre on Summer Greens Drive	Delays
22 Nov 2006	Car broken down on Summer Greens Drive at the location where illegal u-turn manoeuvres are made. Also last day of Matric exams.	Delays and fewer u-turn vehicles
24 Nov 2006	Heavy congestion on the N1 and N7 freeways.	Uncertain
28 Nov 2006	Last exam for Primary school pupils	Uncertain
29 Nov 2006	Athletics Interhouse for local primary schools	Uncertain
1 Dec 2006	Last day of school	Volume drop
4 Dec 2006	First day of school holidays	Volume drop
15 Dec 2006	Accident on Bosmansdam Road, west of the Left-in access to Summer Greens.	More u-turn vehicles likely

5.3 Number Plate Details

The numberplate prefix lettering system in use in South Africa gives an indication of where the vehicle was registered and typically identifies the residential area of the owner. Table 5.3.1 shows the rank ordered distribution of the numberplate locations observed.

Table 5.3.1 : Distribution of Number Plates					
Prefix	**Location**	**Percentage of vehicles**	**Prefix**	**Location**	**Percentage of vehicles**
CA	Cape Town	71.34%	Government	-	1.67%
CY	Bellville	11.72%	Special -WP	-	1.32%
Other Plates	-	5.74%	CFR	Kraaifontein	1.23%
GP	Gauteng	2.99%	EC	Eastern Cape	1.23%
CF	Kraaifontein	2.76%		Total	100%

Summer Greens falls within the "CA" number prefix jurisdiction and the majority of the vehicles observed, up to 71.3% had such plates. Just under 12% of the observed plates originated from the neighbouring registration area of Bellville ("CY"). A relatively high proportion (3% of all observed vehicles) were Gauteng numberplates.

5.4 Modal Trip Charateristics

The first analysis conducted on the final dataset (viz. Dataset version 3) was to determine the overall modal split and whether the modal distribution differed during the two surveyed school and holiday periods. Table 5.4.1 shows the Modal distribution of the final dataset.

Table 5.4.1 : Modal Distribution of Dataset version 3 (No. of Trips per 4-hour period)

Date	Day	Bus	Heavy	Heavy (Refuse)	Police	MBT	Car	Total	Ave veh/day	St Dev
13/11	Mon	14	16	-	1	31	1682	1744	1775	37.8
14/11	Tue	15	15	-	1	30	1650	1711		
15/11	Wed	13	19	-	1	32	1675	1740		
16/11	Thur	14	19	-	-	30	1703	1766		
17/11	Fri	18	14	-	-	32	1738	1802		
20/11	Mon	15	12	1	4	21	1697	1750		
21/11	Tue	15	14	-	-	29	1702	1760		
22/11	Wed	13	16	-	1	35	1738	1803		
23/11	Thur	14	17	-	1	28	1745	1805		
24/11	Fri	13	18	-	1	28	1738	1798		
27/11	Mon	15	8	1	2	32	1687	1745		
28/11	Tue	13	8	-		31	1717	1769		
29/11	Wed	13	8	-	2	31	1701	1755		
30/11	Thur	15	14	-	1	24	1777	1831		
1/12	Fri	12	14	-	2	35	1785	1848		
4/12	*Mon*	*10*	*17*	*1*	*2*	*30*	*1654*	*1714*	*1695*	*23.1*
5/12	*Tue*	*10*	*14*	-	*1*	*31*	*1633*	*1689*		
6/12	*Wed*	*10*	*7*	-	*1*	*29*	*1631*	*1678*		
7/12	*Thur*	*10*	*12*	-	*1*	*33*	*1634*	*1690*		
8/12	*Fri*	*10*	*12*	-	*1*	*32*	*1672*	*1727*		
11/12	*Mon*	*10*	*11*	-	-	*34*	*1634*	*1689*		
12/12	*Tue*	*11*	*8*	-	*1*	*31*	*1640*	*1691*		
13/12	*Wed*	*10*	*23*	-	-	*34*	*1601*	*1668*		
14/12	*Thur*	*10*	*12*	-	-	*31*	*1617*	*1670*		
15/12	*Fri*	*11*	*20*	-	-	*31*	*1674*	*1736*		
Total		314	348	3	24	765	42125	43579		
Total (%)		0.7%	0.8%	0.0%	0.1%	1.8%	96.7%	100.0%		

Figure 5.4.1 shows a time series plot of all the modal trips combined and figures 5.4.2 and 5.4.3 show the separate trip modal distribution for private cars and all other vehicles respectively for the daily 4-hour survey period

Figure 5.4.1 : Time series plot for all vehicle modes (4-hour period)

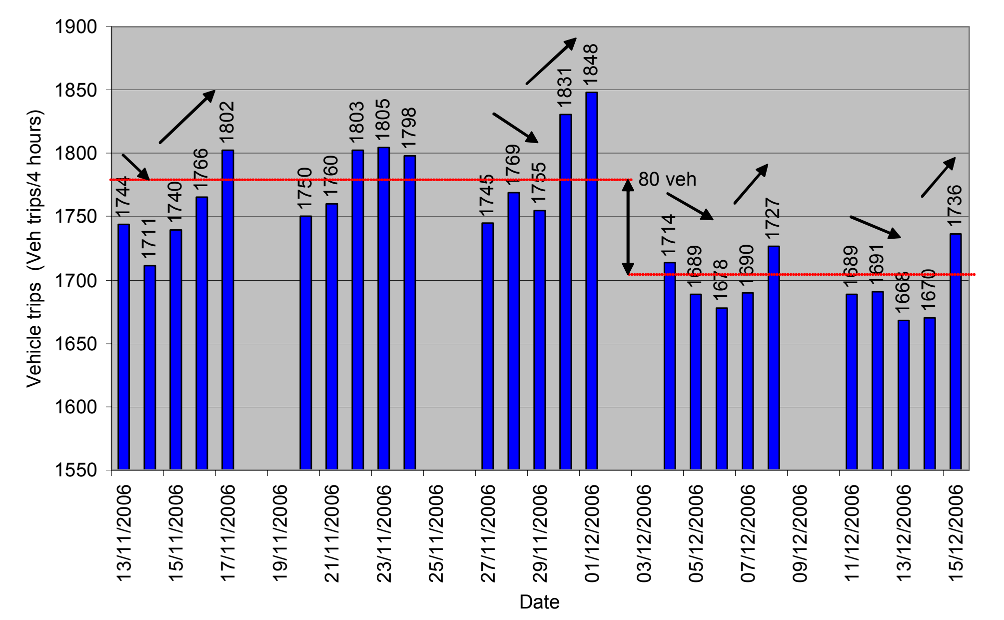
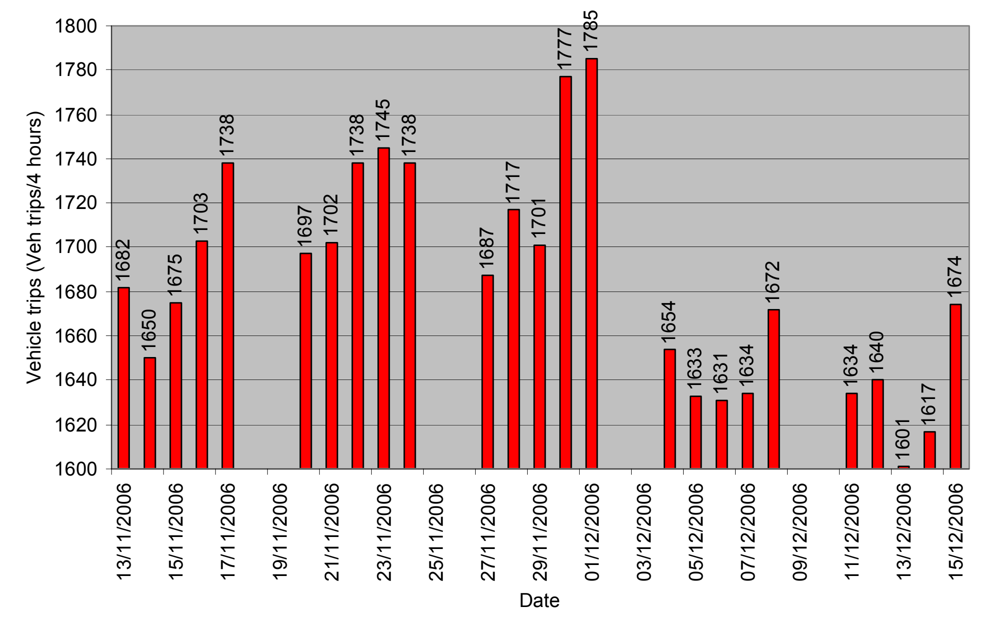


Figure 5.4.2 : Time series plot for Private car mode only (4-hour period)



From Figure 5.4.1, the decrease in the 4-hour trip volumes is easily identifiable with an average drop of 80 vehicles or 4.5% between the school and holiday traffic volumes. Unfortunately, it was not possible to identify trip purpose in the dataset but it can be assumed that there are a high proportion of commuters using the private car mode. Except for the second week of the survey, there is a tendency for volumes to drop from Monday to Wednesday and “bounce back” over Thursday and Friday which supports similar findings by Zhou and Golledge (2000).

Figure 5.4.3 : Time series plot for non-Private car mode (4-hour period)

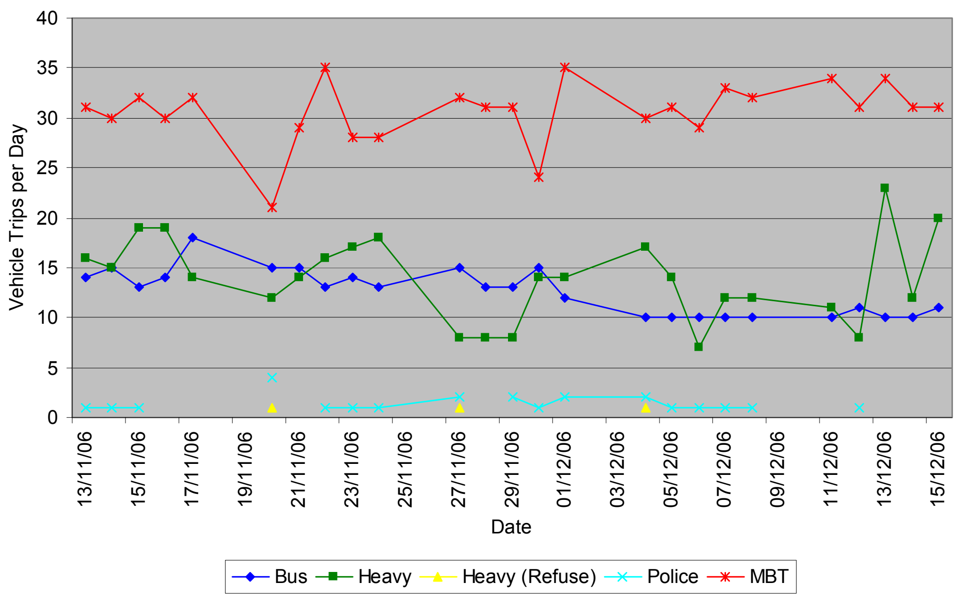


Figure 5.4.2 shows that the private car mode graph almost exactly follows the overall data graph of Figure 5.4.1 by virtue of the high proportion of this mode in the data, but with a greater drop over the holiday period. Figure 5.4.3 shows that daily MBT trips account for approximately twice the number of bus trips and with the heavy vehicle trips almost similar to the daily bus trips.

5.5 Comparison of School versus Holiday Period Travel Behaviour

5.5.1 Traffic Volumes

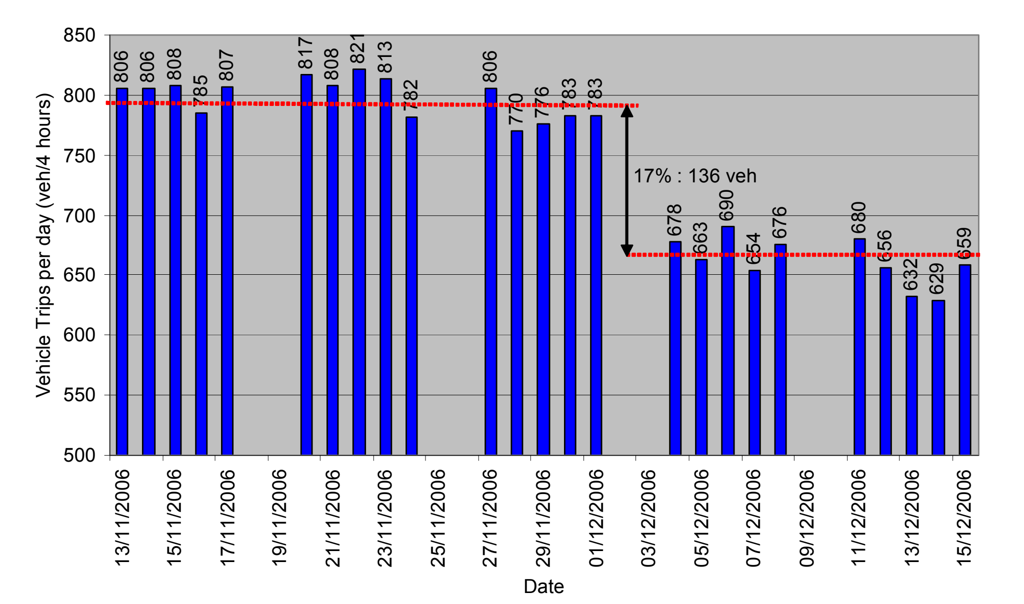
In the previous section, Figure 5.4.2 showed a significant decline in the private car usage over the holiday period whilst Figure 5.4.3 shows that the total trip volumes of the other modes (except buses) do not drop significantly over the holiday period. In fact, there is an increase in minibus-taxi activity over the holiday period. An ANOVA test conducted to test the differences between the daily volumes indicated a statistically significant difference between the school and holiday period volumes at the 5% level of significance. Details of the ANOVA analysis are included in Appendix 3.1. The ANOVA test revealed insignificant differences between the weekly volumes within the school period (first three weeks) and between the last two weeks in the holiday period. Pendyala (2003) also reported insignificant volume differences when comparing across reported "normal" days.

It was decided to analyse the peak hour (06:45 – 07:45) to determine whether the travel characteristics determined above for the entire 4-hour period changes for the peak hour. Table 5.5.1 shows the volume distribution over the survey period for the private car mode only during the peak hour.

Table 5.5.1 : Peak hour volume distribution (Private car only)				
Date	**Day**	**Peak hour car Volumes**	**Ave Daily Pk hour volume**	**Standard Deviation**
13 Nov 2006	Mon	806	798	16.3
14 Nov 2006	Tue	806		
15 Nov 2006	Wed	808		
16 Nov 2006	Thu	785		
17 Nov 2006	Fri	807		
20 Nov 2006	Mon	817		
21 Nov 2006	Tue	808		
22 Nov 2006	Wed	821		
23 Nov 2006	Thu	813		
24 Nov 2006	Fri	782		
27 Nov 2006	Mon	806		
28 Nov 2006	Tue	770		
29 Nov 2006	Wed	776		
30 Nov 2006	Thu	783		
1 Dec 2006	Fri	783		
4 Dec 2006	*Mon*	678	662	20.2
5 Dec 2006	*Tue*	663		
6 Dec 2006	*Wed*	690		
7 Dec 2006	*Thu*	654		
8 Dec 2006	*Fri*	676		
11 Dec 2006	*Mon*	680		
12 Dec 2006	*Tue*	656		
13 Dec 2006	*Wed*	632		
14 Dec 2006	*Thu*	629		
15 Dec 2006	*Fri*	659		

The average difference between the observed school and holiday peak hour volume is 136 vehicles representing a 17% drop in peak hour volume. Also noticeable is the smaller standard deviation, particularly for the school period, when compared to the 4-hour analysis (refer to Table 5.4.1). Figure 5.5.1 shows the time series plot of the peak hour volumes for the five week survey period.

Figure 5.5.1 : Time series plot for Private car mode (Peak hour period)



From the private car time series plot, there is no evidence of the Zhou and Golledge (2000) volume “bounce back” phenomena as observed with the 4-hour time series plot. As already indicated, the average difference between school and holiday peak hour volumes is 17% which is greater than the 4.5% difference recorded for the full 4-hour time period.

An ANOVA test conducted on the daily peak hour trip volumes revealed that the 17% difference is statistically significant at the 5% level of significance (refer to Appendix 3.2 for details of the calculation). By comparison, a study conducted by Lesley (2002) in West Wallasey (UK), revealed a drop from 1212 to 659 vehicles per hour during the holiday period. This represents an even more significant 45.6% drop in volume over the peak hour. However, it is argued that this percentage is heavily dependant on the location of the count. The closer to the school the count is executed, the greater the percentage difference will be.

The ANOVA results revealed significant trip volume differences between weeks 1, 2 and 3 with weeks 4 and 5 for the peak hour period as mentioned above. However, significant differences between weeks 2 and 3 as well as between weeks 4 and 5 was observed statistically, which did not occur for the 4-hour survey period analysis. In other words the week immediately before school holidays (week 3) and the week immediately thereafter (week 4) show statistically different average peak hour volumes for private cars and can be attributed to motorists adjusting their departure times during these two weeks.

5.5.2 Vehicular trip rates

A comparison between the number of individual vehicles and the total number of trips was made. Table 5.5.2 shows the average trips per vehicle per mode per day for the entire survey period.

Table 5.5.2 : Average Trips made per Vehicular Mode

Date	Day	Bus	Heavy	Heavy (Refuse)	Police	MBT	Car
13 Nov 2006	Mon	1.4	1.0		1.0	1.7	1.1
14 Nov 2006	Tue	1.4	1.0		1.0	1.4	1.1
15 Nov 2006	Wed	1.3	1.0		1.0	1.4	1.1
16 Nov 2006	Thu	1.4	1.0			1.6	1.1
17 Nov 2006	Fri	1.3	1.0			1.5	1.1
20 Nov 2006	Mon	1.3	1.0	1.0	4.0	1.9	1.1
21 Nov 2006	Tue	1.3	1.2			1.6	1.1
22 Nov 2006	Wed	1.2	1.0		1.0	1.8	1.1
23 Nov 2006	Thu	1.1	1.1		1.0	1.4	1.1
24 Nov 2006	Fri	1.2	1.1		1.0	1.6	1.1
27 Nov 2006	Mon	1.2	1.0	1.0	2.0	1.6	1.1
28 Nov 2006	Tue	1.2	1.1			1.6	1.1
29 Nov 2006	Wed	1.2	1.1		2.0	1.3	1.1
30 Nov 2006	Thu	1.2	1.1		1.0	1.4	1.1
1 Dec 2006	Fri	1.2	1.0		2.0	1.7	1.1
4 Dec 2006	*Mon*	*1.1*	*1.1*	*1.0*	*2.0*	*1.4*	*1.1*
5 Dec 2006	*Tue*	*1.1*	*1.0*		*1.0*	*1.7*	*1.1*

Table 5.5.2 : Average Trips made per Vehicular Mode							
Date	**Day**	**Bus**	**Heavy**	**Heavy (Refuse)**	**Police**	**MBT**	**Car**
6 Dec 2006	*Wed*	*1.1*	*1.2*		*1.0*	*1.5*	*1.1*
7 Dec 2006	*Thu*	*1.1*	*1.0*		*1.0*	*1.6*	*1.1*
8 Dec 2006	*Fri*	*1.1*	*1.0*		*1.0*	*1.5*	*1.1*
11 Dec 2006	*Mon*	*1.1*	*1.0*			*1.5*	*1.1*
12 Dec 2006	*Tue*	*1.1*	*1.0*		*1.0*	*1.6*	*1.1*
13 Dec 2006	*Wed*	*1.1*	*1.1*			*1.5*	*1.1*
14 Dec 2006	*Thu*	*1.1*	*1.2*			*1.7*	*1.1*
15 Dec 2006	*Fri*	*1.1*	*1.1*			*1.4*	*1.1*
Ave (Overall Period)		1.2	1.1	1.0	1.4	1.6	1.1
Ave (School)		1.2	1.0	1.0	1.5	1.6	1.1
Ave (Holiday)		*1.1*	*1.1*	*1.0*	*1.2*	*1.5*	*1.1*

The table shows a higher trip rate for public transport vehicles as expected. Not much difference in average trips rates can be observed between the school and holiday period apart from the police vehicle mode with a slightly lower trip rate during the holiday period.

5.5.3 Day of the Week Trip Volume Variation

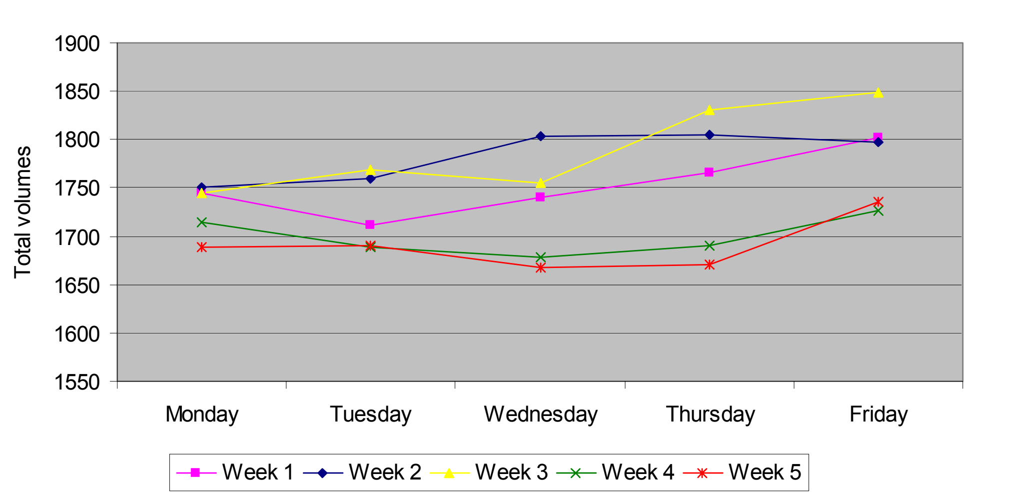
Research by Jordaan and van As (1991, pg 3-2 and 4-2), found that Fridays are similar to other weekdays except that the Friday afternoon has lower peak hour volumes with an earlier peak start time. However their research also mentioned that the Friday ADT can be as much as 15% more than the average Monday to Thursday ADT. This was based on the research of 45 datasets obtained from 12 counting stations in the Johannesburg and Port Elizabeth municipalities.

Table 5.5.3 shows the Day of the week trip volume variation over the five week survey period.

Table 5.5.3 : Day of the Week Trip Volume variation across the 5-week survey period											
Day	**Week**					**Overall**		**School**		**Holiday**	
	1	2	3	*4*	*5*	Total	Total (%)	Ave Total	Total (%)	Ave Total	Total (%)
Mon	1744	1750	1745	*1714*	*1689*	8642	19.8%	1746	19.7%	1702	20.1%
Tues	1711	1760	1769	*1689*	*1691*	8620	19.8%	1747	19.7%	1690	19.9%
Wed	1740	1803	1755	*1678*	*1668*	8644	19.8%	1766	19.9%	1673	19.7%
Thus	1766	1805	1831	*1690*	*1670*	8762	20.1%	1801	20.3%	1680	19.8%
Fri	1802	1798	1848	*1727*	*1736*	8911	20.4%	1816	20.5%	1732	20.4%
Total	**8763**	**8916**	**8948**	***8498***	***8454***	**43579**	**100.0%**	**8876**	**100.0%**	**8476**	**100.0%**
Total (%)	20.1%	20.5%	20.5%	*19.5%*	*19.4%*						

Figure 5.5.2 graphically shows the average Day of the week trip volume over the 5-week survey period for all data records in Dataset version 3.

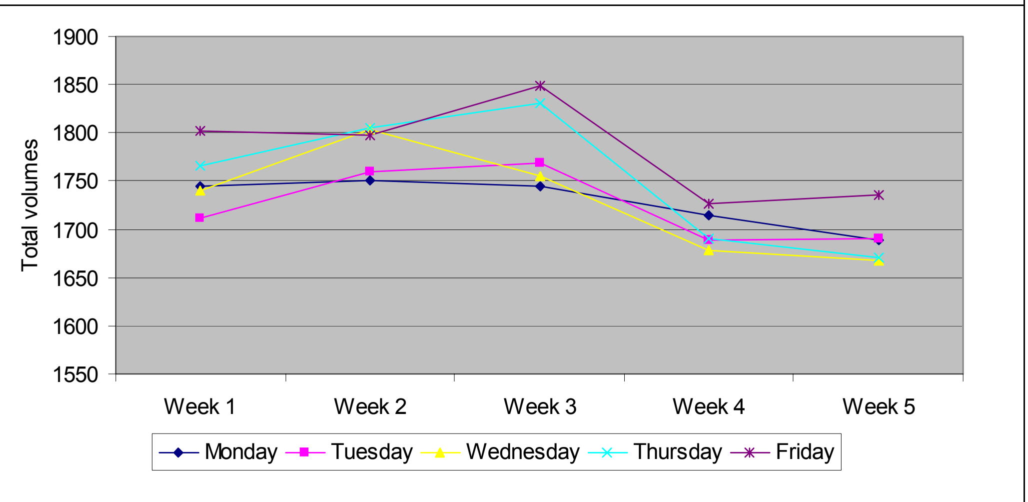
Figure 5.5.2 : Average Day of the week trip volume variation across weeks



The previous ANOVA test mentioned in Section 5.5.1 has already confirmed the significant difference between school and holiday traffic volumes and this can also be seen in the figure above. The graph again confirms the findings of Zhou and Golledge (2000, p19) where, except for the second week of the survey, there is a tendency for volumes to drop from Monday to Wednesday and “bounce back” over Thursday and Friday.

Figure 5.5.3 graphically shows the average Day of the week trip volume plot across days for all data records in Dataset version 3.

Figure 5.5.3 : Average Day of the week Trip Volume variation across days



Since it has already been determined that the school and holiday period traffic volumes are significantly different, only the average day of week variations taken across days within the school and holiday periods were analysed. This was tested with ANOVA at the 5% level of significance. Details of the ANOVA analysis is included in Appendix 3.3 and 3.4 for the school and holiday periods respectively.

The ANOVA results for the school period revealed that Mondays and Tuesdays with Thursdays and Fridays are significantly different in terms of daily trip volumes. Only Wednesday can thus be considered a typical weekday as it was not calculated to be significantly different to the rest of the weekdays. One might consider Wednesday to be the midpoint between the volume “drop down” and “bounce back” indicated by Zhou and Golledge (2000).

The ANOVA results for the holiday period trip volumes revealed that Mondays, Tuesdays, Wednesdays and Thursdays with Fridays are significantly different including Monday with Wednesday, albeit marginally so with $t_{1,3} = 2.59 > t_{1-\infty/2}, n\text{-}k = 2.571$.

According to research conducted 15 years ago by Papenfus and van As (1992), it was observed that the largest variation in traffic volumes occurs on Fridays and recommended that counts not be undertaken on these days. They also found that traffic did vary considerably from the average on the days which schools close and re-open, as well as public holidays. These findings are also confirmed with the Summer Greens data, conducted over a five week period.

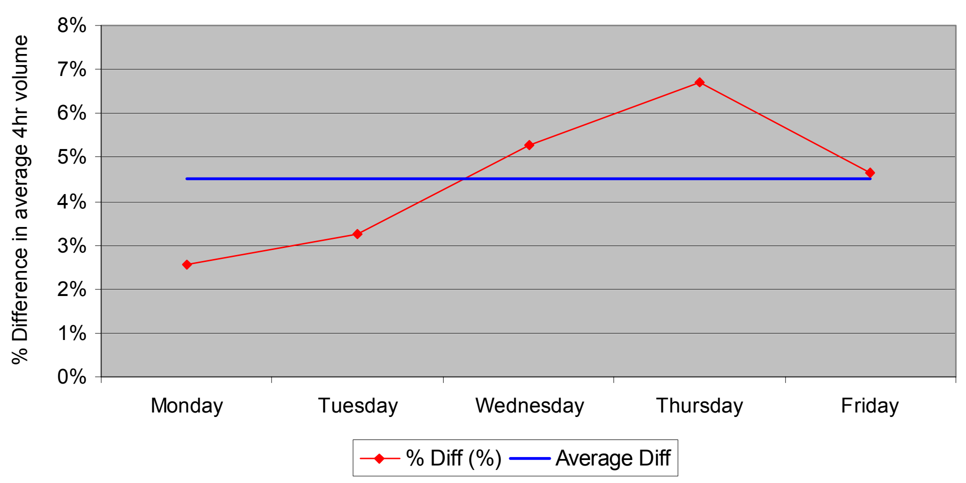
Table 5.5.4 shows the average Day of the week trip volume variation for both the school and holiday period.

Table 5.5.4 : Day of the Week trip volume differences across Days

Day	**School**		**Holiday**		**School - Holiday**	
	Ave Total	Total (%)	Ave Total	Total (%)	Diff	Diff (%)
Mon	1746	19.7%	1702	20.1%	**44.8**	**2.6%**
Tues	1747	19.7%	1690	19.9%	**56.7**	**3.2%**
Wed	1766	19.9%	1673	19.7%	**93.0**	**5.3%**
Thus	1801	20.3%	1680	19.8%	**120.7**	**6.7%**
Fri	1816	20.5%	1732	20.4%	**84.5**	**4.7%**
Total	**8876**	**100.0%**	**8476**	**100.0%**	**399.7**	**4.5%**

Figure 5.5.4 shows the day of week percentage difference between the school and holiday traffic volumes as indicated in Table 5.5.4.

Figure 5.5.4 : Percentage Daily Volume Difference between School and Holiday traffic



From the figure, it can be seen that the average 4-hour day on day difference between school and holiday traffic increases from Monday to Thursday and drops on Friday. The blue line represents the average weekly difference of 4.5% between the school and holiday period. The graph begins to show the deviation from the average weekly difference and begins to indicate the daily correction factor one could apply to counts conducted on certain days of the week during a holiday period.

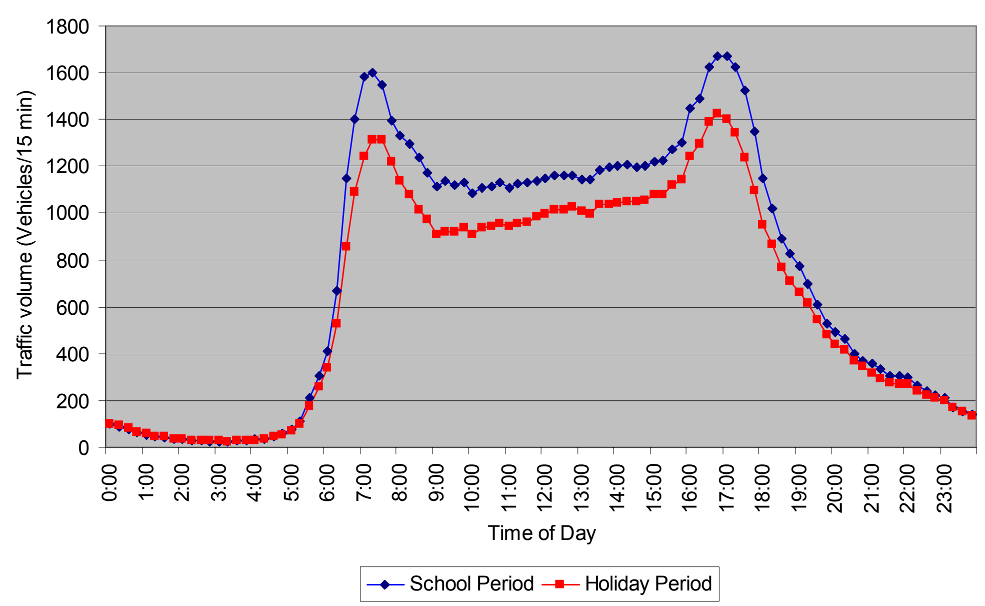
For instance, if a traffic count had to be conducted on a Monday in the holiday period from 06:00 to 10:00, it would be 1.9% (4.5% - 2.6%) below the average percentage volume difference between the school and holiday period. The graph again shows that Wednesdays can be considered a typical day as it has a low difference of 0.8% against the 4.5% weekly average difference. Interestingly, Fridays at 0.2% difference almost co-incides with the 4.5% weekly average difference, meaning that a holiday count conducted on Friday for that time period would represent the average weekly count during a typical school weekday for the same time period. This phenomena is not conclusive however as the results are based on only five weeks of data and is mentioned here only as an observation.

5.5.4 Peak Hour Spreading

In an attempt to address the secondary objective and peak hour spreading hypothesis described in Section 1.3, the entire City of Cape Town traffic count database consisting of 498 count sites, was searched for hourly data which covered both the school and holiday period in the months of November and December. Due to the nature of traffic counting, relatively few multi-day records are kept in the holiday period as they are not normally used in transportation analysis by the profession at large.

Only one site, viz. Site 19. located on the N7 freeway, north of the N1 but south of the Bosmansdam Arterial, which is just to the east of the study area was found suitable and used for analysis. Fifteen minute counts for the full day was available for the school period from 11 November 1998 to 4 December 1998 (13 days) and for the holiday period from 10 December 1998 to 18 December 1998 (7 days). An average for each 15-min period over each day for both of these periods was calculated and plotted as shown in Figure 5.5.5.

Figure 5.5.5 : Ave. Daily 15-min counts for School& Holiday period for Site 19 (Source : CoCT)



The figure shows a consistent volume drop of approximately 200 vehicles per 15-min period between 06:00 and 18:00 and does not exhibit any peak spreading during the holiday period at 08:00 as originally hypothesised.

5.5.5 The "Cross-Over" Point

Before the "cross-over" point is defined, it is important to show the 15-min volumes of the final version 3 dataset. Table 5.5.5 shows the total 15-minute trips observed over the four hour survey period.

Figure 5.5.6 shows a time-series plot of the 15-min observations and shows the duration of the two hour peak period (06:30 to 08:30) as well as the peak hour (06:45 to 07:45).

Figure 5.5.6 : Time series plot in 15-min time intervals (Dataset version 3)

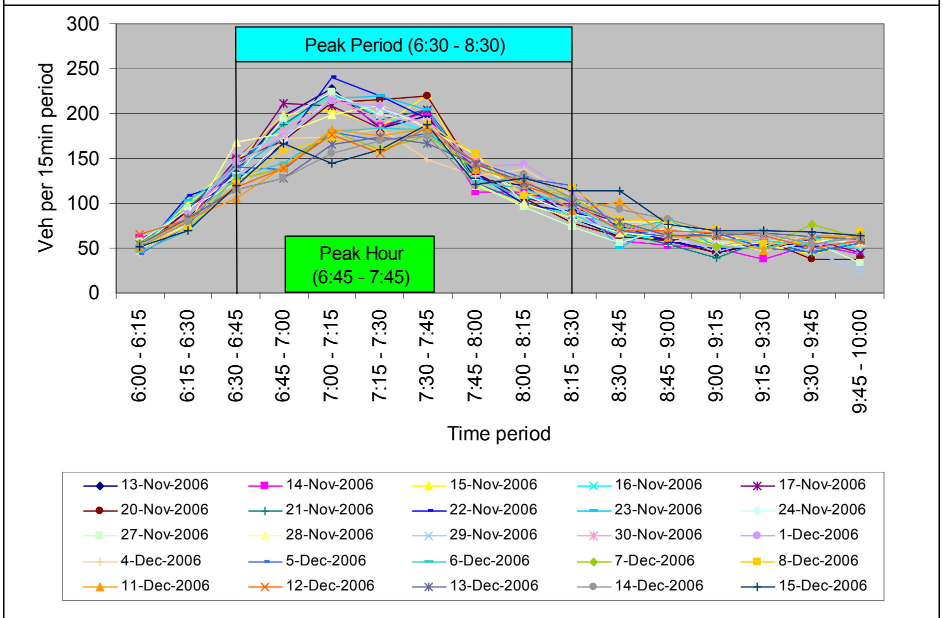


Figure 5.5.7 shows the average 15-min volumes for the school and holiday periods plotted as a two separate lines on a time series graph.

Figure 5.5.7 : Time series plot in average 15-min time intervals

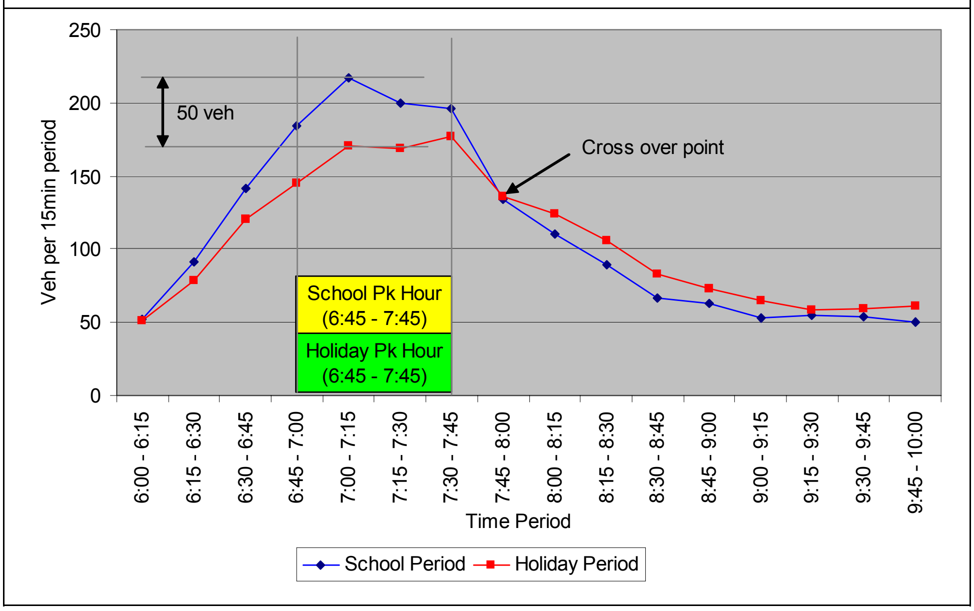


Table 5.5.5 : Trips observed per 15-min time interval (Dataset version 3)

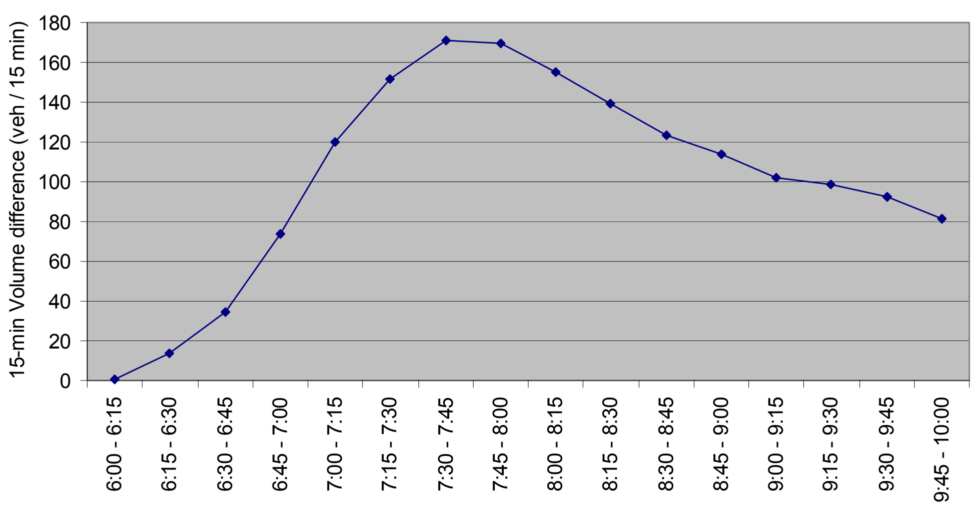
Date	Day	5:45-6:00	6:00-6:15	6:15-6:30	6:30-6:45	6:45-7:00	7:00-7:15	7:15-7:30	7:30-7:45	7:45-8:00	8:00-8:15	8:15-8:30	8:30-8:45	8:45-9:00	9:00-9:15	9:15-9:30	9:30-9:45	9:45-10:00	10:00-10:15	Total
13/11	Mon	1	54	84	136	197	228	184	197	128	120	83	62	60	44	56	53	57	-	**1744**
14/11	Tue	1	61	78	150	196	222	186	202	112	112	96	58	53	50	37	54	43	-	**1711**
15/11	Wed	-	48	99	147	198	204	185	221	119	99	85	66	57	58	53	43	57	1	**1740**
16/11	Thur	-	57	95	140	186	221	197	181	152	100	88	64	62	53	57	64	49	-	**1766**
17/11	Fri	19	51	93	136	211	208	184	204	134	105	96	78	58	68	52	60	45	-	**1802**
20/11	Mon	27	48	91	149	169	213	215	220	134	106	78	62	58	45	60	38	37	-	**1750**
21/11	Tue	32	56	94	143	188	223	193	204	122	101	83	68	54	39	59	45	56	-	**1760**
22/11	Wed	34	45	109	126	167	240	219	195	134	99	90	75	57	49	54	52	58	-	**1803**
23/11	Thur	14	48	103	137	174	216	219	204	129	105	105	50	82	52	50	61	55	1	**1805**
24/11	Fri	24	52	94	122	171	218	205	188	145	110	87	79	79	57	47	57	62	1	**1798**
27/11	Mon	26	57	93	130	195	223	198	190	122	96	74	55	73	63	59	57	34	-	**1745**
28/11	Tue	16	49	76	168	178	199	210	183	154	100	84	67	62	53	56	57	57	-	**1769**
29/11	Wed	22	51	85	153	177	214	205	180	143	129	82	71	66	46	60	46	25	-	**1755**
30/11	Thur	22	49	87	140	180	216	195	192	149	127	99	72	66	61	56	62	58	-	**1831**
1/12	Fri	21	49	88	146	174	214	208	187	141	143	112	76	64	52	62	53	58	-	**1848**
4/12	*Mon*	*28*	*43*	*84*	*113*	*172*	*173*	*184*	*149*	*131*	*137*	*108*	*75*	*79*	*67*	*56*	*64*	*51*	-	***1714***
5/12	*Tue*	*23*	*43*	*75*	*140*	*137*	*179*	*169*	*178*	*146*	*128*	*120*	*70*	*63*	*66*	*50*	*46*	*56*	-	***1689***
6/12	*Wed*	*19*	*46*	*70*	*131*	*144*	*181*	*183*	*182*	*123*	*116*	*94*	*71*	*80*	*60*	*59*	*53*	*66*	-	***1678***
7/12	*Thur*	*21*	*55*	*84*	*126*	*139*	*180*	*160*	*175*	*139*	*122*	*106*	*77*	*67*	*51*	*50*	*77*	*61*	-	***1690***
8/12	*Fri*	*14*	*51*	*74*	*121*	*158*	*172*	*158*	*188*	*156*	*109*	*117*	*80*	*81*	*69*	*54*	*57*	*68*	-	***1727***
11/12	*Mon*	*13*	*51*	*82*	*106*	*140*	*182*	*175*	*183*	*137*	*127*	*91*	*101*	*63*	*64*	*47*	*64*	*63*	-	***1689***
12/12	*Tue*	*26*	*65*	*82*	*118*	*139*	*176*	*156*	*185*	*146*	*120*	*101*	*69*	*70*	*66*	*64*	*50*	*58*	-	***1691***
13/12	*Wed*	*22*	*54*	*83*	*115*	*128*	*165*	*173*	*166*	*143*	*124*	*100*	*79*	*64*	*64*	*66*	*62*	*60*	-	***1668***
14/12	*Thur*	*13*	*52*	*79*	*115*	*128*	*156*	*170*	*175*	*120*	*132*	*105*	*93*	*82*	*68*	*66*	*54*	*62*	-	***1670***
15/12	*Fri*	*13*	*51*	*69*	*119*	*167*	*145*	*160*	*187*	*121*	*128*	*114*	*114*	*77*	*69*	*70*	*68*	*64*	-	***1736***
Totals		**451**	**1286**	**2151**	**3327**	**4213**	**4968**	**4691**	**4716**	**3380**	**2895**	**2398**	**1832**	**1677**	**1434**	**1400**	**1397**	**1360**	**3**	**43579**
School Period			52	91	142	184	217	200	197	135	110	89	67	63	53	55	53	50		***1758***
Holiday Period			51	78	120	145	171	169	177	136	124	106	83	73	64	58	60	61		***1676***
% difference			1.1%	14.3%	14.9%	21.1%	21.3%	15.7%	10.0%	-1.2%	-12.9%	-18.0%	-24.0%	-14.5%	-22.3%	-6.7%	-11.3%	-21.6%		4.6%
School Pk hr			469	634	743	798	749	641	531	401	330	272	237	224	211					
Holiday Pk hr			395	515	605	662	653	606	543	449	385	326	278	255	243					
School - Holiday ave volume			1	13	21	39	46	31	20	-2	-14	-16	-16	-9	-12	-4	-6	-11		82
Cumulative School - Holiday average volume			1	14	35	74	120	151	171	169	155	139	123	114	102	99	93	82		

Note : Figures in italics represent the school holiday period.

Both school and holiday periods share the same peak hour time period viz. 06:45 to 07:45. In order to compare the school versus holiday traffic volumes, the volumes are aggregated weekly. There is a noticeable difference in volumes before the 07:30 to 07:45 time period in the order of 50 vehicles per 15-min period. Also, from the time series plot above and from Table 5.5.5, the holiday average 15-min period volumes are in fact higher than the school period by 12.5% to 24% for the period from 08:00 to 09:15.

The point at which this starts to occur is termed the "cross over" point and typically occurs during the 07:45 to 08:00 time interval. The higher holiday volumes after the "cross over" point is explained by the fact that working parents are no longer required to drop scholars off at school before 08:00 am and appear to have a more unrestricted departure time. This freedom is aided by the overall 4.5% lower volumes experienced during the holiday period, which allows workers to leave home later but yet reach their destinations at the same time as in the school period. Figure 5.5.8 shows the cumulative difference in 15-min volumes between the school and holiday period.

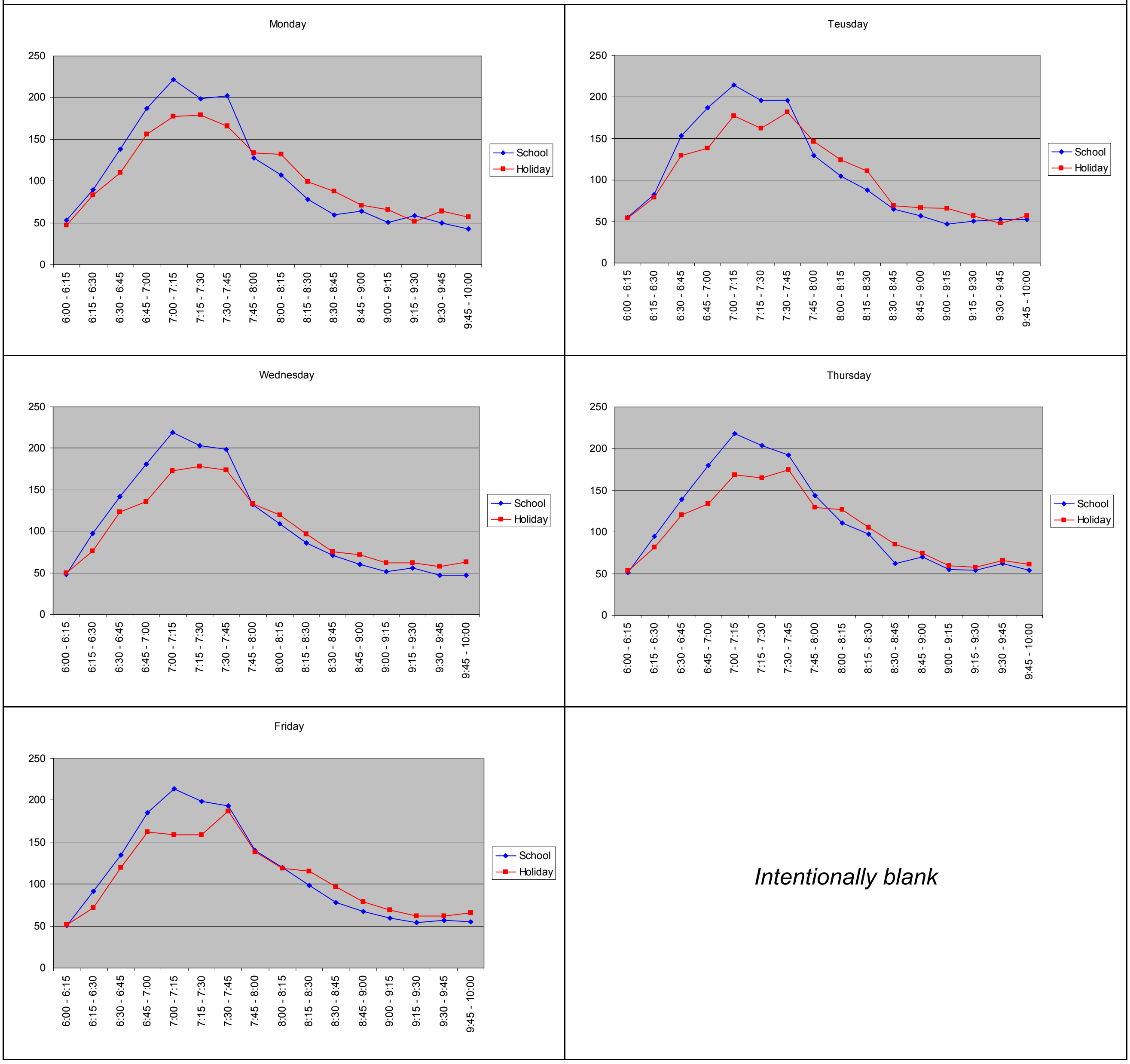
Figure 5.5.8 : Cumulative difference between school and holiday average 15-min volumes



Note that, due to the "cross over" effect, the percentage difference increases during the peak hour and reduces over time over the survey period, but at 10:00 does not return back to 0%. Thus in this study, it can be shown that the earlier hypothesis that holiday traffic volumes are similar to school traffic volumes over the morning period (06:00 to 10:00) is true to a certain extent due to peak spreading (as shown by the "cross over" point theory) but not sufficiently so for traffic to be equal. It has been shown in earlier tables that the school period average 4-hour traffic volume is 4.5% more than the holiday period equivalent.

The next step was to determine whether each day of the week, on average, displayed a "cross over" point. The average daily 15-min period volumes for each day of the week for the school and holiday period is shown in Figure 5.5.9.

Figure 5.5.9 : “Cross Over” evidence for time series plots for individual Days of week



The result of this analysis revealed that all days of the week exhibit this "cross over" point during the 07:45 to 08:00 session.

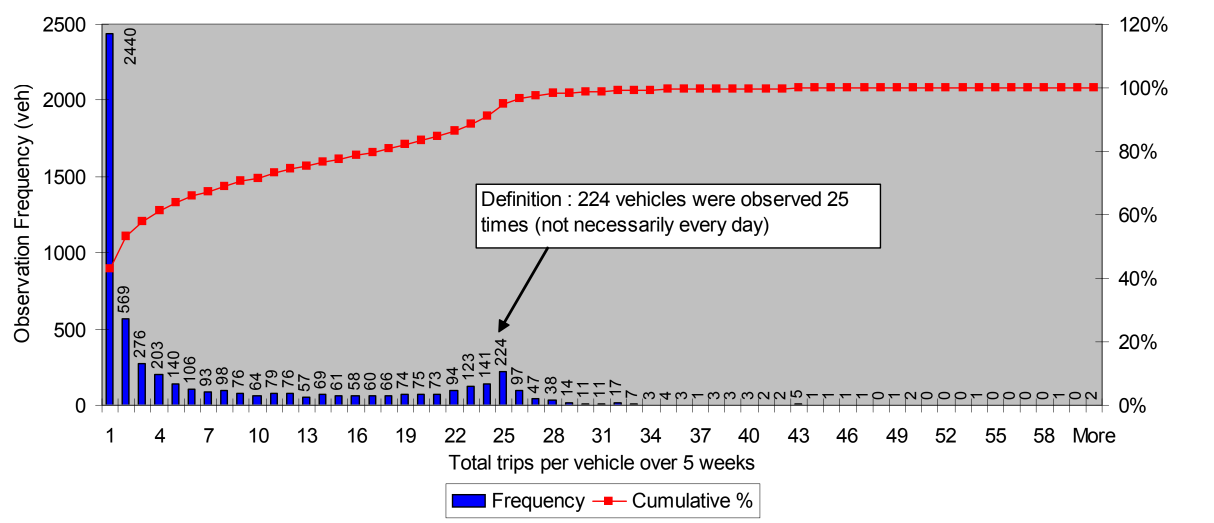
In summary, the activity of dropping off school children seems to show priority in a scheduling sense due to the peaking of traffic towards the 08:00 hour when schools in Cape Town start. This scheduling requirement then falls away during the holiday period leaving the commuter with a more flexible departure time schedule, leading to peak spreading and a “cross over” effect during the holiday period.

5.6 Trip Observation Frequency

5.6.1 Trip Observation Frequency for the Overall Period :

Figure 5.6.1 shows the histogram of the entire Dataset version 3 rank ordered according to number of observations.

Figure 5.6.1 : Histogram of Observation Frequencies (Entire dataset)

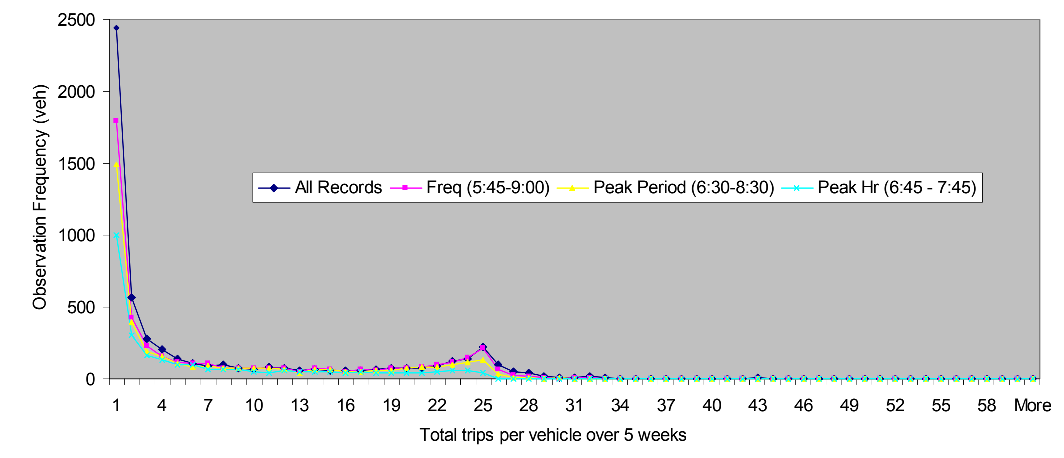


The histogram shows that 2440 vehicles were observed only once ever during the entire 25-day survey period. A total of 224 vehicles were observed 25 times in the same period which does not necessarily mean that this trip was done every day over 25 days (for instance, a vehicle could have been observed five times every Monday instead of once everyday for 25 days).

Most trips occur only once during the 25 day survey period ie. 42.98% but it is assumed that this could be lower since it covers the period until 10:00 and may therefore constitute a "non-commuter" portion of traffic. A total of 8.9% of trips undergo 25 or more trips.

To determine the impact of the commuter portion on the frequency histogram, three separate histogram analyses were conducted. These were conducted during the 05:45 to 09:00 period, the 06:30 to 08:30 peak period and finally the 06:45 to 07:45 peak hour period. These three histogram plots together with the overall histogram plot is shown in Figure 5.6.2.

Figure 5.6.2 : Histogram Plots of Observation Frequencies for various time periods

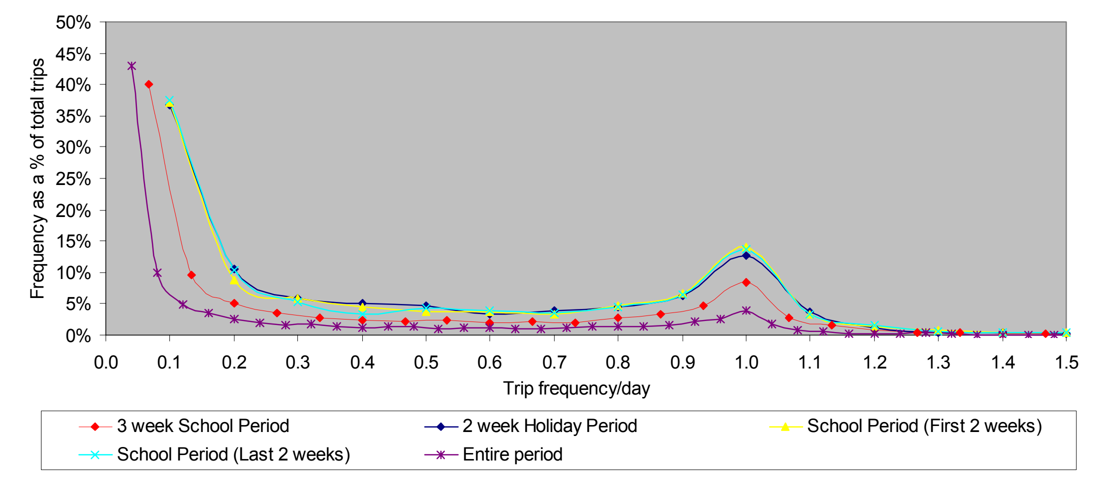


From the plot of all four time period scenarios, most trips still occur only once during the 25 day survey period and the frequencies of these "once-off" trips dropped only 6.7% from 43% (overall data) to 36.3% (peak hour data). For trip occurrences of 25 or more, frequencies came down by 7.2% from 8.9% (overall data) to 1.7% (peak hour data). From the figure, there is a noticeable drop in the "1 to 2" occurrence frequencies as well as the "23 to 26" occurrence frequencies with reducing time ranges. Whilst one would expect the frequencies to drop for the "once-off" frequency for the peak hour due to a higher returning commuter proportion, one would not expect a flattening of the peak at around the 25 trip frequency which would supposedly constitute the majority of commuters.

5.6.2 Trip Observation Frequency differences between Holiday and School Period :

The previous analysis observed occurrence frequencies for the entire period and compared selective histogram data for various daily time band scenarios ranging from the entire dataset to the observations made in the peak hour only. This section analyses the same trip observation frequencies but according to weekly time bands. Figure 5.6.3 shows the histogram results of the various scenarios tested between the school and holiday periods. Note that the numbers of trips are factored to "occurrences per day" due to the 3 week school period and 2 week holiday period.

Figure 5.6.3 : Histogram Observation Frequencies for various weekly periods



From Figure 5.6.3, no significant difference between school and holiday period trip frequencies are observed when comparing similar time period durations ie. two weeks, following almost identical curves. As expected and shown in this graph, a lowering of trip frequencies per day (returning trips) is observed the longer the duration period selected for analysis.

Research by Jones and Clark (1998) found that the longer the observed period is, the higher the number of different performed activities and thus the greater the variability becomes. The research conducted by (Schlich and Axhausen, 2003) also confirmed the tendency of decreasing stability with increasing observation period.

5.7 Extent of Habitual Behaviour

The following sections deals with the analysis of repetitive or habitual travel behaviour observed in the Summer Greens data.

5.7.1 Frequency of Appearance

The frequency of appearance per week is defined as the *number of days in the week* a particular vehicle appears and does not take into account the total number of appearances or multiple observations of that same vehicle per day. In other words, a vehicle that appeared five times on Monday for that entire week would only have a "Frequency of Appearance" per week value of one. Table 5.7.1 shows the explanation of "Frequency of Appearance" and "No. of trips w.r.t frequency of Appearance" definition of a hypothetical vehicle observed over four time intervals over a period of one week. The table has already been mentioned in the literature review but is included here for reference.

Table 5.7.1 : Explanation of Vehicle Appearance and Proportion of trips per week for a vehicle

Time Interval	Monday	Tuesday	Wednesday	Thursday	Friday	Total
1	x	x	x	-	-	3
2	-	x	-	-	-	1
3	x	x	-	-	-	2
4	x	x	-	-	-	2
Minimum	1	1	1	0	0	**3**
Sum	3	4	1	0	0	**8**

x : indicates time period within which vehicle was observed

From Table 5.7.1, it can be seen that the vehicle made three daily appearances per week (ie. Monday, Tuesday and Wednesday) whilst the proportion of trips made is eight trips per week (based on three trips made on Monday, four on Tuesday and one trip on Wednesday). In other words, the vehicle in the table which can be seen to have appeared on three separate days per week can be associated with undertaking a total of eight trips over that week.

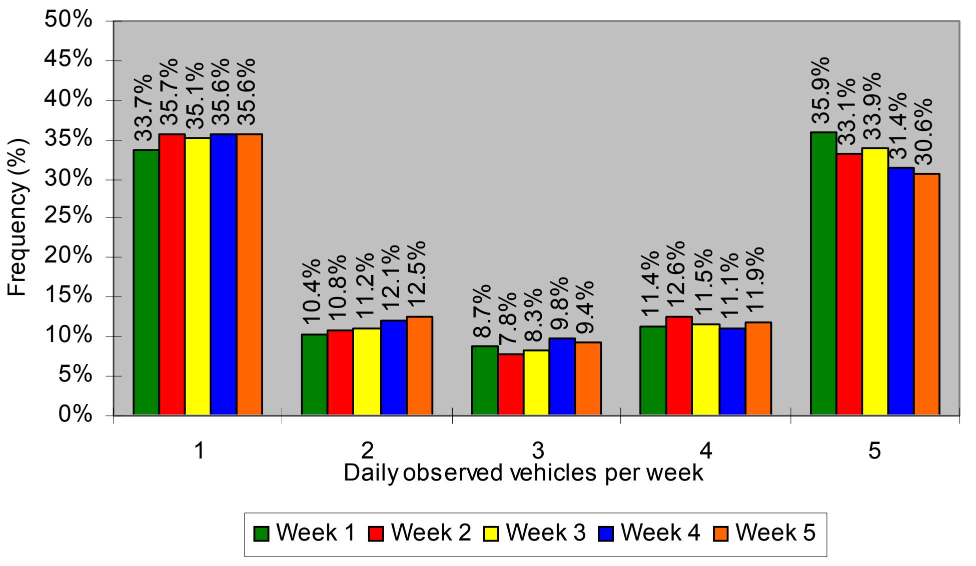
Table 5.7.2 shows the frequencies of vehicle appearances per week in terms of volumes (appearances per week) and proportions (%). The methodology used in obtaining the weekly data, uses the "min count" value (described earlier) of the same observed vehicle appearances per day, summing up the "min count" totals for the five individual weeks, setting up a pivot table and performing an enquiry. Finally the differences between weeks are tested using an ANOVA table.

Table 5.7.2 : Frequency of Appearance per week (overall Dataset)

Frequency of vehicles observed per week (No.)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
Vehicles not observed	*3036*	*2896*	*2903*	*2950*	*2948*	*2947*
1	890	994	975	*971*	*971*	960
2	274	299	310	*331*	*341*	311
3	230	218	230	*268*	*257*	241
4	300	350	319	*302*	*324*	319
5	947	920	940	*855*	*836*	900
Total	**5677**	**5677**	**5677**	***5677***	***5677***	**5677**
Frequency of vehicles observed per week (%)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
1	33.7%	35.7%	35.1%	*35.6%*	*35.6%*	35.2%
2	10.4%	10.8%	11.2%	*12.1%*	*12.5%*	11.4%
3	8.7%	7.8%	8.3%	*9.8%*	*9.4%*	8.8%
4	11.4%	12.6%	11.5%	*11.1%*	*11.9%*	11.7%
5	35.9%	33.1%	33.9%	*31.4%*	*30.6%*	33.0%
Total	**100.0%**	**100.0%**	**100.0%**	***100.0%***	***100.0%***	**100.0%**

Figure 5.7.1 provides a plot of the average percentages of appearance frequencies across weeks for all the data records in Dataset version 3.

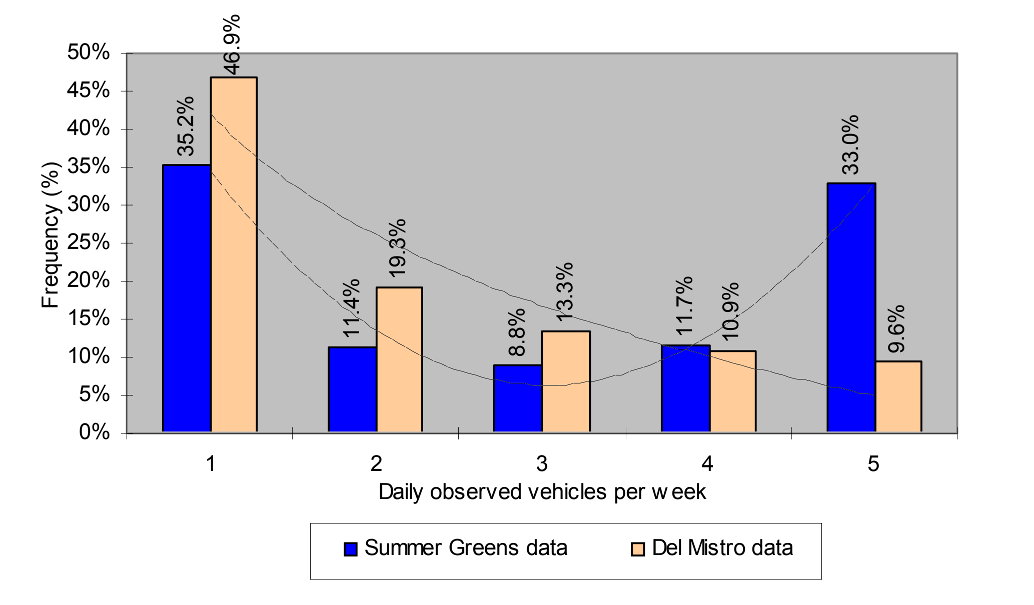
Figure 5.7.1 : Plot of Frequency of Appearance per week



The graph shows that trip making per day is fairly uniform across all weeks except for the "5 day/week" pattern. The “5 day per week” trips reduce over the last two week holiday period ie. over weeks four and five. Up to 70% of trips collectively consist of either one or five vehicle trip appearances per week. An ANOVA test was conducted (refer to Appendix 3.5) to determine if significant differences in appearance frequencies exist between weeks. The result of the analysis revealed insignificant differences between all weeks at the 5% level of significance.

The average weekly frequency of appearance is shown in Figure 5.7.2. The figure incorporates the results of the Del Mistro and Behrens study (2006) conducted on a citybound arterial entering the Cape Town CBD for comparison purposes. The Del Mistro and Behrens dataset is referred to further in the text as the Del Mistro data.

Figure 5.7.2 : Average Weekly Percentage Frequency of Appearance



From the graph, the Summer Greens data shows significantly more "5 day per week" appearances than the comparative Del Mistro data and also shows less “1 day per week” data. This is considered reasonable since the Summer Greens survey was conducted at an exit of a residential area and one would therefore expect more frequent commuter type users. The Summer Greens data displays an almost similar “1 day per week” appearance percentage as the “5 day per week” appearance value resulting in a “U”- shaped data curve over the five week survey period. This curve is compared to the left to right sloping curve of the Del Mistro data.

From the differences in the two studies and based on the fact that the Summer Greens data can be considered to contain more “Origin” type data and the Del Mistro data more “Destination” type data, it is hypothesised that as one approaches a destination (like the CBD), the more the data will resemble the Del Mistro curve and conversely, the closer observations are conducted at a residential area or origin, the more “U-shaped” the data becomes. This is because the closer a survey station is to a popular destination, the more possibility and likelihood of unique vehicles entering the stream (ie. “one day per week” data) with a resulting bias towards this portion of the graph.

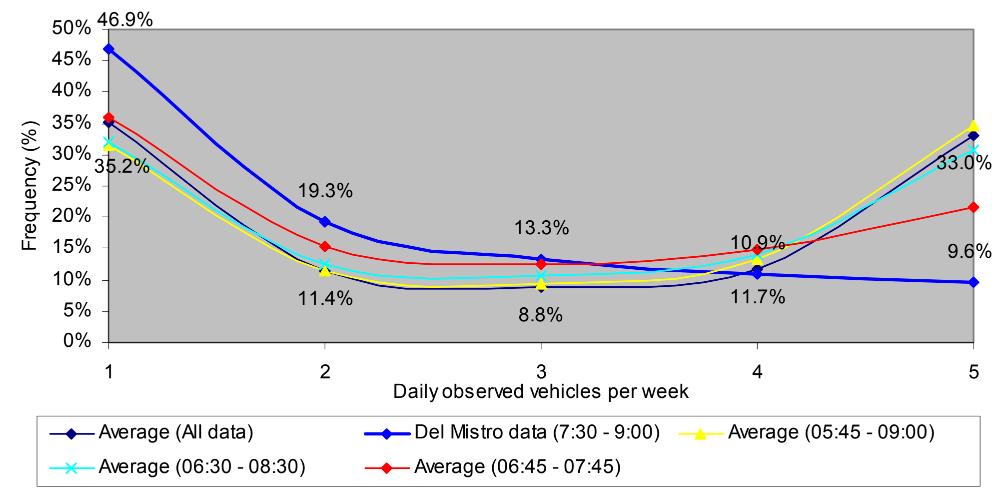
Should the “Destination” data resemble the left to right slanted curve like that of the Del Mistro data curve, then it is further hypothesised that the Summer Greens data, as an “Origin” dataset, should be expected to have a mirror image of the Del Mistro curve ie. slanted from right to left. From the results, this is not the case as there are still a high proportion of “1 day appearances per week “ in the Summer Greens dataset. It is thought however, that the curvature of the Summer Greens data may change with different time periods due to a reducing proportion of commuters expected after 08:30 am.

To determine the potential impact of a commuter portion on the frequency distribution, a separate analysis was conducted during the 05:45 to 09:00 period (included in Appendix 4.1), the 06:30 to 08:30 peak period (Appendix 4.2) and finally the 06:45 to 07:45 peak hour period included in Appendix 4.3. A summary of these three plots together with the overall data plot and Del Mistro data is shown in Table 5.7.3 and plotted in Figure 5.7.3. Note that the Del Mistro study was conducted from 07:30 to 09:00 am.

Table 5.7.3 : Average Frequency of Appearance (various time periods)

Frequency of vehicles observed per week	Average (06:45 - 07:45)	Average (06:30 - 08:30)	Average (05:45 - 09:00)	Average (All data)	Del Mistro Average
1	36.0%	32.0%	31.5%	35.2%	46.9%
2	15.3%	12.6%	11.4%	11.4%	19.3%
3	12.4%	10.6%	9.3%	8.8%	13.3%
4	14.7%	13.9%	13.2%	11.7%	10.9%
5	21.6%	30.8%	34.6%	33.0%	9.6%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 5.7.3 : Average Percentage trips with respect to Frequency of Appearance for various time periods



From the graph, it becomes apparent that the shorter and more closer to the peak hour the Summer Greens data is analysed, the more closer the data curve changes shape from a U-curve to begin resembling the Del Mistro (destination orientated) dataset curve, particularly at the "5-day per week" end of the curve. This is contrary to what is expected as one would assume to have a higher proportion of commuters closer to the peak hour and hence have a higher "5 day per week" proportion.

The results of this analysis begins to suggest that the "5 day per week" commuter is not too restricted by time and has variable departure times not necessarily always departing (or observed) in the peak hour. This also disproves the hypotheses stated earlier that the frequency of appearance is expected to be a mirror image of the Del Mistro curve slanting from right to left for "Origin" type survey stations.

5.7.2 Number of trips with respect to Frequency of Appearance

The frequency of appearance per week was defined in the previous section as the number of days a particular vehicle appears over one week and did not take into account the total number of appearances (or trips) per day.

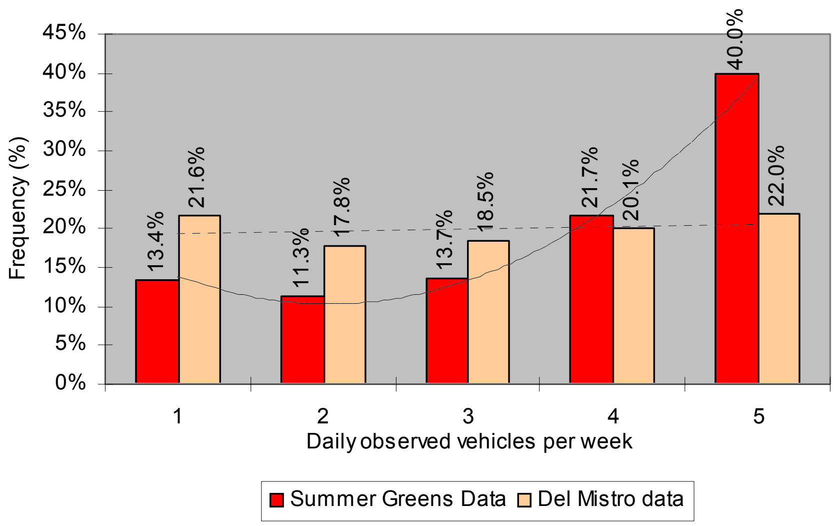
Table 5.7.4 shows the number of trips made with respect to the vehicle appearance frequency per week (ie. one to five) and corresponding percentage calculation. The methodology used in obtaining the data, associates the “sum count” (trips per day) of the data with the “min count” appearance frequency as defined in Table 5.7.1, setting up a pivot table, performing an enquiry and testing the differences using an ANOVA table.

Table 5.7.4 : No. of trips w.r.t Frequency of Appearance per week (overall Dataset)

Frequency of vehicles observed per week (No.)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
Vehicles not observed	*3036*	*2896*	*2903*	*2950*	*2948*	*2947*
1	927	1035	1023	*1020*	*1010*	1003
2	592	646	655	*708*	*728*	666
3	748	690	741	*885*	*828*	778
4	1287	1511	1375	*1284*	*1406*	1373
5	5209	5034	5154	*4601*	*4482*	4896
Total	8763	8916	8948	*8498*	*8454*	8716
Frequency of vehicles observed per week (%)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
1	10.6%	11.6%	11.4%	12.0%	11.9%	11.5%
2	6.8%	7.2%	7.3%	8.3%	8.6%	7.7%
3	8.5%	7.7%	8.3%	10.4%	9.8%	9.0%
4	14.7%	16.9%	15.4%	15.1%	16.6%	15.7%
5	59.4%	56.5%	57.6%	54.1%	53.0%	56.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 5.7.4 provides a plot of the average percentage number of trips undertaken by the associated vehicle appearance frequency per week (ie. vehicles observed once per week to five times a week) for all the data records in Dataset version 3. The figure incorporates the results of the Del Mistro and Behrens study (2006) for comparison purposes.

Figure 5.7.4 : Plot of Average Percentage of trips w.r.t. Frequency of Appearances per week



From the graph, it can be observed that the Del Mistro trips are evenly spread out over the five daily frequencies. By comparison, the Summer Greens data shows high proportion of trips in the "5 day per week" category (indicating multiple daily trips). An ANOVA test was conducted (refer to Appendix 3.6) to determine if significant differences in observed frequencies exist between the individual weeks of the Summer Greens data. The result of the analysis revealed insignificant differences between all weeks at the 5% level of significance.

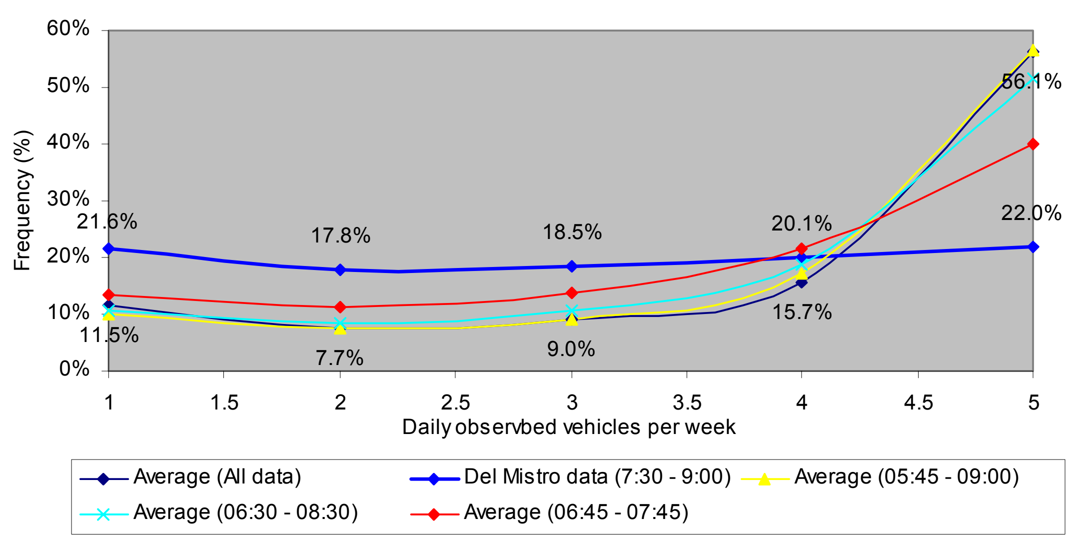
As in the previous section, a separate analysis was conducted during the 05:45 to 09:00 period (included in Appendix 5.1), the 06:30 to 08:30 peak period (Appendix 5.2) and finally the 06:45 to 07:45 peak hour period (Appendix 5.3) in order to determine the impact of the commuter portion on the trip making frequency distribution.

A summary of these three plots together with the overall data plot and Del Mistro data is shown in Table 5.7.5 and plotted in Figure 5.7.5.

Table 5.7.5 : Percentage of trips w.r.t. average Frequency of Appearance (various time periods)

Frequency of vehicles observed per week	Average (06:45 - 07:45)	Average (06:30 - 08:30)	Average (05:45 - 09:00)	Average (All data)	Del Mistro Average
1	13.4%	10.6%	10.1%	11.5%	21.6%
2	11.3%	8.4%	7.4%	7.7%	17.8%
3	13.7%	10.6%	9.0%	9.0%	18.5%
4	21.7%	18.6%	17.1%	15.7%	20.1%
5	40.0%	51.7%	56.4%	56.1%	22.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 5.7.5 : Average Percentage trips with respect to Frequency of Appearance for various time periods



From the graph, it is observed that the number of trips made in the Del Mistro study is more evenly distributed whilst a significant number of Summer Greens trips (56.1%) are made by motorists appearing everyday. Again, the closer to the peak hour period the data is analysed, the closer the Summer Greens curve tends towards the Del Mistro curve. When Figure 5.7.5 is compared against Figure 5.7.3, we can deduce that although there is a large amount (46.9% in Figure 5.7.3) of vehicles that appeared only once a day in the week, these vehicles constituted only 11.5% of all the trips made. Far more important and expected is the large amount of trips (56.1%) made by those vehicles observed every day of the week.

5.7.3 Frequency of Appearance per following day

An analysis was conducted on the proportion of vehicles returning on the following day expressed as a percentage of the 5677 vehicle records in dataset version 3. The methodology employed to obtain this data is as follows :

1. Conduct a summation of the "min count" for the Monday to Tuesday, Tuesday to Wednesday, Wednesday to Thursday and Thursday to Friday day of week combinations for each of the five weeks.

2. This calculation yields a value of 0, 1 or 2 for each vehicle. A value of 0 is associated with no matches on either day, a value of 1 representing an appearance on either of the two days and a value of 2 representing an appearance on both days of the week for the combination selected.

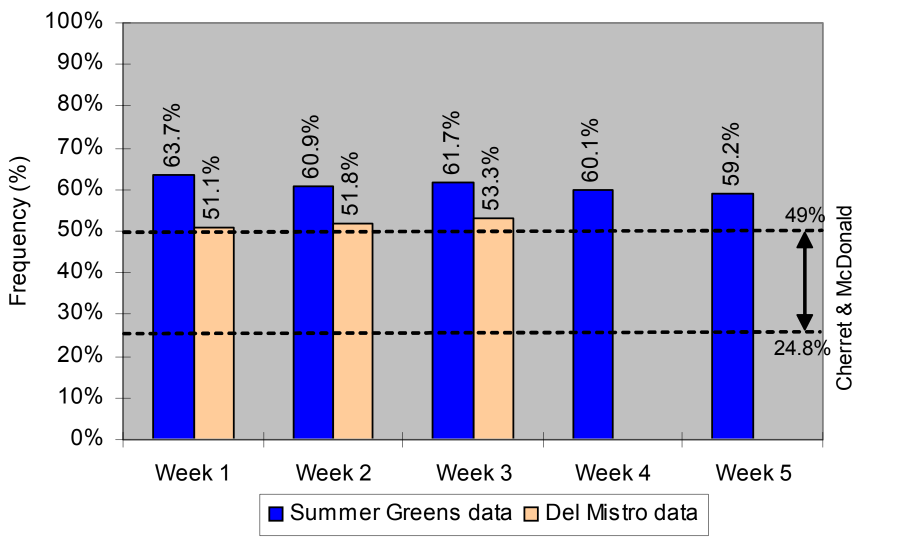
3. A value of 2 is considered a "following day" data match and the process is repeated for the next vehicle until all vehicle records in the dataset is analysed.

Table 5.7.6 shows the results of the frequency per following day results presented as a percentage of total vehicles and shows the comparison with the Del Mistro dataset. Details of the data analysis used to derive the results in the table are included in Appendix 6.1.

Table 5.7.6 : Frequency per Following Day						
% of vehicles also recorded on the following day	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
Mon-Tues	65.2%	60.2%	61.8%	*60.2%*	*59.7%*	61.4%
Tues-Wed	63.9%	62.0%	62.6%	*60.6%*	*61.0%*	62.0%
Wed-Thurs	63.3%	60.6%	64.2%	*59.6%*	*60.2%*	61.6%
Thurs-Fri	62.4%	60.7%	58.3%	*60.1%*	*56.0%*	59.5%
All Week	63.7%	60.9%	61.7%	*60.1%*	*59.2%*	**61.1%**
Del Mistro data	51.1%	51.8%	53.3%	*No Survey*	*No Survey*	52.0%

From the table, the difference between the overall averages of the Summer Greens and Del Mistro datasets is 9.1%. Figure 5.7.6 shows the plot of the average weekly data in comparison to the Del Mistro dataset.

Figure 5.7.6 : Plot of Average Frequency per Following day



From the figure, the Summer Greens data can be observed to be on average 9.1% higher than the Del Mistro data. This is logical in view of the fact that there are more "5 trips per day" occurrences in the Summer Greens data than the Del Mistro data and due to it's close proximity to the origin of trips or residential area.

The Summer Greens average percentage following on subsequent days is 61.1% when compared to the 52% of the Del Mistro data. Cherret and McDonald (2002) reported an average frequency per following day of between 24.8% to 49% only, but it is argued here that this figure is largely dependant on location and the time period analysed. Bonsall et al (1984) found a 50% following day return rate when surveying numberplates.

5.7.4 Frequency of Appearance per subsequent week

The frequency of appearance per subsequent week is defined as the frequency of observation of a particular vehicle on a certain day of week and observed on that same day in the subsequent week. The methodology used to derive the data is to perform a "min count" of a particular vehicle per day after which a macro programme was written to count up the matches as shown in Table 5.7.7.

Table 5.7.7 : Methodology used to determine Freq. of Appearance per subsequent week

Vehicle	Week 1					Week 2					Repetitious trips/week
	Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri	
Veh 1	-	x	-	-	-	-	x	-	-	-	1
Veh 2	x	-	x	-	-	x	-	x	-	-	2
Veh 3	-	x	-	-	-	-	-	x	-	-	0
Veh 4	x	x	x	x	x	x	x	x	x	x	5

Note that, by definition, although “Veh 3” was observed in the subsequent week (ie. week 2), it did not perform the trip on the same day and therefore does not qualify as a “repetitious trip/week” match.

Table 5.7.8 shows the repetitious trips per week determined for the entire five week Summer Greens dataset.

Table 5.7.8 : Repetitious trips per subsequent week (volumes)

Repetitious Trips/week	Weeks 1 and 2	Weeks 2 and 3	Weeks 3 and 4	Weeks 4 and 5	Weeks 1 and 3	Weeks 1 and 4	Weeks 1 and 5	Weeks 2 and 4	Weeks 2 and 5	Weeks 3 and 5
0	4070	4032	4083	4097	4090	4189	4249	4163	4214	4156
1	268	297	315	320	266	280	259	269	279	294
2	181	191	200	197	163	181	180	201	186	196
3	194	197	217	195	223	221	201	211	187	184
4	304	301	240	277	291	241	261	248	262	268
5	660	659	622	591	644	565	527	585	549	579
Total	5677	5677	5677	5677	5677	5677	5677	5677	5677	5677

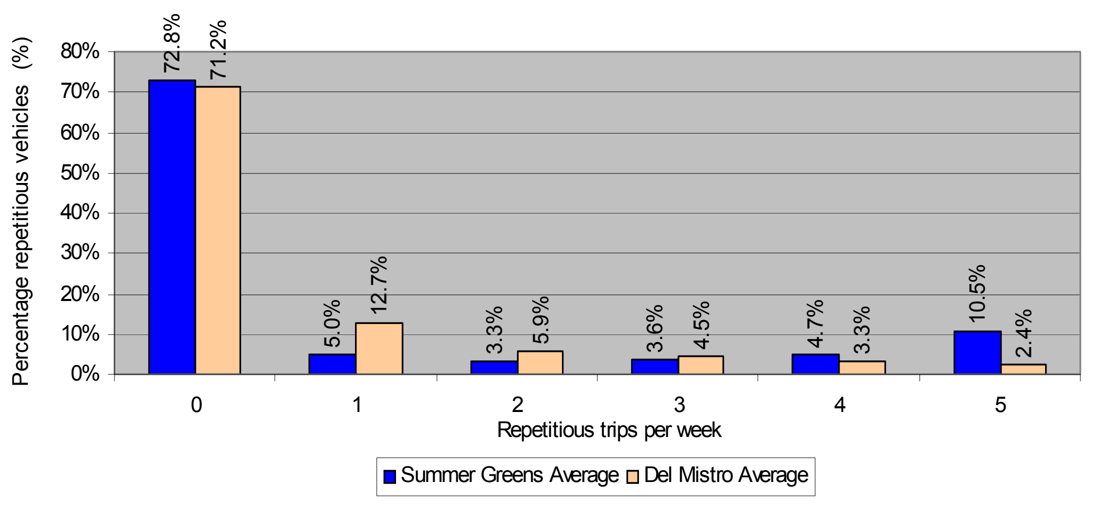
Table 5.7.9 shows the same repetitious trips per subsequent week data presented in a percentage format with overall five week averages and compared against the Del Mistro (2006) dataset.

Table 5.7.9 : Repetitious trips per subsequent week (percentages)

Trips/week	Weeks 1 and 2	Weeks 2 and 3	Weeks 3 and 4	Weeks 4 and 5	Weeks 1 and 3	Weeks 1 and 4	Weeks 1 and 5	Weeks 2 and 4	Weeks 2 and 5	Weeks 3 and 5	S/Greens Average	Del Mistro Average
0	71.7%	71.0%	71.9%	72.2%	72.0%	73.8%	74.8%	73.3%	74.2%	73.2%	72.8%	71.2%
1	4.7%	5.2%	5.5%	5.6%	4.7%	4.9%	4.6%	4.7%	4.9%	5.2%	5.0%	12.7%
2	3.2%	3.4%	3.5%	3.5%	2.9%	3.2%	3.2%	3.5%	3.3%	3.5%	3.3%	5.9%
3	3.4%	3.5%	3.8%	3.4%	3.9%	3.9%	3.5%	3.7%	3.3%	3.2%	3.6%	4.5%
4	5.4%	5.3%	4.2%	4.9%	5.1%	4.2%	4.6%	4.4%	4.6%	4.7%	4.7%	3.3%
5	11.6%	11.6%	11.0%	10.4%	11.3%	10.0%	9.3%	10.3%	9.7%	10.2%	10.5%	2.4%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100 %	100%

Figure 5.7.7 shows a graph of the percentage differences between the Summer Greens data and the Del Mistro data in terms of repetitious trips per week.

Figure 5.7.7 : Repetitious Vehicle percentage comparison : Summer Greens data with Del Mistro data



From the figure, it is observed that the Summer Greens data closely matches the Del Mistro data, except for the "5 trips per week" and "1 trip per week" category. Although more Summer Greens trips are made in the "5 repetitious trips per week" category, as can be expected, it is interesting to note the relatively low "1 trip per week" volume (5%) when compared to the Del Mistro data (12.7%). It was not possible to test the significance of the Summer Greens data against the Del Mistro data since the latter sample size was not available. An ANOVA test (included in Appendix 3.15) to determine the significance within school weeks (ie. between weeks 1 and 2 and between weeks 2 and 3) and within holiday weeks (ie. weeks 4 and 5) revealed insignificant differences within school weeks and holiday weeks.

5.7.5 First Departure Time

A comparison of mean departure times of first time vehicle observations was conducted. Table 5.7.10 shows the comparison of departure time means by day of the week. Due to the close proximity of the survey station to the residential area, the recorded vehicle observation times can be considered to be within five minutes of true origin departure times. For the purposes of this analysis, the first time of departure is taken to equal the recorded vehicle observation time.

Table 5.7.10 : Comparison of Departure Time Means by Day of Week

Week / Day	Monday	Tuesday	Wednesday	Thursday	Friday	Average
Week 1	7:33:58	7:32:41	7:33:21	7:34:34	7:34:52	-
Week 2	7:30:49	7:31:22	7:33:05	7:34:48	7:36:38	-
Week 3	7:31:37	7:35:29	7:32:31	7:36:16	7:36:52	-
Week 4	*7:40:34*	*7:38:53*	*7:41:09*	*7:40:35*	*7:41:58*	-
Week 5	*7:42:11*	*7:39:04*	*7:42:43*	*7:44:28*	*7:45:45*	-
Average	7:35:50	7:35:30	7:36:34	7:38:08	7:39:13	7:37:03
Average (school period)	7:32:08	7:33:11	7:32:59	7:35:13	7:36:07	7:33:55
Average (holiday period)	7:41:23	7:38:58	7:41:56	7:42:31	7:43:52	7:41:44
Standard Dev (school)	0:01:38	0:02:06	0:0:25	0:00:55	0:01:05	-
Standard Dev (holiday)	0:01:08	0:00:07	0:01:06	0:02:44	0:02:40	-

Figures 5.7.8 and 5.7.9 shows a plot of mean observed departure times reported across "Days of the Week"

and reported across weeks respectively. Note that the times observed have been converted to a "seconds" clock starting at 0 seconds at 0:00 (midnight) and ending at 86 400 seconds at 24:00 (midnight).

From Figure 5.7.8, the average departure time during the school period increases from Monday to Friday from 07:32 to 07:36, an increase of four minutes. The same pattern occurs during the holiday period, but less significant ie. from 07:41 to 07:43, a difference of only two minutes.

From Figure 5.7.9, there is a significant difference (confirmed by an ANOVA test conducted at the 5% level of significance and included in Appendix 3.7) of average departure times between the school period (weeks 1 to 3) and the holiday period (weeks 4 and 5) with an average difference of 7 minutes and 49 seconds with much later departures occurring during the holiday period.

Figure 5.7.8 : Mean Observed Departure Time reported across Days of the Week

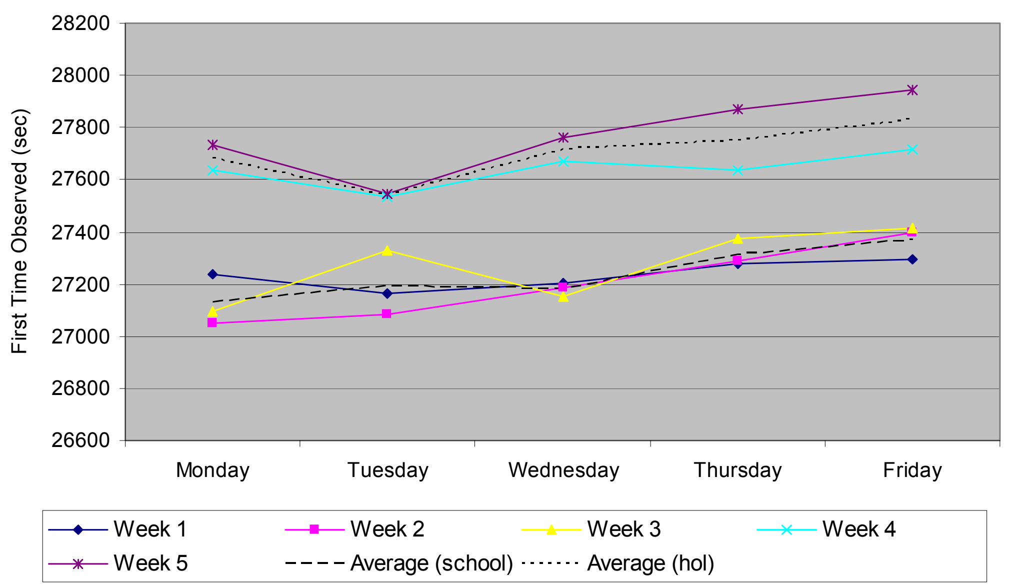
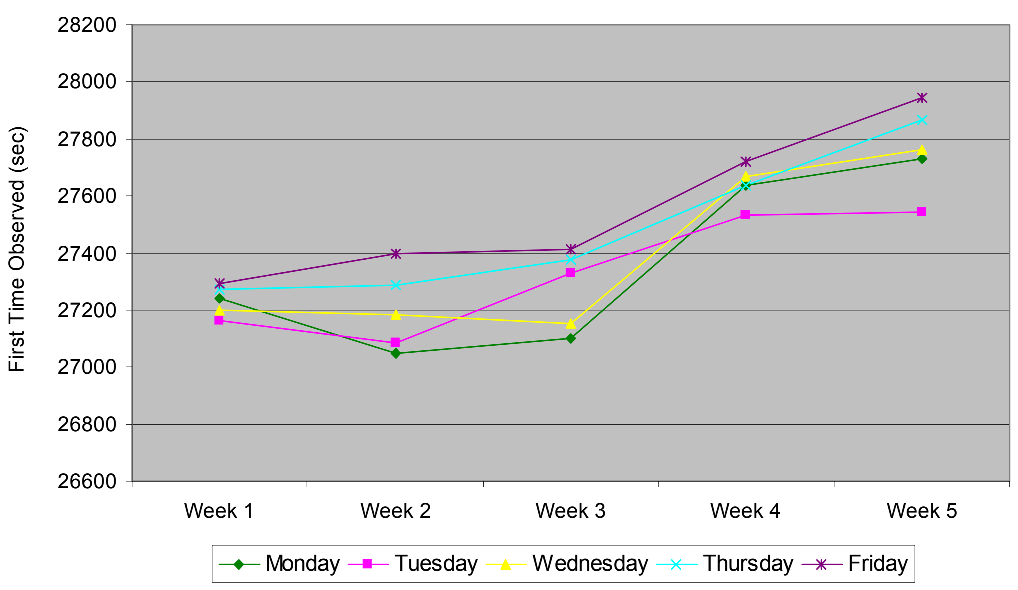


Figure 5.7.9 : Mean Observed Departure Time reported across Weeks



An ANOVA test analysis (included in Appendix 3.8) conducted across the days of the week in the school period revealed the following significant differences at the 5% level of significance :

- Significant difference between Monday with Thursday and Friday
- Significant difference between Tuesday with Friday
- Significant difference between Wednesday and Friday

The ANOVA analysis conducted on the holiday period only (included in Appendix 3.9) revealed that the hypothesis that the "means are equal" can be accepted with the only significant difference (at the 5% level of significance) occurring between Tuesday and Friday.

The Summer Greens school period ANOVA results indicate that departure times on Fridays are different to all other days of the week, except for Thursday, which means that both Thursdays and Fridays exhibit significantly different trip departure times than the other remaining weekdays (excluding weekends). This is consistent with the findings by Pendyala (2003) who also found that both Thursdays and Fridays are different in trip making characteristics than other weekdays and with Zhou and Golledge (2000) who found that Fridays are different from other days of the week with respect to trip making behaviour. It should be noted that, in his research, Pendyala mentioned that he was uncertain whether the Thursday phenomena was a simple data issue or a true behavioural issue and recommended that further research be conducted in this regard. The holiday period ANOVA results however show that departure times are more uniform for most days except for a significant difference between Tuesday and Fridays.

According to research conducted 15 years ago by Papenfus and van As (1992), it was then observed that the largest variation in traffic volumes occurs on Fridays and recommended that counts not be undertaken on these days. They also found that traffic did vary considerably from the average on the days which schools close and re-open, as well as public holidays. These findings are also confirmed with the Summer Greens data, conducted over a five week period.

The mean first departure times reported across all days of the 5-week survey period is shown in Table 5.7.11.

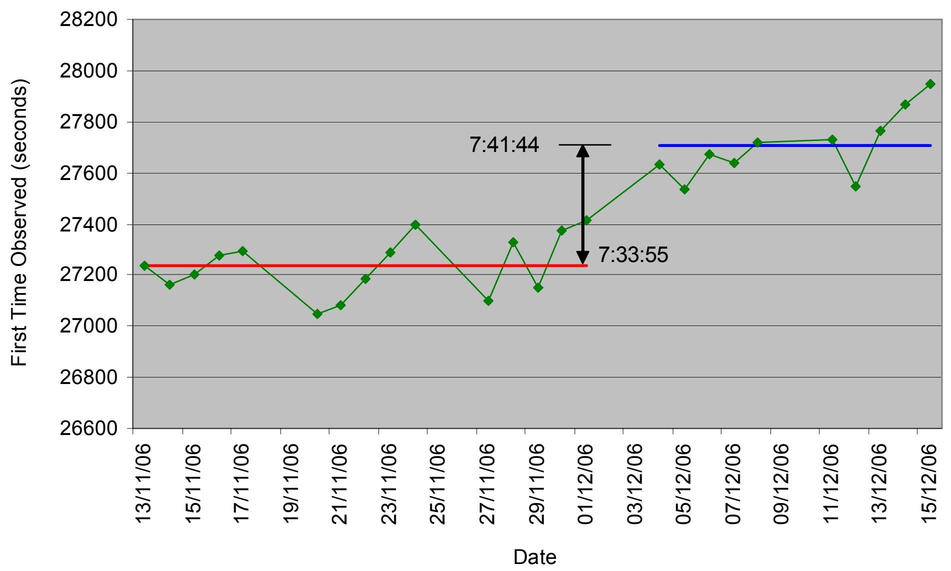
Table 5.7.11 : Comparison of Trip Departure times between School and Holiday Period Days

Date	Day	Day No.	Average Observed Time	Vehicle sample (N)	Average	St Dev
13-Nov-2006	Monday	1	7:33:58	1601	7:33:55	01:55
14-Nov-2006	Tuesday	2	7:32:41	1587		
15-Nov-2006	Wednesday	3	7:33:21	1602		
16-Nov-2006	Thursday	4	7:34:34	1613		
17-Nov-2006	Friday	5	7:34:52	1660		
20-Nov-2006	Monday	6	7:30:49	1608		
21-Nov-2006	Tuesday	7	7:31:22	1636		
22-Nov-2006	Wednesday	8	7:33:05	1671		
23-Nov-2006	Thursday	9	7:34:48	1671		
24-Nov-2006	Friday	10	7:36:38	1660		
27-Nov-2006	Monday	11	7:31:37	1602		

Table 5.7.11 : Comparison of Trip Departure times between School and Holiday Period Days						
Date	Day	Day No.	Average Observed Time	Vehicle sample (N)	Average	St Dev
28-Nov-2006	Tuesday	12	7:35:29	1653		
29-Nov-2006	Wednesday	13	7:32:31	1639		
30-Nov-2006	Thursday	14	7:36:16	1678		
1-Dec-2006	Friday	15	7:36:52	1689		
4-Dec-2006	*Monday*	*16*	*7:40:34*	*1603*	7:41:44	02:11
5-Dec-2006	*Tuesday*	*17*	*7:38:53*	*1576*		
6-Dec-2006	*Wednesday*	*18*	*7:41:09*	*1566*		
7-Dec-2006	*Thursday*	*19*	*7:40:35*	*1579*		
8-Dec-2006	*Friday*	*20*	*7:41:58*	*1596*		
11-Dec-2006	*Monday*	*21*	*7:42:11*	*1580*		
12-Dec-2006	*Tuesday*	*22*	*7:39:04*	*1571*		
13-Dec-2006	*Wednesday*	*23*	*7:42:43*	*1571*		
14-Dec-2006	*Thursday*	*24*	*7:44:28*	*1561*		
15-Dec-2006	*Friday*	*25*	*7:45:45*	*1617*		

Figure 5.7.10 shows a plot of the first departure times across all reported survey days.

Figure 5.7.10 : Mean Observed Departure Times reported across all days in the Survey Period



The figure shows a significant difference in the average departure times between the school and holiday periods. The ANOVA test included in Appendix 3.7 has already confirmed this significant difference between weeks. The average school period departure time is 07:34 with a standard deviation of 1:55. The average holiday period departure time is 07:42 with a standard deviation of 2:11, demonstrating almost a full 10 minute later departure time over the average school period departure time.

It is hypothesised here that the later departure time selected by motorists in the holiday period is triggered by either lower traffic volumes during the holiday period allowing for an average saving of 10 minutes travel time, or due to a saving of 10 minutes due to the freedom of not having to drop off school children en route to work, or a combination of both.

5.7.6 Returning Vehicle Departure Time Differences

A time distribution analysis was conducted on the time difference of occurrence of all "following day repeat" vehicles. This was calculated using the time difference between the first appearance (or occurrence) of both the initial and following day trip. Table 5.7.12 shows the average time difference distribution across weeks for the five week survey period for all following day repeat vehicles. The methodology employed to obtain the data is as follows:

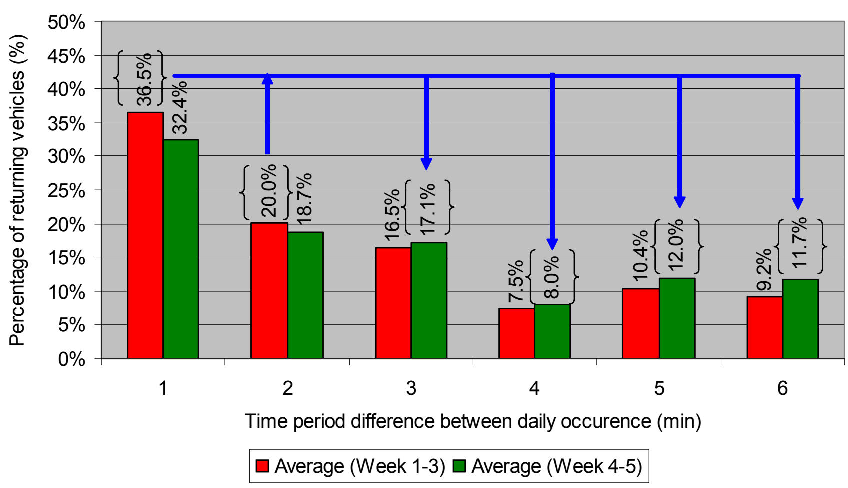
1. Determine if the vehicles are returning vehicles. This is done by identifying if the value of the summation of the "min count" equals two.
2. Then determine the actual observation time of the first occurrence of the vehicle for the initial and the returning day.
3. Calculate the time differences between days and repeat the process for all records.
4. Plot a histogram of the time differences.

Table 5.7.12 : Distribution of Repeat Vehicle time differences across weeks

Minutes	Week 1	Week 2	Week 3	Week 4	Week 5	Average (Week 1-5)	Average (Week 1-3)	Average (Week 4-5)
No repeat								
0-5	37.6%	37.6%	34.2%	32.5%	32.4%	34.8%	36.5%	32.4%
5-10	20.0%	19.9%	20.2%	19.3%	18.0%	19.5%	20.0%	18.7%
10-20	16.7%	15.8%	16.9%	17.0%	17.3%	16.7%	16.5%	17.1%
20-30	6.9%	7.3%	8.2%	8.2%	7.8%	7.7%	7.5%	8.0%
30-60	9.9%	10.3%	11.0%	11.5%	12.5%	11.0%	10.4%	12.0%
> 1 hour	9.0%	9.0%	9.5%	11.5%	12.0%	10.2%	9.2%	11.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

From Table 5.7.12, it is apparent that a small proportion of repeat vehicles (± 5%) occurring in the lower range average time differences ie. 0 to 5 and 5 to 10 minutes in the school period (week 1 to 3) shift to the upper time difference ranges (over ten minute range) during the holiday period (week 4 and 5), confirming the availability of a more flexible daily schedule for motorists during this period. This shift from lower range to upper range time differences is shown in Figure 5.7.11.

Figure 5.7.11 : Comparison of the Average Time Difference Distribution of following day repeat vehicles between the school and holiday period



A proportional z-statistic test was done on the average time distribution of following day repeat vehicles to determine if the differences between the weekly school and holiday period averages, as plotted in Figure 5.7.11 are significantly different. The results of the z-statistic test (included in Appendix 3.10) revealed that only the "0-5 minute" and ">1hour" periods are significantly different for Week 1-3 versus Week 4-5 at the 5% level of significance.

Tables 5.7.13 show the average time difference distributions across days of the week for the entire five week period.

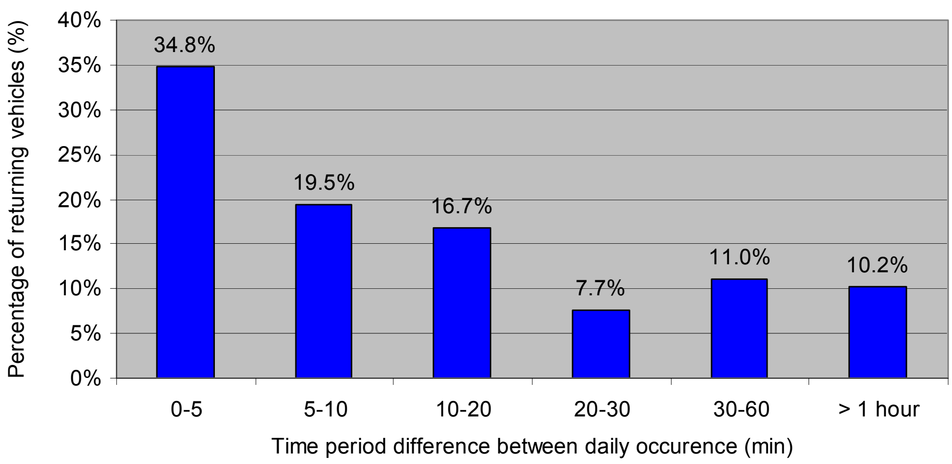
Table 5.7.13 : Distribution of Repeat Vehicle time differences across days

Minutes	Mon-Tues	Tues-Wed	Wed-Thur	Thur-Fri	Average	Cum. Ave
No repeat						
0-5	34.9%	35.7%	36.0%	32.7%	34.8%	34.8%
5-10	20.0%	1-9.3%	19.1%	19.5%	19.5%	54.3%
10-20	16.6%	17.5%	16.3%	16.6%	16.7%	71.1%
20-30	8.0%	7.7%	7.5%	7.6%	7.7%	78.7%
30-60	11.0%	10.3%	10.8%	12.1%	11.0%	89.8%
> 1 hour	9.6%	9.4%	10.3%	11.5%	10.2%	100.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	-

From Table 5.7.13, it becomes apparent that there are no significant differences between the proportions of vehicles reappearing within the specified time bands for all days of the week, except between Thursday and Friday as expected, where a drop of 4% in the “0-5” minute band is taken up by the “>30” minute time difference band, indicating that on Fridays, motorists tend to display greater departure time variability, irrespective of whether it is a school or holiday period.

A histogram showing the distribution of time difference of following day repeat vehicles is plotted in Figure 5.7.12.

Figure 5.7.12 : Time Difference Distribution of following day repeat vehicles



The study by Cherret and McDonald (2002) revealed that between 61.9% to 67.6% of all returning vehicles appeared within five minutes of each other. From the Summer Greens data, it is observed that only 34.8% of returning vehicles appeared within five minutes of each other over the entire five week period. However, this value rises to 54% when the time period window is extended to ten minutes. This result may however change appreciably for peak hour returning vehicles only, which could be conducted in further research.

5.7.7 Returning Vehicle "Median Switch"

In Section 2.2, the concept of a "median switch" was first mentioned and was used by Li, Geunsler, Ogle and Wang (2004) to measure departure time variability in a study conducted in Atlanta, Georgia (USA). A median switch is used to study the time deviation of a motorist's usual travel behaviour. According to the definition, a motorist is said to "switch" when the absolute difference between the departure time being tested and the median of all the motorist's departure times is greater than a certain selected test criteria (t_c) (which could be 5 minutes or 10 minutes for example). The median is selected to avoid the influence of outliers.

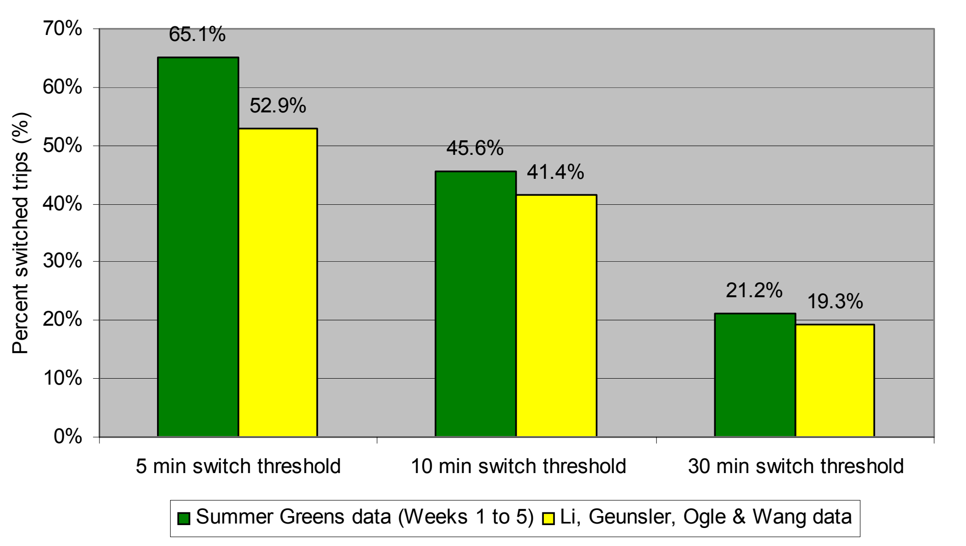
Table 5.7.14 shows the proportion of returning vehicles of the total Dataset version 3 sample which underwent a "median switch" during the entire five week survey period.

Table 5.7.14 : Comparison of "median switch" results between Summer Greens and Atlanta data

Summer Greens Data (Weeks 1 to 5)			
Description	5 min switch threshold	10 min switch threshold	30 min switch threshold
No of median switch (veh)	15951	11172	5191
Sample of returning veh	24509	24509	24509
% of Sample	65.1%	45.6%	21.2%
Atlanta Data (Source : Li, Geunsler, Ogle and Wang data)			
Description	5 min switch threshold	10 min switch threshold	30 min switch threshold
No of median switch (veh)	148	116	54
Sample of returning veh	280	280	280
% of Sample	52.9%	41.4%	19.3%

Figure 5.7.13 shows the graphic representation of the "median switch" differences between the Summer Greens data and the Atlanta (Georgia) data.

Figure 5.7.13 : Comparison of Summer Greens with Atlanta "median switch" data



From Figure 5.7.13, the Summer Greens data shows more variability ie. there is a bigger proportion of motorists performing departure time “median switches”, which may be due to flexible working times. A proportional z-statistic test was done on the two datasets to determine if the differences between the Summer Greens and Atlanta “median switch” proportions are significantly different. The results of the z-statistic test (included in Appendix 3.11) revealed that only the "5 minute" switch criteria is significantly different at the 5% level of significance.

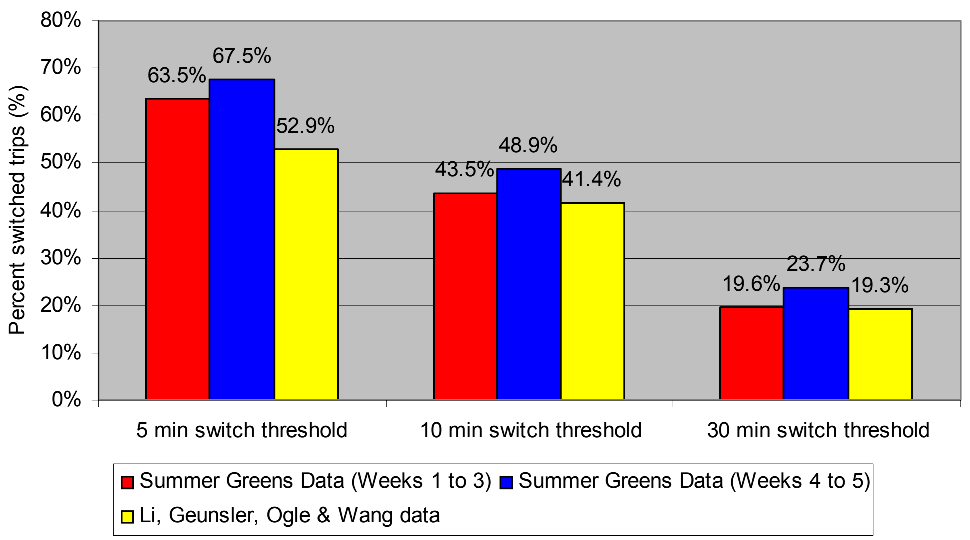
It was decided to analyse the school and holiday period “median switch” occurrences separately to determine the impact (and significance) of a “more flexible” schedule during the holiday period (weeks 4 and 5). Table 5.7.15 tabulates the proportion of returning vehicles of the total Dataset sample which underwent a “median switch” analysed separately during the school period (first 3 weeks and the holiday period (last 2 weeks).

Table 5.7.15 : Comparison of Summer Greens school and holiday period “median switch” vehicles

Summer Greens School Period Data (Weeks 1 to 3)			
Description	5 min switch threshold	10 min switch threshold	30 min switch threshold
No of median switch (veh’s)	9577	6559	2953
Sample of returning veh	15071	15071	15071
% of Sample	63.5%	43.5%	19.6%
Summer Greens Holiday Period Data (Weeks 4 to 5)			
Description	5 min switch threshold	10 min switch threshold	30 min switch threshold
No of median switch (veh’s)	6374	4613	2238
Sample of returning veh	9438	9438	9438
% of Sample	67.5%	48.9%	23.7%

Figure 5.7.14 shows the graphic representation of the differences between the Summer Greens school versus holiday “median switch” vehicle proportions including the Atlanta (Georgia) data for comparison purposes.

Figure 5.7.14 : Comparison of school versus holiday period “median switch” vehicles



The figure shows a closer correlation of the school period data with the Atlanta data and the results of the z-statistic test (included in Appendix 3.12) when comparing the Summer Greens data with the Atlanta (Georgia) data again revealed that only the "5 minute" switch criteria is significantly different at the 5% level of significance. However, the results of the z-statistic test (included in Appendix 3.13) when comparing the Summer Greens holiday period data with the Atlanta (Georgia) data revealed that all three switch criteria viz. the 5, 10 and 30 minute switch thresholds are significantly different at the 5% level of significance. The outcome of this test may be influenced by the fact that the Atlanta survey was conducted over a normal school period.

Finally, a z-statistic comparison between the Summer Greens school data versus the holiday data (included in Appendix 3.14) also indicated significant differences for all three switch criteria at the 5% level of significance, again confirming the flexibility “available” to motorists during the holiday period.

5.8 Unique Vehicles

In Section 5.6.1, the distribution of trip frequencies was discussed where it was shown that 2440 vehicles (out of 5677 vehicles) or 42.98%, were only ever observed once during the five week survey period. This section deals with these “unique” vehicles in more detail.

Table 5.8.1 provides a detail of the breakdown in time periods of all “unique” vehicles observed. In the table, “Non-unique” vehicles are defined as vehicles observed on more than one day. Theoretically, the Summer Greens survey data should constitute only a small proportion of unique vehicles unless residents only use their car once in five weeks, or is a result of the influence of u-turners, visitor-guests, delivery vehicles, taxis and bus operations, or local households who own more than one car. We will see that this proportion is greatly influenced by time of day.

Table 5.8.1 : Unique vehicles per 15-minute time periods (Overall Summer Greens data)

Time Period	Unique (no.)	Non-unique (%)	Unique (%)	Non-unique (%)	Ave Non-unique (%)
5:45-6:00	21	197	Outside window*		
6:00-6:15	37	277			
6:15-6:30	58	350	14.2%	85.8%	75.4%
6:30-6:45	112	434	20.5%	79.5%	
6:45-7:00	132	377	25.9%	74.1%	
7:00-7:15	145	354	29.1%	70.9%	
7:15-7:30	130	260	33.3%	66.7%	
7:30-7:45	165	214	43.5%	56.5%	55.8%
7:45-8:00	138	169	45.0%	55.0%	
8:00-8:15	171	137	55.5%	44.5%	41.3%
8:15-8:30	166	102	61.9%	38.1%	
8:30-8:45	162	75	68.4%	31.6%	31.8%
8:45-9:00	150	79	65.5%	34.5%	
9:00-9:15	162	67	70.7%	29.3%	
9:15-9:30	221	41	84.4%	15.6%	12.6%
9:30-9:45	273	29	90.4%	9.6%	
9:45-10:00	262	10	Outside window*		
Total	2185	2688	-	-	-

*This time period is considered to be outside the window of analysis.

The first two time periods from 05:45 to 06:15 and the last time period from 09:45 to 10:00 is excluded as vehicles observed in these time periods could erroneously be identified as "unique" vehicles due to the fact that they are bordering on the limits of the survey and may in fact return just earlier or later than these limits on other days.

From the table, we note that the average percentage of non-unique (returning) vehicles decreases with later time periods as follows :

From 6:15 to 7:30 : 75% returning vehicles
From 7:30 to 8:00 : 56% returning vehicles
From 8:00 to 8:30 : 41% returning vehicles
From 8:30 to 9:15 : 32% returning vehicles
From 9:15 to 9:45 : 12% returning vehicles

The application of this finding is important for VMS applications as it is argued that the display of information on such signage is more effective the higher the proportion of returning vehicles. It is assumed that returning vehicles would be familiar with the road network and more adept and willing to change their usual route should VMS indicate an incident location or other congestion situation on their usual planned route. In the Summer Greens situation, VMS (or RDS) data would optimally be displayed (or broadcasted) before 07:30 when 75% of the vehicles are returning vehicles. Based on the previous argument, it is hypothesised that the impact of VMS and RDS would diminish with time after 07:30.

By comparison, a numberplate survey conducted by Cherrett and McDonald (2002), in 1994 and 1996 at two sites in Southampton (refer to Section 2.2) found that the percentage of returning vehicles (non-unique) that appeared on more than one day formed 80% of the traffic before 08:15 but only 60% between the 08:45 to 09:00 peak period.

A further analysis was conducted on the Summer Greens data to determine the impact of school and holiday periods on the "unique" vehicle proportions with time. For this analysis, and in an attempt to "focus" on the commuter proportion of the study, it was decided to remove heavy vehicles, minibus-taxis and "u-turn" vehicles from the dataset, as it is assumed that these vehicles are more likely to be unique vehicles and so may influence the behaviour results that is desired from the "commuter" proportion of motorists.

Table 5.8.2 provides a detail of the breakdown in time periods of all observed unique vehicles (for car vehicles only) observed during the school (weeks 1 to 3) and holiday (weeks 4 and 5) survey periods.

Table 5.8.2 : Comparison of Unique vehicles per 15-minute time periods : School vs Holiday period (Car vehicles only)

Time Period	School Period			Holiday Period		
	Unique (No.)	Not Unique (No.)	Not Unique (%)	Unique (No.)	Not Unique (No.)	Not Unique (%)
5:45-6:00	12	119	n/a	16	94	n/a
6:00-6:15	39	189	n/a	14	150	n/a
6:15-6:30	44	262	14.4%	34	201	14.5%
6:30-6:45	75	352	17.6%	49	276	15.1%
6:45-7:00	92	319	22.4%	47	258	15.4%
7:00-7:15	103	317	24.5%	68	255	21.1%

Table 5.8.2 : Comparison of Unique vehicles per 15-minute time periods : School vs Holiday period (Car vehicles only)						
Time Period	School Period			Holiday Period		
	Unique (No.)	Not Unique (No.)	Not Unique (%)	Unique (No.)	Not Unique (No.)	Not Unique (%)
7:15-7:30	99	226	30.5%	56	206	21.4%
7:30-7:45	105	166	38.7%	56	201	21.8%
7:45-8:00	104	126	45.2%	67	152	30.6%
8:00-8:15	94	111	45.9%	90	108	45.5%
8:15-8:30	85	63	57.4%	95	77	55.2%
8:30-8:45	84	59	58.7%	77	60	56.2%
8:45-9:00	94	55	63.1%	80	50	61.5%
9:00-9:15	91	38	70.5%	95	41	69.9%
9:15-9:30	147	28	84.0%	95	24	79.8%
9:30-9:45	164	18	90.1%	114	19	85.7%
9:45-10:00	149	5	n/a	131	6	n/a
Total	1381	2140		1023	1928	-

Table 5.8.3 shows the average percentage of unique vehicles per morning period time slice observed at the Winchester Road and Bassett Avenue surveys as observed by Cherrett and McDonald (2002).

Table 5.8.3 : Percentage Unique vehicles observed in the 1996 Winchester Rd and Bassett Ave surveys (Source : Cherrett and McDonald, 2002)		
Time Slice	Bassett Ave	Winchester Road
07:45 – 08:00	19.0%	18.0%
08:00 – 08:15	18.5%	22.0%
08:15 – 08:30	26.0%	27.0%
08:30 – 08:45	32.0%	34.0%
08:45 – 09:00	39.0%	41.0%

Figure 5.8.1 shows a summary of the percentage unique vehicles for each of the three Summer Greens Scenarios (viz, overall data (all vehicles), school data (cars only) and holiday data (cars only) together with the results of the Cherrett and McDonald (2002) study.

Figure 5.8.1 : Summary plot of Unique vehicle proportions for Summer Greens data (School and Holiday periods) and Cherrett & McDonald (2002) study from 07:45 – 09:00

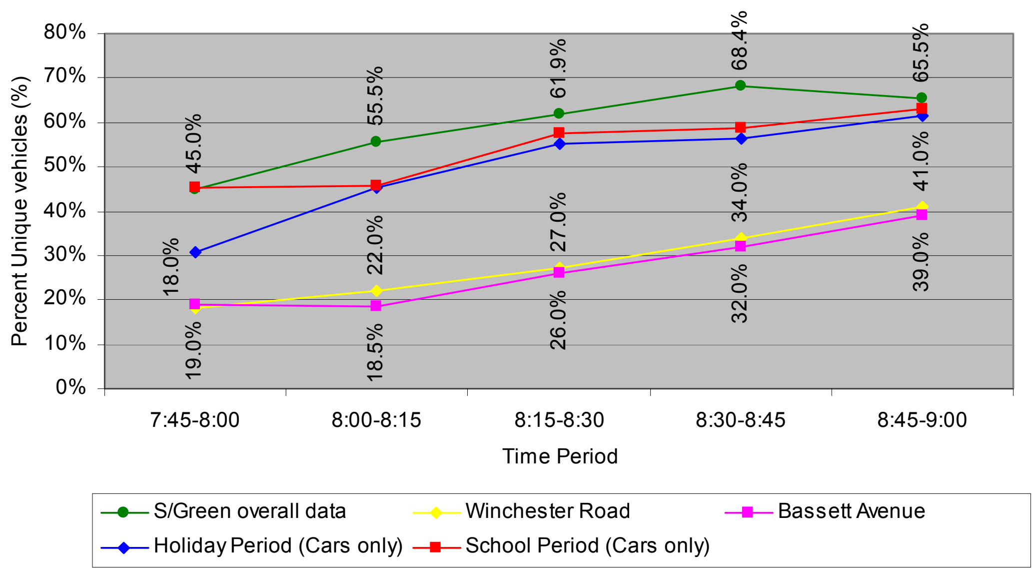


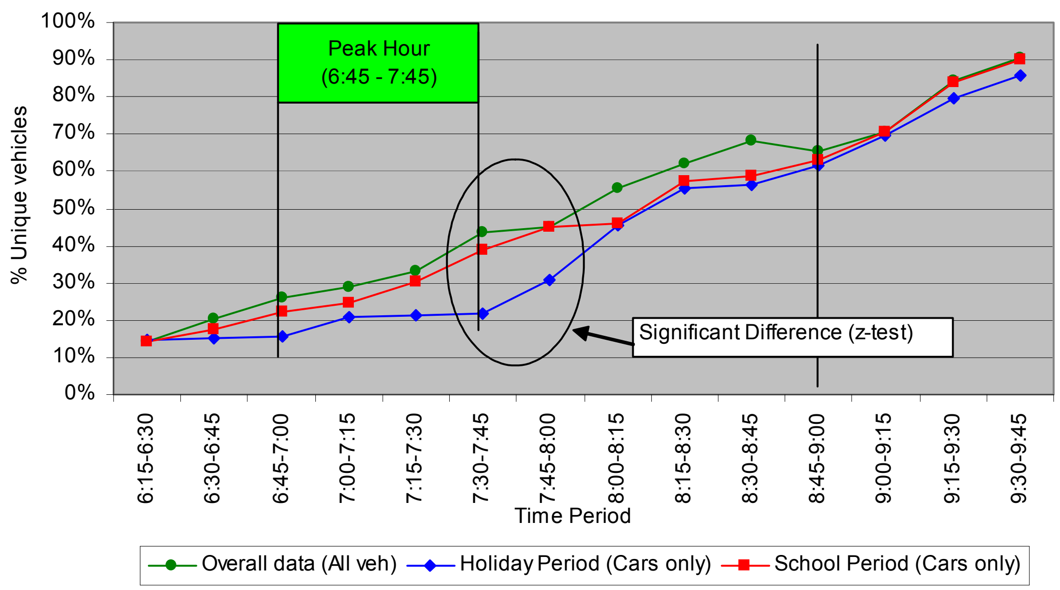
Figure 5.8.1 shows that the removal of the heavy vehicles, minibus-taxis and “u-turn component of the dataset reduces the unique vehicle occurrence, but more so during holiday period.

Figure 5.8.1 also shows the data between 07:45 and 9:00 am only and shows that 45% of all Summer Greens vehicles observed in the 07:45 to 08:00 time slot were unique ie. never observed again in the 5-week survey period. This is a difference of 26% when compared to an average of 19% for the Cherret and McDonald data for the same time period.

Both datasets show an increase in the percentage of unique vehicles with time and both datasets appear to do so at the same rate with a consistent difference of approximately 30% between the two dataset points with the Summer Greens data having more unique vehicles per time slot than the Cherret and McDonald data. This is contrary to expected results, as since the Summer Greens data was obtained from surveys conducted at the only possible residential exit route, the unique vehicle proportions would therefore not be expected to be more than the Cherret and McDonald data.

Figure 5.8.2 shows a summary of the percentage unique vehicles for each of the three Summer Greens Scenarios (viz, overall data (all vehicles), school data (cars only) and holiday data (cars only) over the full time duration of the survey.

Figure 5.8.2 : Summary plot of Unique vehicle proportions for Summer Greens data (School and Holiday periods) for the full time duration of the survey



From Figure 5.8.2 it is shown that vehicles appearing on more than one day formed 75% of the total traffic before 07:00 am for the overall Summer Greens dataset. In the peak hour (06:45 to 07:45), vehicles appearing more than one day reduces from 75% to 55% over the one hour period. After the peak hour, the vehicles appearing more than once, reduces even further from 55% to 10%.

A proportional z-statistic test was done on the unique vehicle proportions of the Summer Greens school and holiday period data as plotted in Figure 5.8.2 to determine if any significant difference exist. The results of the z-statistic test (included in Appendix 3.16) revealed that no significant difference in the overall, school and holiday data is observable after 08:45 at the 5% level of significance. The only significant difference calculated is the two 15-min periods within the 07:30 to 08:00 time period, where significantly more unique vehicles are observed during the school period. In fact, over an average 4-hour survey day, it is observed that there are fewer unique vehicles during the holiday period than the school period perhaps as a result of a lowered business and commercial activity.

In summary and with particular reference to the Summer Greens travel behaviour results, VMS (or RDS) data would optimally be displayed (or broadcasted) before 07:45 when at least 75% of the vehicles are returning vehicles. After 08:15, less than 40% of vehicles are returning vehicles and based on the previous argument, the impact of VMS and RDS would diminish after this time.

5.9 Action Space

The concept of using “Action Space” plots to represent travel behaviour data was used effectively by Schönfelder (2001). The boxplots allow a clear representation of the most important statistics and a comparative assessment of the extent of dispersion. The box of which the inner line shows the median, is limited by the first and the third quartile of the distribution.

Table 5.9.1 shows the statistical data of the vehicle time observation of the Summer Greens dataset. The analysis shown in the table excludes all recorded vehicles prior to 06:00 and after 10:00 am. Data with values beyond the ends of the first and the third quartile of the distribution is not shown here.

Table 5.9.1 : Daily record statistics of vehicle time observations

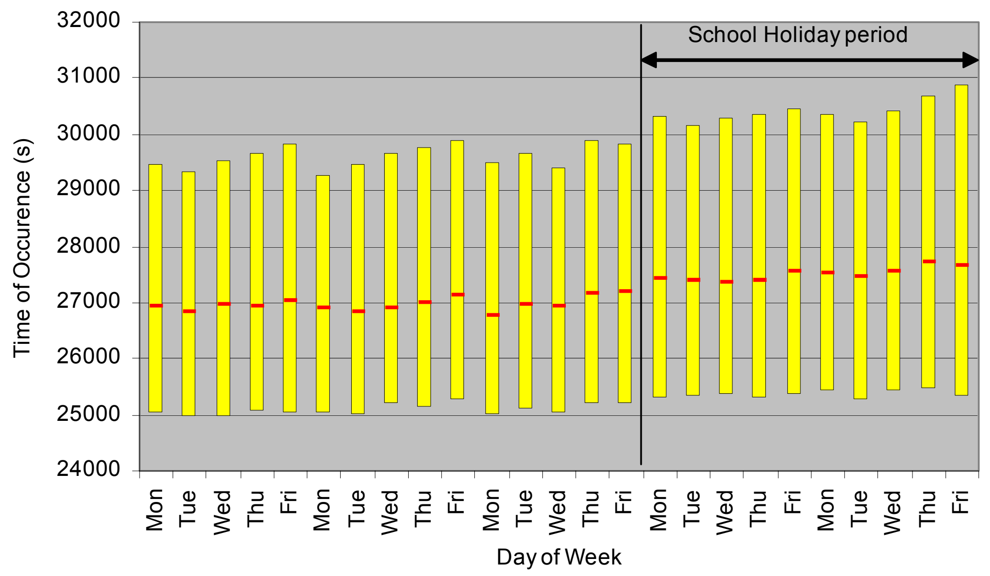
Week	Day	DOW	Min	25th %tile	50th %tile (Median)	75th %tile	Max	25th to 75th %tile bandwidth
1	1	Mon	6:00:23	6:56:58	7:28:59	8:11:03	9:58:37	1:14:05
	2	Tue	6:00:21	6:55:50	7:27:10	8:08:47	9:59:42	1:12:56
	3	Wed	6:00:39	6:55:58	7:29:11	8:12:20	9:59:47	1:16:21
	4	Thu	6:00:32	6:57:20	7:28:44	8:14:09	9:59:59	1:16:48
	5	Fri	6:00:01	6:56:56	7:30:35	8:17:11	9:59:50	1:20:15
2	6	Mon	6:00:07	6:57:05	7:28:06	8:08:02	9:59:36	1:10:57
	7	Tue	6:00:20	6:56:29	7:27:13	8:11:18	9:58:58	1:14:49
	8	Wed	6:00:08	6:59:42	7:28:29	8:14:19	9:59:36	1:14:37
	9	Thu	6:00:21	6:58:24	7:29:52	8:16:00	9:59:51	1:17:36
	10	Fri	6:00:05	7:00:39	7:32:08	8:18:17	9:59:56	1:17:38
3	11	Mon	6:02:04	6:56:38	7:26:14	8:11:47	9:59:47	1:15:09
	12	Tue	6:00:00	6:57:58	7:29:39	8:14:34	9:59:45	1:16:36
	13	Wed	6:00:15	6:57:08	7:28:39	8:09:49	9:52:07	1:12:41
	14	Thu	6:00:08	6:59:46	7:32:37	8:18:07	9:59:30	1:18:21
	15	Fri	6:00:05	6:59:58	7:32:57	8:17:06	9:59:58	1:17:07
4	*16*	*Mon*	6:00:08	*7:01:15*	*7:37:01*	*8:25:10*	*9:58:35*	1:23:55

Table 5.9.1 : Daily record statistics of vehicle time observations

Week	Day	DOW	Min	25th %tile	50th %tile (Median)	75th %tile	Max	25th to 75th %tile bandwidth
	17	*Tue*	6:00:06	*7:01:58*	*7:36:41*	*8:22:30*	*9:59:55*	1:20:31
	18	*Wed*	6:00:12	*7:02:22*	*7:35:58*	*8:24:41*	*9:59:52*	1:22:19
	19	*Thu*	6:00:01	*7:01:11*	*7:36:46*	*8:25:48*	*9:59:35*	1:24:37
	20	*Fri*	6:00:15	*7:02:35*	*7:39:01*	*8:27:33*	*9:59:51*	1:24:58
5	*21*	*Mon*	6:00:03	*7:03:46*	*7:38:40*	*8:26:10*	*9:59:56*	1:22:23
	22	*Tue*	6:00:02	*7:01:05*	*7:37:27*	*8:23:46*	*9:59:59*	1:22:41
	23	*Wed*	6:00:13	*7:03:19*	*7:39:11*	*8:27:09*	*9:59:54*	1:23:49
	24	*Thu*	6:00:42	*7:04:00*	*7:41:55*	*8:31:12*	*9:59:33*	1:27:12
	25	*Fri*	6:00:24	*7:02:10*	*7:40:58*	*8:34:48*	*9:59:58*	1:32:38

Figure 5.9.1 shows the extent of the dispersion of action spaces for the Summer Greens dataset over the full duration of the survey. The red line indicates the median time of all vehicle times observed with the 75th percentile value forming the upper boundary of the box (or "action space") and the 25th percentile value forming the lower boundary of the "action space". In the figure, time has been converted to a 24-hour second clock.

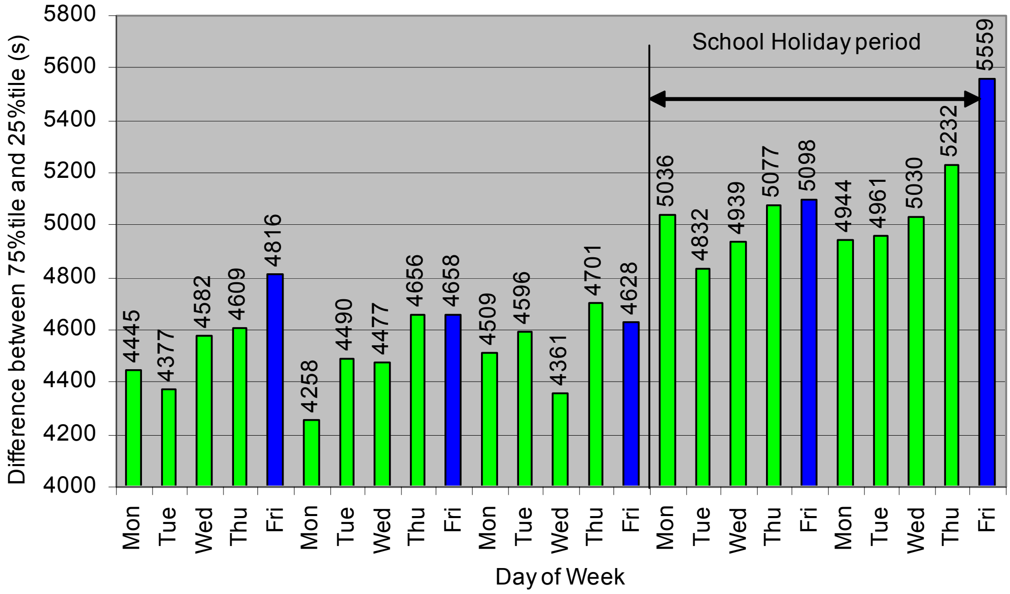
Figure 5.9.1 : Plot of Vehicle Time occurrence "Action Space"



From Figure 5.9.1 it can be observed that the median times during both the school and holiday periods are uniform, with the school period median time averaging at 7:29:22, which is slightly lower than the holiday period median, averaging at 7:38:21, a difference of approximately nine minutes.

In order to view the bandwidth action space differences more clearly, it was decided to plot the 25th to 75th percentile bandwidth values on a common zero axis and is shown in Figure 5.9.2 below. For ease of reference, all Friday bandwidths are indicated in blue.

Figure 5.9.2 : Plot of 25th to 75th Percentile Bandwidth



From Figure 5.9.2, the bandwidth observations on Fridays confirm the findings of Schönfelder (2001), also refer to Section 2.2, who found that there was more extensive use of time area space on Fridays. Interestingly, although there are greater traffic volumes recorded during the school period, the area time spread for this period is far less than the holiday period across all days of the week. The holiday period is visibly less time constrained with larger area spaces, particularly on Fridays, even though there is less traffic. The bandwidth data also appears to increase linearly from week 1 with maximum values calculated in week 5. A linear regression exercise revealed a coefficient of regression value (R^2) of 0.68 for the entire survey period.

It should also be noted that the first Monday of the holiday period experiences almost the same area space as Friday of that week. Greater use of cars on Friday outside peak times may account for the greater variation in time area spaces.

An ANOVA test was conducted (refer to Appendix 3.17) to confirm the significance of the visual differences observed in the 25th to 75th percentile bandwidth action spaces. The result of the analysis confirmed the expected significant difference between the school period (weeks 1 to 3) versus holiday period (weeks 4 and 5) bandwidths. However, no significant differences in daily bandwidths within these periods were calculated at the 5% level of significance.

A final ANOVA test was conducted (refer to Appendix 3.18) on the median values of the data sample confirmed the significance of the median differences between the school and holiday periods (ie. significant differences between the school period weeks (weeks 1 to 3) and holiday period (weeks 4 and 5) but with an unexpected significant median difference calculated between week 4 and 5 as well. This final result again confirms the time flexibility available to motorists during even the first week of the holiday period and the results show even more flexibility in the second week of the holiday period.

5.10 Measuring Variability

How does one measure travel behaviour variability? Several methods have been proposed by various researchers, discussed in Chapter 2 and summarised by Schlich (2001b) who compared several methods of variability measurement. These methods allow the degree of travel behaviour variability to be compared for various datasets. Most of the formulae developed however use multi-criteria characteristics such as travel mode, trip purpose, trip distance, trip destination etc. and can therefore not be applied to the limited Summer Greens dataset.

A more applicable method suggested here, and presented in this thesis purely as a theoretical exercise, is an adaptation of the Similarity index Clarke/Jones, SC_{ij} , which compares trip similarity based on a time budget rather than on trips. This index method is exclusively based on times of performed activities and ignores attributes like traffic mode and other attributes.

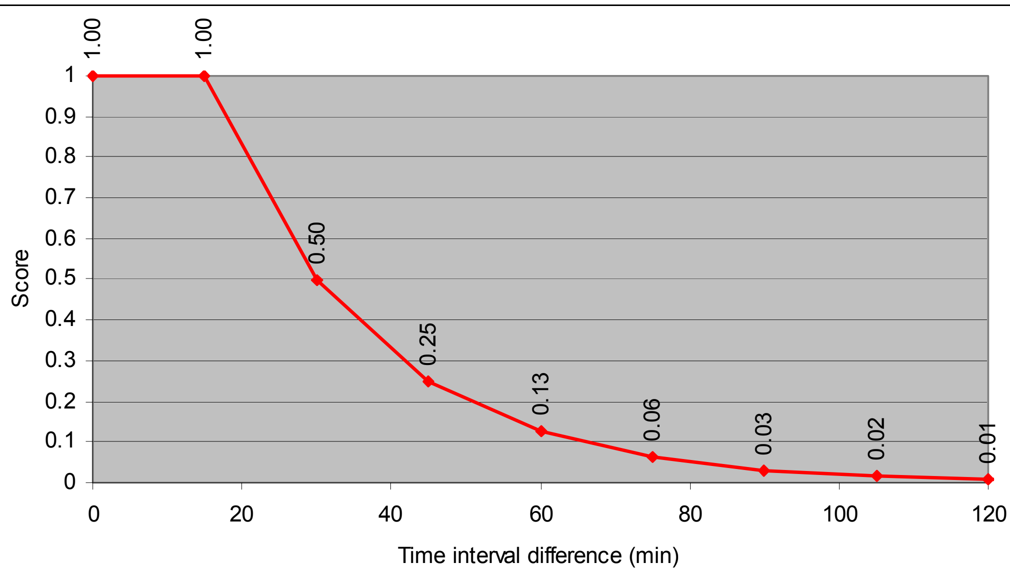
The similarity index used in the analysis of the Summer Greens dataset, is termed Similarity index Hermant, $SHer_{ij}$ with the following equation formulated to calculate the index:

$$SHer_{ij} = \sum_{n=1}^{max}\left[\frac{(\alpha \times T_w)}{(5 \times nw)} + \frac{(\beta \times T_{int})}{(4 \times nw)}\right]$$

The primary attribute (T_w) is the total number of daily trips (maximum 1 per day) observed over the analysis period consisting of a number of weeks (nw). The total minimum number of trips per week is counted (ie. multi trips per day are excluded) and a maximum score of 1 is allocated for 5 trips per week representing a maximum weekly repetitive pattern.

The secondary attribute (T_{int}) is the time interval of recurring trips. The greater the difference in returning time difference, the lower the score. Figure 5.10.1 shows a theoretical profile of the time interval scoring.

Figure 5.10.1 : Time interval difference scoring chart

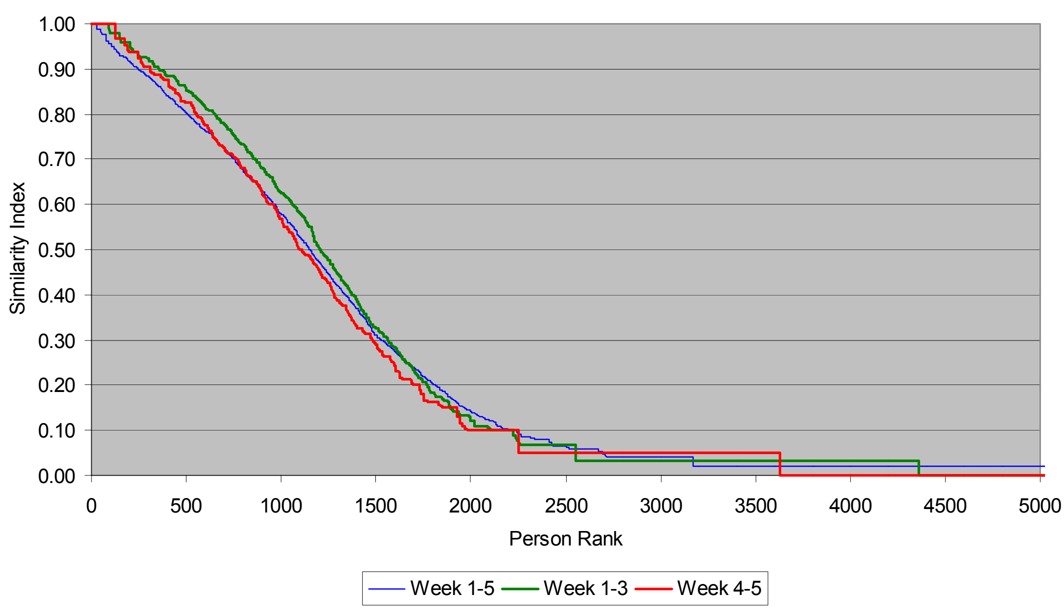


From Figure 5.10.1, a returning vehicle observed to within 15 minutes of the previous day would be allocated a score of 1 whilst a returning vehicle with a time interval difference of 30 minutes would be allocated a score of 0.5. The scoring is only allocated for vehicles returning on successive days. A vehicle appearing on Monday and again on Wednesday, even with a 5 minute time interval, would not be allocated any points. As only four comparisons per week can be made (viz. Monday with Tuesday, Tuesday with Wednesday etc.) a maximum score of 4 can be achieved for this attribute. The total for all five weeks are added together and divided by 20 to provide a maximum score of 1 representing an identical activity pattern.

The final score is obtained by addition of the two attributes after applying a relative weight to both the primary attribute (α) and secondary attribute (β). For the purposes of this analysis, an equal weighting of 0.5 was applied to both α and β. Finally, the scoring is rank ordered and plotted. Figure 5.10.2 shows the distribution of the Similarity index Hermant, $SHer_{ij}$, over the entire five week period showing the first three week school period and the last two week holiday period for comparison purposes. An index value of one indicates identical activity whilst zero represent no matches or no commonality.

Figure 5.10.2 shows the similarity index scoring rank ordered for all 5677 observed vehicles in the dataset. From the figure, week 1 to 3 (green line) displays more identical activity than the red line representing the holiday period (week 4 to 5), which displays less identical patterns since uniformly below the green line which was the expected result.

Figure 5.10.2 : Summer Greens Distribution of Similarity Indices

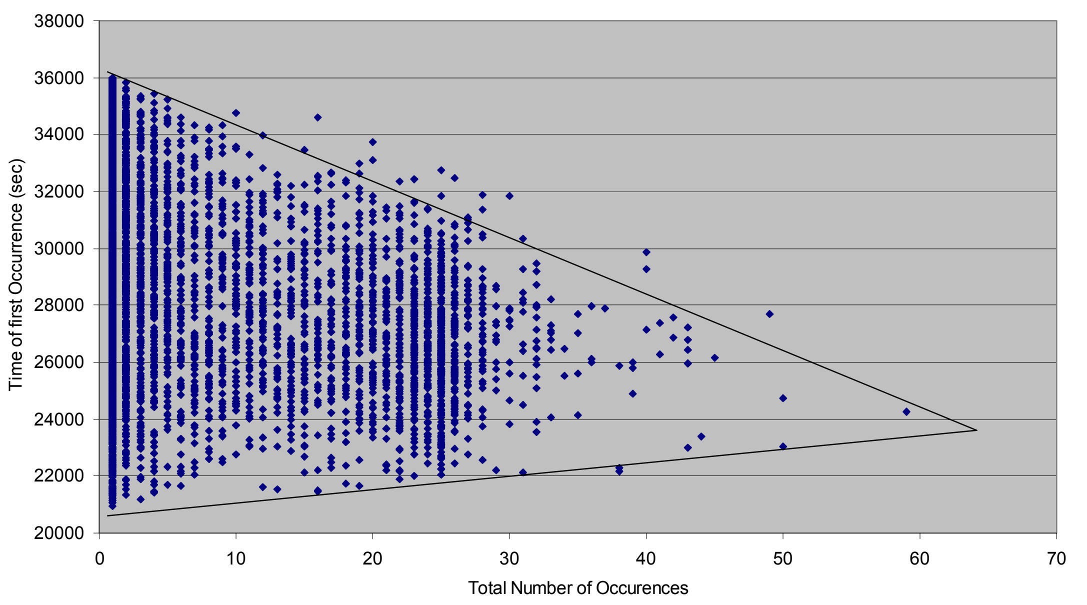


5.11 The Relationship between Departure time and Observation Frequency

The research by Cherrett and McDonald (2002) concluded that an understanding of the variation of departure times can help in determining the optimum times to display important traffic information to drivers via variable message signs (VMS) as discussed in Section 5.8. The subject of vehicle departure times is the focus of this section but with the objective of congestion pricing in mind.

The purpose of identifying the relationship between departure times and weekly trip frequencies is to provide some understanding and background before applying congestion pricing theories discussed later in Chapter 6. With this in mind, it was decided to analyse private vehicles (ie. cars) only, as this mode of transport would be the most affected and is essentially the primary target of congestion pricing. A raw plot showing the average "first time of occurrence" for each of the 5309 vehicles, over the five week survey period is shown in Figure 5.11.1. The data is arranged along the x-axis according to the total no of occurrences.

Figure 5.11.1 : Summer Greens raw plot of average "first time of occurrence"



From the figure it appears that the time range of occurrence (y-axis) diminishes with increasing frequency of occurrence (x-axis). This raw data was analysed into a histogram together with 25th, 50th and 75th percentile times of occurrence for further analysis. The data is tabulated in Table 5.11.1.

Table 5.11.1 : Data histogram of "first time of occurrence"

Total Occurrences	Data Records	25th %tile	50th %tile (Median)	75th %tile	25th to 75th %tile bandwidth
1	2230	7:27:34	8:25:49	9:22:40	1:55:05
2	502	7:19:54	8:13:07	9:11:23	1:51:29
3	262	7:13:18	8:08:33	9:06:01	1:52:42
4	185	7:09:44	8:01:47	8:58:10	1:48:26
5	136	7:14:16	8:01:05	9:00:26	1:46:09
6	100	7:00:40	7:48:34	8:51:32	1:50:52
7	89	6:51:06	7:31:33	8:31:48	1:40:42
8	92	6:58:16	7:34:45	8:38:45	1:40:29
9	71	7:05:37	7:55:41	8:42:15	1:36:38
10	62	7:12:17	7:52:45	8:33:43	1:21:26
11	75	6:54:57	7:41:28	8:25:58	1:31:01
12	76	7:03:58	7:42:20	8:27:43	1:23:44
13	55	6:46:12	7:25:49	8:30:14	1:44:01
14	65	6:53:41	7:21:07	8:10:31	1:16:50

Table 5.11.1 : Data histogram of "first time of occurrence"

Total Occurrences	Data Records	25th %tile	50th %tile (Median)	75th %tile	25th to 75th %tile bandwidth
15	61	6:52:00	7:28:38	8:12:11	1:20:11
16	56	6:57:33	7:33:10	8:21:50	1:24:17
17	60	6:45:18	7:24:45	8:13:56	1:28:37
18	64	6:51:42	7:23:59	8:11:13	1:19:31
19	73	6:54:43	7:32:45	8:19:53	1:25:10
20	75	6:56:30	7:28:14	8:09:20	1:12:50
21	74	6:56:58	7:24:18	7:56:16	0:59:18
22	91	6:47:44	7:18:32	7:57:01	1:09:17
23	121	6:55:22	7:20:49	7:49:01	0:53:38
24	139	6:54:19	7:22:17	7:49:56	0:55:37
25	221	6:53:44	7:19:11	7:43:50	0:50:06
26	96	6:54:27	7:20:19	7:50:27	0:56:00
27	47	6:52:27	7:25:44	7:53:01	1:00:33
28	37	6:57:04	7:25:27	8:03:13	1:06:09
29	14	7:02:50	7:20:56	7:34:39	0:31:49
30	11	6:51:53	7:32:46	7:57:30	1:05:37
31	11	7:04:37	7:32:37	7:59:17	0:54:39
32	17	6:51:46	7:26:47	7:53:47	1:02:00
33	7	7:01:41	7:23:35	7:39:13	0:37:31
34	2	7:02:43	7:08:43	7:37:52	0:35:08
35	4	6:42:32	7:23:38	7:37:17	0:54:44
36	3	7:07:19	7:16:15	7:40:21	0:33:02
37	1	7:26:17	7:36:17	7:44:40	0:18:23
38	3	6:06:19	6:10:38	6:51:53	0:45:34
39	3	6:41:02	6:49:46	7:08:42	0:27:40
40	3	7:28:11	7:40:21	8:29:01	1:00:50
41	2	6:47:26	6:52:32	8:05:42	1:18:15
42	2	7:26:36	7:31:02	7:35:40	0:09:03
43	5	7:06:58	7:17:38	7:27:23	0:20:25
44	1	6:11:05	6:17:35	6:22:08	0:11:03
45	1	7:01:04	7:08:21	7:21:34	0:20:30
49	1	6:52:41	7:51:13	8:16:55	1:24:14
50	2	6:23:47	6:36:49	6:49:28	0:25:41
59	1	6:12:43	6:15:46	7:22:37	1:09:53

The data presented in the table is plotted as a series of two graphs. The first graph in Figure 5.11.2 shows the relationship of frequency of appearance with the total number of occurrences. Figure 5.11.3 shows the action space bandwidth (ie 25^{th} to 75^{th} percentile values) of the "first times of occurrence" associated with each vehicle identified within the survey time period 05:45 to 10:00.

Figure 5.11.2: Average "first time of occurrence" Action Space Plot

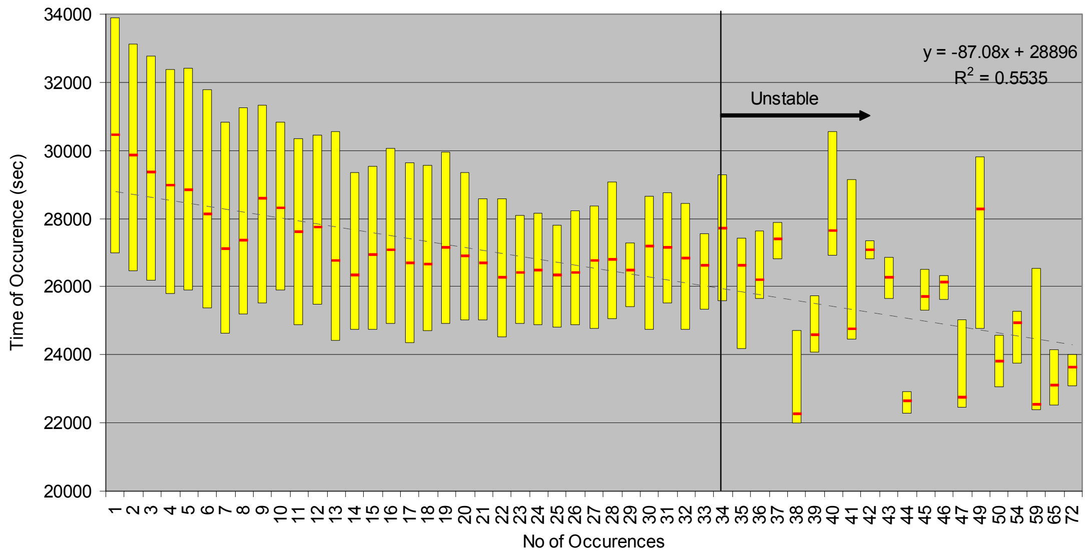


Figure 5.11.3 : Histogram showing average "first time of occurrence" bandwidths

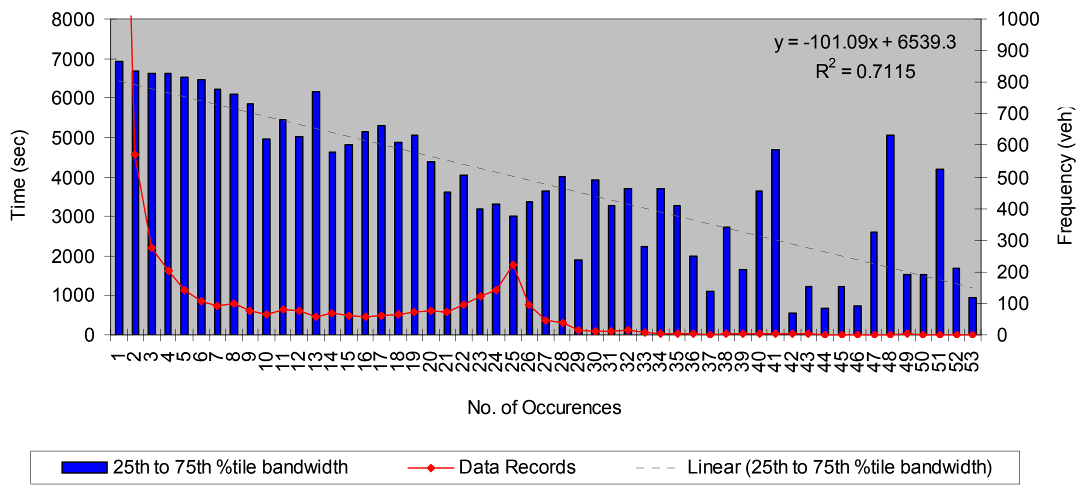


Figure 5.11.2 shows that there is a gradually decreasing tendency of the median "first occurrence observation" times (red tick) relative to "no. of occurrences" and that there is some "instability" after a total occurrence of around 34 observations per vehicle for the entire survey period. This translates to an average trip rate of 1.36 per day and the area of instability is attributable to private car business activity conducted after the peak period rather than commuting activity. The yellow bar in the graph shows the extent of the 25th to 75th percentile action space relative to its true position in time (y-axis).

Figure 5.11.3 plots the action space on a common zero axis which confirms the decreasing action space bandwidth with increasing observation frequencies observed earlier in the raw plot in Figure 5.11.1. The red line in the graph indicates the actual number of vehicles associated with each frequency. Note the high proportions of vehicles associated with the "less than five occurrences" per survey period and the high number of vehicles observed in the "23 to 27 occurrences" area.

6. APPLICATION OF DATA

6.1 Introduction

An example of the application of road behaviour theory pertains to electronic road pricing feasibility studies. Policy issues facing planners and politicians such as "how many car owners would be affected by a road pricing scheme, if charges were imposed only on Monday through Friday from 06:00 to 10:00 am ?" is one question that would benefit from day-to-day travel behaviour research to determine the most effective scheme.

According to Pendyala (2003), multiday data provides information about the distribution of the frequency of participation, in addition to the mean participation rate. Jones and Clarke (1988) indicate that information on the frequency of participation allows the planner to gauge the exposure of different demographic and travel segments to various policy scenarios.

The City of Cape Town's ITP document (2006) has reported that millions of rand is lost to the economy as a result of the congestion in Cape Town with peak periods now extending towards three hours on a daily basis. The same report indicated that "*the need and practicality of congestion pricing in Cape Town should be evaluated*" through use of Travel Demand Management Strategies (TDM), Intelligent Transportation Systems (ITS) using VMS and/or RDS and finally Transportation Systems Management (TSM) measures. The ITP document also contributes rising congestion levels to increasing car ownership.

6.2 Car Ownership in South Africa

Recent research by Venter (2007) supports the fact that international households purchase a car as soon as they can afford to do so and in fact there is an acceleration of such a car ownership trend in South Africa due to certain local factors such as socio-economic changes, car prices, spatial factors etc. In fact, of all South African cities, Cape Town has the leading "car access" statistic per household at 49% of all metro households compared to Johannesburg at 32%.These factors are reported to be outside the control of government with a resultant rise in traffic demand and hence congestion due to increased use of personal cars. According to the State of Cape Town report (2006), in 2001 there were 787 644 vehicles registered in Cape Town and by 2003 this number had grown to 810 967 vehicles – an increase of 11 661 vehicles per year (1.47% p.a.) or equivalent to an additional 32 vehicles per day adding to the congestion of the existing network everyday of the year.

Economic prosperity of a nation leads to congestion which unfortunately detrimentally affects continued economic prosperity and the cycle repeats itself. In the U.S.A, it has been estimated that congestion is costing Americans $200 billion each year. (2006)

In order to combat this congestion, there is a clear acknowledgment of the need to understand people's attitudes, habits and desires, before designing TDM measures that are considered merely as "hopeful" wait-and-see measures.

According to Venter (2007), South African transport trips for people that already have car access, can be classified according to Table 6.1 :

Table 6.1 : Car Usage patterns for People that already have car access		
Car Usage	**Definition**	**RSA proportions (NHTS,2003)**
Car Dependant	Households that own and only uses car	70%
Car Deprived	Households that own a car but only use public transport	25%
Car Discriminating	Households that have a car but occasionally uses public transport	5%

From the table, we see that there are already 25% of car owners who always use public transport and TDM policies should be aimed at supporting this population segment as well as supporting the needs of the car discriminating population to become less car dependant. However more understanding is required to determine why these households choose to travel either always, or occasionally, by pubic transport. In order for TDM strategies to be even more effective, strategies should be targeted at the car dependant 70% of the population. The means to achieve this may be through more restrictive type TDM approaches like congestion pricing.

"To be successful, a TDM strategy needs to change travel behaviour which over time become habitual and are no longer subjected to continuous deliberation."
Source : R. Behrens, University of Cape Town

Recent studies conducted by Del Mistro, Behrens, Lombard and Venter (2007) suggest that the majority of triggers prompting travel behaviour change are not transport related but related to other factors such as change in family and/or work circumstances. The paper concludes that TDM measures aimed at these triggers would yield better TDM results. It must however be mentioned that the findings of the Del Mistro et al (2007) study may not be consistent with the specific socio-economic and demographic makeup of the Summer Greens area.

6.3 Congestion pricing example

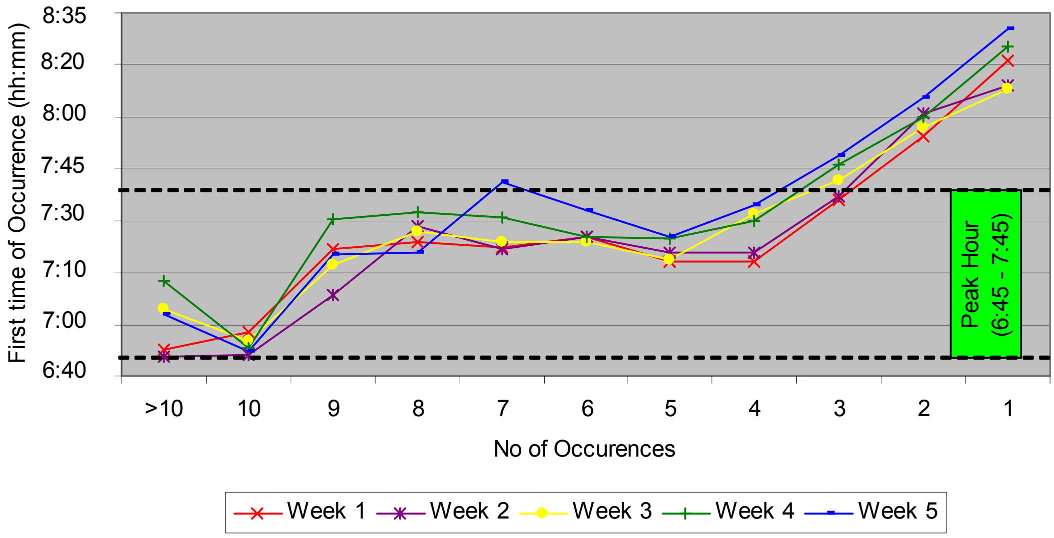
The data collected in this thesis project presents a theoretical opportunity to examine the impact of congestion pricing on daily vehicular volumes.

The first step towards this analysis, was obtaining the median values and occurrence frequencies for each of the five weeks separately. A summary table showing the median "first time of occurrence" values associated with occurrence frequencies observed during the 06:00 to 10:00 time period is shown in Table 6.3.1 with the same data plotted in Figure 6.3.1. The individual assessments of each of the five weeks are included in appendences 7.1 to 7.5 for reference.

Table 6.3.1 : Median Values of "First Time of Occurrence" per week

Period	No of Occurrences per week										
	>10	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Week 1	6:48:22	6:54:01	7:20:33	7:22:55	7:21:30	7:24:31	7:17:05	7:17:05	7:36:27	7:57:11	8:21:32
Week 2	6:46:25	6:46:58	7:06:01	7:28:15	7:20:46	7:24:45	7:19:30	7:19:36	7:37:50	8:04:33	8:13:32
Week 3	7:01:18	6:51:03	7:15:49	7:26:18	7:22:59	7:23:09	7:17:14	7:31:57	7:42:49	8:00:00	8:12:04
Week 4	7:10:48	6:49:15	7:30:36	7:32:54	7:30:59	7:24:45	7:24:17	7:29:35	7:47:47	8:03:26	8:25:46
Week 5	6:59:45	6:48:02	7:19:02	7:19:54	7:42:29	7:33:00	7:24:46	7:34:41	7:50:51	8:09:35	8:31:38

Figure 6.3.1 : Median "First Time of Occurrence" for all weeks



From Figure 6.3.1, it is apparent that weeks 4 and 5 have later median departure times than weeks 1 to 3. Also the "4" to "9" times per week occurrences have median times falling within a narrow 07:15 to 07:30 departure time band.

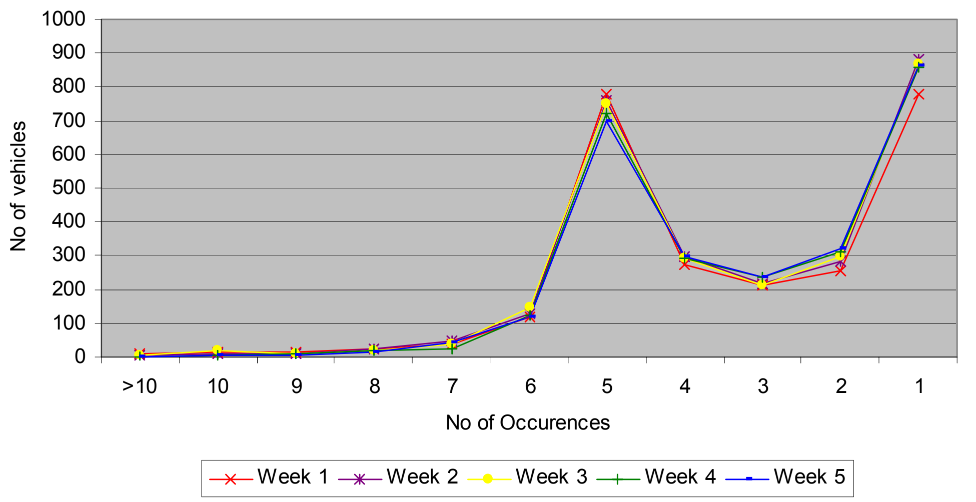
A summary table showing the total number of vehicles associated with occurrence frequencies is shown in Table 6.3.2.

Table 6.3.2 : No. of Vehicles associated with Weekly Occurrence Frequency

Period	No of Occurrences per week											
	>10	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Total**
Week 1	9	15	12	23	37	120	777	273	214	255	777	2797	5309
Week 2	6	10	11	22	48	126	760	298	216	281	881	2650	5309
Week 3	7	18	8	19	40	148	750	293	210	296	868	2652	5309
Week 4	1	7	11	20	25	124	722	292	236	311	857	2703	5309
Week 5	2	7	6	13	44	120	697	296	238	320	863	2703	5309
Total	25	57	48	97	194	638	3706	1452	1114	1463	4246	13505	26545
Total (%)	0.1%	0.2%	0.2%	0.4%	0.7%	2.4%	14.0%	5.5%	4.2%	5.5%	16.0%	50.9%	100%
Total	25	57	48	97	194	638	3706	1452	1114	1463	4246		13040
Total (%)	**0.2%**	**0.4%**	**0.4%**	**0.7%**	**1.5%**	**4.9%**	**28.4%**	**11.1%**	**8.5%**	**11.2%**	**32.6%**		**49.1%**

Figure 6.3.2 shows the plot of the number of vehicles associated per weekly occurrence frequency.

Figure 6.3.2 : Total number of vehicles for all weeks per associated Weekly Occurrence Frequency

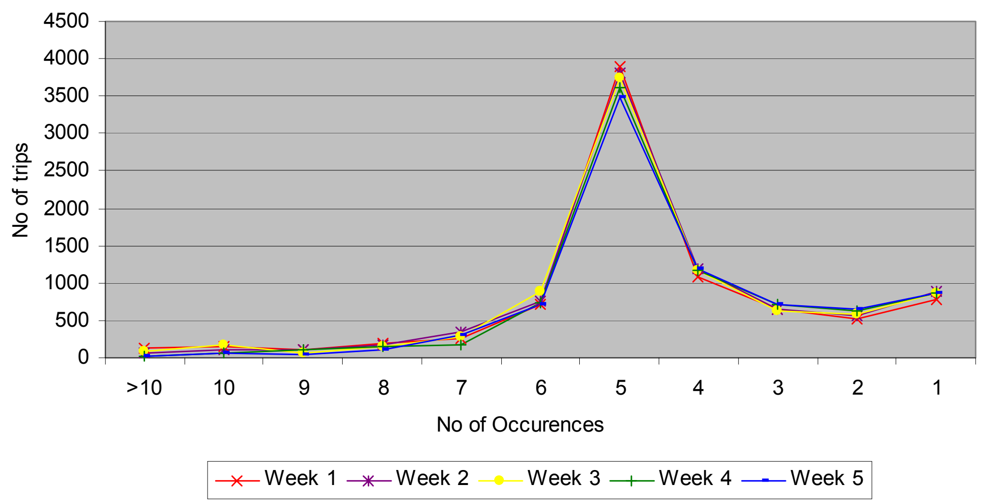


A summary table showing the total number of vehicle trips associated with occurrence frequencies is shown in Table 6.3.3. The data is plotted in Figure 6.3.3.

Table 6.3.3 : No. of Vehicle Trips per associated Weekly Occurrence Frequency

Period	No of Occurrences per week											
	>10	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**Total**
Week 1	121	150	108	184	259	720	3885	1092	642	510	777	8448
Week 2	70	100	99	176	336	756	3800	1192	648	562	881	8620
Week 3	83	180	72	152	280	888	3750	1172	630	592	868	8667
Week 4	11	70	99	160	175	744	3610	1168	708	622	857	8224
Week 5	24	70	54	104	308	720	3485	1184	714	640	863	8166
Total trips	309	570	432	776	1358	3828	18530	5808	3342	2926	4246	42125
Total (%)	**0.7%**	**1.4%**	**1.0%**	**1.8%**	**3.2%**	**9.1%**	**44.0%**	**13.8%**	**7.9%**	**6.9%**	**10.1%**	**100%**

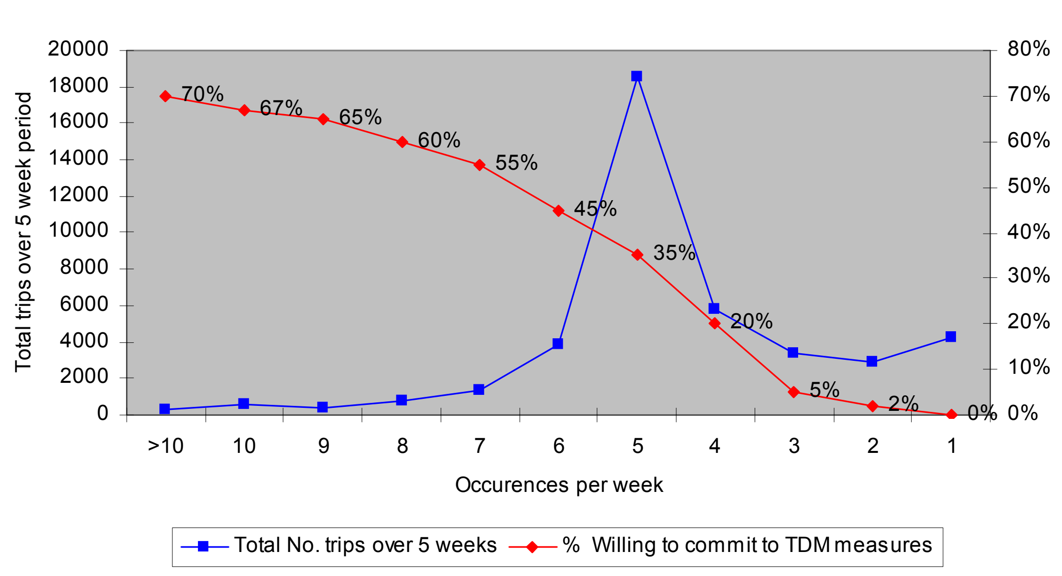
Figure 6.3.3 : Total number of trips for all weeks per associated Weekly Occurrence Frequency



It is clear from the two figures that TDM policies should be targeted at the once a day (five times per week) motorist as it is this group that contributes the most trips on the road network. From the data tables above, 28.4% of vehicles observed on average five times per week, constituted an average of 44% of the entire week's trips. Conversely, 32.6% of vehicles which was observed on average only once during the week constituted only 10.1% of the week's trips.

The determination of the impact of congestion pricing on this community requires a certain assumption to be made with regard to the willingness of these users to commit to such a TDM measure. For the purposes of this exercise, the assumption regarding the percentage willingness of users to commit to a TDM measure is shown in Figure 6.3.4 and is dependant, on a sliding scale, on the number of vehicle occurrences per week. In other words, it is assumed that the more often a motorist undergoes a trip, the more likely that this motorist will adjust to a desirable TDM behaviour than the once-off motorist who will not, or find it unnecessary, to do this adjustment.

Figure 6.3.4 : Assumption with respect to Willingness to Commit to TDM measures

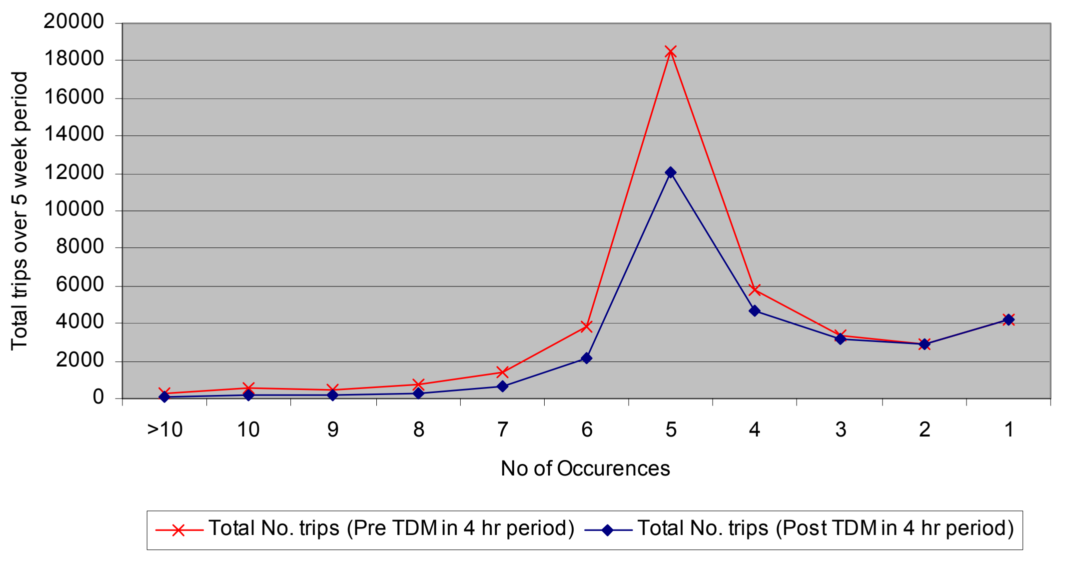


A more accurate representation of the willingness to commit to TDM measures would of course be ascertained via the results from Stated Preference (SP) surveys which was not conducted. Furthermore, the proportion would also be affected by trip purpose which could unfortunately not be identified during the Summer Greens survey. The assumptions made in this regard nevertheless provide a way of illustrating the application of TDM measures and that the results presented in the following section must be considered in this context.

A summary table showing the total number of vehicle trips after TDM measures associated with occurrence frequencies is shown in Table 6.3.4. The total number of weekly trips for both the Pre- and Post TDM scenarios is plotted in Figure 6.3.5.

Table 6.3.4 : Number of Post-TDM Vehicle Trips per associated Occurrence Frequency												
Period	No of Occurrences per week											
	>10	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**Total**
Week 1	36	50	38	74	117	396	2525	874	610	500	777	5995
Week 2	21	33	35	70	151	416	2470	954	616	551	881	6197
Week 3	25	59	25	61	126	488	2438	938	599	580	868	6206
Week 4	3	23	35	64	79	409	2347	934	673	610	857	6033
Week 5	7	23	19	42	139	396	2265	947	678	627	863	6006
Total trips	93	188	151	310	611	2105	12045	4646	3175	2867	4246	30438

Figure 6.3.5: Total number of Pre- and Post – TDM trips for all weeks (Summer Greens)



The figure shows that there is a substantial drop in weekly trip numbers for the "5 day per week" occurrence, despite only a 35% "willingness" assumption allocated for this group. The drop in total number of trips over the individual weeks over the 4-hour period is as follows :

Week 1 : 29.0%
Week 2 : 28.1%
Week 3 : 28.4%
Week 4 : 26.6%
Week 5 : 26.4%

The overall average drop in weekly trips due to the hypothetical TDM measure is 27.7% for all data within the four hour survey period. However, it is argued that TDM measures would become less effective after 07:45 (see analysis of unique vehicles in Section 5.8) when a greater proportion of unique vehicles are present in the vehicle stream and so the calculated 27.7% drop in traffic should be seen as an average drop over the entire four hours. This percentage drop in traffic volumes resulting from a TDM measure may be higher during the 06:00 to 08:00 morning hours and slightly lower after 08:00 due to the argument just mentioned and is worthy of further research.

7. CONCLUSIONS

This study explored the daily morning peak period variability in travel behaviour which included the differences in travel behaviour variability experienced in the school period versus the holiday period for a typical residential suburb in Cape Town.

Comparison of day-to-day variability found in the numberplate-based dataset against that reported in the literature and day-to-day appearance of unique vehicles found in the traffic stream as well as the variation of these proportions over the survey period was made. The analysis also included the comparison of day-to-day appearance of returning vehicles found in the traffic stream and determines the variation of the departure times.

The study has provided valuable insight into actual morning peak period behaviour over a period of five weeks. The following conclusions are made : (Relevant section references are indicated within parenthesis after each conclusion).

<u>Survey Technique :</u>

- Pilot studies conducted revealed that full numberplate observations and simultaneous survey of occupancies was not possible. (1.3)
- It was found that a single enumerator could achieve a 100% sample rate and accurately record entire vehicle numberplates for volumes of up to a maximum of 840 vehicles per hour including vehicle classification but only for a short duration. This is compared to the 700 vehicles per hour capacity recorded by Cherret and McDonald (2002) and 1200 vehicles per hour capacity recorded by Bonsall et al (1988). (1.3)
- The value of pilot studies to identify problems should never be underestimated. (4.4)

<u>Data Transcribing and accuracy :</u>

- Numberplate data entry should aim to separate the letter and number fields in the database to assist in error checking. (4.8)
- The average percentage of unreadable plates for the Summer Greens survey dataset is 1.835%. This is compared to the 1 to 3.3% of sample unreadable plates reported by Cherret and McDonald (2002). (5.2)

<u>Traffic Volumes :</u>

- Slightly higher 4-hour traffic volumes were recorded on both Mondays and Fridays for all weeks of the five week survey. (5.1)
- Weather conditions <u>did not</u> seem to play a part in the volume pattern and rain days did not adversely affect the volume pattern in the Summer Greens survey in any way. In fact rain days appeared to have reduced traffic volumes. (5.1)
- Except for the second week of the survey, there is a tendency for volumes to drop from Monday to Wednesday and “bounce back” over Thursday and Friday which supports similar findings by Zhou and Golledge (2000). (5.4)

- From the private car peak hour volumes, there is no evidence of the Zhou and Golledge (2000) volume "bounce back" phenomena as observed with the 4-hour time series plot. (5.5.1)
- Statistical testing conducted for the school period 4-hour traffic volumes revealed that Mondays and Tuesdays with Thursdays and Fridays are significantly different. Only Wednesday can thus be considered a typical weekday as it was not calculated to be significantly different to the rest of the weekdays. (5.5.3)
- The statistical test results for the holiday period 4-hour traffic volumes revealed that Mondays, Tuesdays, Wednesdays and Thursdays with Fridays are significantly different including Monday with Wednesday, revealing even greater traffic volume variability on Fridays than during the school period. (5.5.3)

School versus Holiday Traffic Patterns

- An average difference of 80 vehicle trips over a 4-hour period was observed between the school period and the holiday period. This constitutes a 4.5% drop in average trip volumes. (5.1)
- The average difference between the observed school and holiday period peak hour volume is 136 vehicles representing a 17% drop in peak hour volume with a smaller standard deviation calculated for the school period than the holiday period. This indicates greater traffic volume variability during the holiday period. (5.5.1)
- Statistical testing showed a significant difference between the school and holiday period weekly 4-hour traffic volumes but revealed insignificant differences between the weekly 4-hour traffic volumes within the school period (first three weeks) and between the two weeks of the holiday period, indicating two distinct and different volume patterns for these two periods. (5.5.1)
- However, when analysing only the private car mode, significantly different average peak hour volumes between weeks 2 and 3 as well as between weeks 4 and 5 were calculated statistically, which did not occur for the 4-hour period analysis. The statistically different average peak hour volumes for private cars for the week immediately before school holidays and the week immediately thereafter can be attributed to motorists adjusting their departure times during these two weeks. (5.5.1)
- Both school and holiday periods share the same 06:45 to 07:45 peak hour time period. (5.5.5)
- The activity of dropping off school children seems to show priority in a scheduling sense due to the peaking of traffic towards the 08:00 hour when schools in Cape Town start. This scheduling requirement then falls away during the holiday period leaving the commuter with a more flexible departure time schedule, leading to peak spreading and a "cross over" effect during the holiday period. (5.5.5)
- It was shown that the "cross over" point occurred on all weekdays during the 07:45 to 08:00 time period. (5.5.5)
- The hypothesis made in the body of the report that holiday traffic volumes are similar to school traffic volumes over the morning period (06:00 to 10:00) was found to be true to a certain extent due to peak spreading but not sufficiently so for the overall period traffic volumes to be equal, as it was shown that the school period average 4-hour traffic volume is 4.5% more than the holiday period equivalent. Due to the "cross over" effect, the percentage difference in traffic increases during the peak hour (ie. more school period traffic volume than holiday period traffic volume) and reduces over time over the survey period, but at 10:00 does not return back to a 0% difference. The 4.5% of trips is attributed to motorists that either solely did a trip to drop off children at school, are teachers or practice in a related field who now no longer need to travel in the holiday period or normal working persons taking leave early in

December. (5.5.5)

Trip Frequency :

- No significant difference between school and holiday period trip frequencies are observed when comparing similar time period durations ie. two weeks, following almost identical curves. As expected, a lowering of trip frequencies per day was observed the longer the duration period selected for analysis. (5.6.2)
- Trip making per day is fairly uniform over all the weeks except for the "Five day per week" pattern which reduces over the last two week holiday period as expected. Up to 70% of trips collectively consist of either one or five vehicle trip appearances per week. The result of the statistical testing revealed insignificant differences in appearance frequencies between all weeks. (5.7.1)
- The closer to the peak hour the Summer Greens data is analysed, the more the proportion of "five trips per week" reduce and the more the "one day trips per week" increase. This is contrary to what is expected as one would assume to have a higher proportion of commuters closer to the peak hour and hence have a higher "Five day per week" proportion. The results of this analysis begins to suggest that the "Five day per week" commuter is not too restricted by time and has variable departure times not necessarily always departing (or observed) in the peak hour. (5.7.1)

Trip Frequency with respect to Frequency of Appearance:

- A high 46.9% proportion of vehicles were found to appear only once (a day) in the week, but these vehicles constituted only 11.5% of all the Summer Greens trips made. It was observed that a far larger amount of trips (56.1%) were made by those vehicles observed everyday of the week. (5.7.2)
- A statistical ANOVA test conducted revealed insignificant differences between all weeks for all observed frequency categories (viz. one day per week to five days per week). (5.7.2)

Following Day Trips :

The Summer Greens average percentage "following on subsequent day" parameter was found to be relatively high at 61.1% when compared to the 52% of the Del Mistro (2006) dataset. Bonsall et al (1984) found a comparable 50% "following day" return rate when surveying number plates whilst Cherret and McDonald (2002) reported an even lower average frequency per following day of between 24.8% to 49%. The high percentage rate is attributable to the location of the survey station considered to be an "Origin" station. (5.7.3)

Following Week Trips :

- It was observed that the Summer Greens "following week trip" data closely matched the Del Mistro (2006) data, except for the "5 trips per week" and "1 trip per week" category. More Summer Greens trips (10.5%) are made in the "5 repetitious trips per week" category when compared against the 2.4% of the Del Mistro data. Conversely, the Summer Greens data has relatively low "1 trip per week" volumes (5%) when compared to the Del Mistro data (12.7%). The higher value calculated for the Summer Greens is to be expected on the basis of the survey site proximity to the "origin" of trips. (5.7.4)
- A statistical ANOVA test revealed insignificant differences of "following week trip" data between school weeks (ie. between weeks 1 and 2 and between weeks 2 and 3) and between holiday weeks (ie. weeks

4 and 5). This indicates that the holiday period made no significant impact on the "following week" travel behaviour of Summer Greens. (5.7.4)

Departure Times :

- It was found that the departure time during the school period increases on average from Monday to Friday from 07:32 to 07:36, an increase of four minutes. The same pattern occurs during the holiday period, but less significant ie. from 07:41 to 07:43, a difference of only two minutes. (5.7.5)
- The average departure time over the average school week was found to be 07:34 with a standard deviation of 0:01:55. The average holiday period departure time over the week was found to be 07:42 with a standard deviation of 0:02:11, demonstrating a significant 7 minute 49 second later departure time average in the holiday period. It is hypothesised here that the later departure time selected by motorists in the holiday period is triggered by either 4.5% lower traffic volumes during the holiday period allowing for an average saving of 10 minutes travel time, or due to a saving of 10 minutes due to the freedom of not having to drop off school children en route to work, or a combination of both. (5.7.5)
- During the school period, the Summer Greens Friday departure times are statistically different to all other days of the week, except for Thursday, which means that both Thursday and Fridays exhibit significantly different trip departure times than the other remaining weekdays (excluding weekends). (5.7.5)
- During the holiday period, the departure times are more uniform for most days except for a significant difference between Tuesday and Fridays. (5.7.5)
- Five percent of "following day" repeat vehicles, who were observed to return the following day in the lower range time differences (ie. 0 to 5 and 5 to 10 minutes) during the school period, shift to the upper time difference ranges (over ten minute range) during the holiday period (week 4 and 5), confirming the availability of a more flexible morning departure schedule for motorists during this period. (5.7.6)
- There are no significant differences between the proportions of following day repeat vehicles reappearing within the specified time bands for all days of the week, except between Thursday and Friday as expected, where a drop of 4% in the "0 to 5" minute band is taken up by the ">30" minute time difference band, indicating that on Fridays, motorists tend to display greater departure time variability, irrespective of whether it is a school or holiday period. (5.7.6)
- It was observed that 34.8% of returning (following day repeat) vehicles appeared within five minutes of each other over the entire five week period. However, this value rises to 54% when the time period window is extended to ten minutes. The study by Cherret and McDonald (2002) revealed that between 61.9% to 67.6% of all returning vehicles appeared within five minutes of each other. (5.7.6)

Unique Vehicles :

- As expected, the average percentage of non-unique (returning) vehicles decreases with later time periods from 75% (in the 06:15 to 07:30 time period) to only 12% after 09:15 and is attributable to the increase in business activity during this time. (5.8)

- This finding is important for VMS applications as it is argued that the display of information on such signage is more effective the higher the proportion of returning vehicles and would optimally be displayed (or broadcasted in the case of RDS) before 07:30 when 75% of the vehicles are returning vehicles. It is hypothesised that the impact of VMS and RDS would diminish with time after 07:30. (5.8)

- The results of statistical testing revealed that no significant difference is observable in the overall, school and holiday unique vehicle proportions after 08:45. The only significant difference between the school and holiday period unique vehicle proportions was the two 15-min periods within the 07:30 to 08:00 time period, where significantly more unique vehicles are observed during the school period. In fact, over an average 4-hour day, it is observed that there are fewer unique vehicles during the holiday period than the entire school period perhaps as a result of a lowered business and commercial activity. (5.8)

Action Space :

- Summer Greens time departure bandwidth observations confirm the findings of Schönfelder (2001), who found that there was more extensive use of time area space on Fridays. Also, although there were greater traffic volumes recorded during the school period, the area time spread for this period is much shorter than the holiday period across all days of the week. The holiday period traffic is less time constrained with larger area spaces, particularly on Fridays, even though there is less traffic. The bandwidth data also appears to increase linearly from the first week with maximum values calculated in the last week. (5.9)
- The first Monday of the holiday period experiences almost the same area space as Friday of that week. Greater use of cars on Fridays outside peak times may account for the greater variation in time area spaces. (5.9)
- Statistical testing conducted on the departure time median values found that the significance of the median differences is as per bandwidth calculation (ie. significant differences between the school period weeks (weeks 1 to 3) and holiday period (weeks 4 and 5) but with an unexpected significant median difference calculated between week 4 and 5, which again confirms the time flexibility available to motorists during even the first week of the holiday period and the results show even more flexibility in the second week of the holiday period. (5.9)

Similarity Index :

A similarity index scoring (formulated specifically for this thesis), rank ordered for all 5677 observed vehicles in the dataset, revealed that the school period week (week 1 to 3) displays more identical activity than the holiday period (week 4 to 5). (5.10)

Time of First Occurrence :

There is a gradually decreasing tendency of the “first occurrence” median times relative to increasing “no. of occurrences” and that there is some “instability” after a total occurrence of around 34 observations per vehicle (an average trip rate of 1.36 per day) for the entire survey period. In other words, the action space conforms to a decreasing bandwidth with increasing observation frequencies. The area of instability is attributable to a low sample size in this zone and to private car business activity conducted after the peak period rather than commuting activity. (5.11)

TDM Application

- TDM policies should be targeted at the once a day (five times per week) motorist as it is this group that contributes the most trips on the road network. Approximately 28% of vehicles, which was observed on average five times per week, constituted 44% of the week's total number of trips. Conversely, 33% of vehicles which was observed, on average only once during the week, constituted only 10% of the total week's trips. (6.3)

- The overall average drop in weekly trips due to the hypothetical TDM measure tested is 27.7% conducted for all data within the four hour survey period. This percentage drop in traffic volumes resulting from a TDM measure may be higher during the 06:00 to 08:00 morning hours and slightly lower after 08:00 due to the presence of unique vehicles. (6.3)

8. FUTURE RESEARCH

The study conducted in this research has allowed trip making characteristics of a small suburb in Cape Town to be observed and analysed over a period of five weeks during both a normal school period (over three weeks) and a consecutive two week holiday period.

The data obtained for this study has however been restricted to a certain socio-demographic area and the extent to which socio-demographic differences and sample composition contribute to intra-personal variability merits further investigation. The results of the Summer Greens study can therefore not be extrapolated directly to represent larger samples and areas in Cape Town or elsewhere. Future research in this field can thus start to include the testing of travel variability across other demographic segments.

With specific reference to the Summer Greens survey, an additional “entry” survey could be conducted, in addition to the “exit” survey, to determine the proportions of both entering and exiting vehicles instead of just exiting vehicles surveyed in this thesis. This information would be valuable in determining the proportion of home-school-home trips.

The possibility of seasonal differences such as winter weather and workers absent on summer holidays may show different results than that indicated in this study and is worthy of future research. The possibility may exist as suggested by Parkany and Madron (2004) to modify data to include “summer” or “winter” factors.

As mentioned in Section 5.1, this thesis reported on associated weather conditions experienced during the survey period and it was observed that rain days did not affect the Summer Greens volume pattern in any way. It is argued that there is a general perception that rain significantly impacts or increases traffic volumes and it is hypothesised that the perceived “increased traffic” is as a result of increased delays due to collisions, signal outages etc. typically experienced on such days which, with resulting congestion, make it appear to be higher volume days. Further research could aim to prove or disprove this hypothesis.

In Section 5.5.1, the significant difference between school and holiday traffic volumes was confirmed. However, the results of the Summer Greens data seemed to repeat the findings of Zhou and Golledge (2000, p19) where, except for the second week of the survey, there is a tendency for volumes to drop from Monday to Wednesday and “bounce back” over Thursday and Friday. Whether this is purely coincidental or particular to residential traffic patterns is uncertain and worthy of further research, as the small sample dataset used in this study cannot conclusively support such a behavioural pattern.

The ANOVA statistical testing conducted in Section 5.7.5 during the Summer Greens school period indicated a different departure time average on Fridays to all other days of the week, except for Thursday, which means that both Thursday and Fridays exhibit significantly different trip departure times than the other remaining weekdays (excluding weekends). This is consistent with the findings by Pendyala (2003) who also found that both Thursdays and Fridays are different in trip making characteristics than other weekdays and with Zhou and Golledge (2000) who found that Fridays are different from other days of the week with respect to trip making behaviour. Whether the Thursday phenomena is a simple data issue or a true behavioural issue is uncertain and further research is recommended in this regard.

The research by Cherret and McDonald (2002), revealed that between 61.9% to 67.6% of all returning vehicles appeared within five minutes of each other. From analysis of the Summer Greens data described in Section 5.7.6, it was observed that only 34.8% of returning vehicles appeared within five minutes of each other for all five weeks of the survey period. However, this figure rose to 54% when the time period is extended to ten minutes. This result may also change appreciably for returning vehicles analysed in the peak hour only which could be conducted in further research.

In Section 6.3 of this thesis report, it was found that the overall average drop in weekly trips due to a hypothetical TDM measure is 27.7% for all data within the four hour survey period. However, it is argued that TDM measures would become less effective after 07:45 when a greater proportion of unique vehicles are present in the vehicle stream and so the 27.7% post-TDM drop in traffic can be seen as an average drop over the entire four hours. This percentage drop in traffic volumes resulting from a TDM measure may be higher during the 06:00 to 08:00 morning hours and slightly lower after 08:00 due to the argument just mentioned and is worthy of further research.

A dataset incorporating trips broken down by trip purpose, gender, age group, and household size would provide valuable data for further research. Towards this end, there is further potential in using GPS devices as conducted in research elsewhere in the world (eg. Lexington and Atlanta surveys) to determine travel behaviour. More recently, the University of Stellenbosch is researching methods of cell phone tracking by means of triangulation on the basis of signal strength for devices equipped with GPRS functionality. Such cell phone tracking could, with the owners permission, possibly provide a more accurate travel behaviour data over a longer period of time and could be pursued further in collaboration with the university.

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APPENDIX 1 : PRINTOUT SAMPLE OF RAW DATA SPREADSHEET

Data No.	Date	Day	Day No	Week	Surveyor	Weather	Begin	End	ActualTime	Record Time	HH	MM	SS	Registration Plate	Alternative Plate	Vehicle Type	Car Colour	Car Make	Car Model	Special
1	13-Nov-2006	Monday	1	1	LH	Sunny	05:45	06:00	21587	30	0	0	30	CFR89072						
2	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21623	66	0	1	6	386076						
3	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21657	100	0	1	40	320668						
4	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21665	108	0	1	48	821202						
5	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21679	122	0	2	2	267324						
6	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21684	127	0	2	7	812560						
7	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21697	140	0	2	20	674556						
8	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21727	170	0	2	50	207472						
9	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21732	175	0	2	55	CY291512						
10	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21737	180	0	3	0	234289						
11	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21750	193	0	3	13	136388						
12	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21820	263	0	4	23	109410						
13	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21844	287	0	4	47	CY107530						
14	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21849	292	0	4	52	CFR85674						
15	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21857	300	0	5	0	687652						
16	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21861	304	0	5	4	600826						
17	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21913	356	0	5	56			M				
18	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21929	372	0	6	12	90910						
19	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21945	388	0	6	28	651865						
20	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21949	392	0	6	32	848940						
21	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21955	398	0	6	38	728732						
22	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21982	425	0	7	5	738072						
23	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	21990	433	0	7	13	879306						
24	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22013	456	0	7	36	301EC						
25	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22053	496	0	8	16	CITYS1-WP						
26	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22082	525	0	8	45	CY271569						
27	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22113	556	0	9	16	94514						
28	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22148	591	0	9	51	585684						
29	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22157	600	0	10	0	692GP						
30	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22170	613	0	10	13	919688						
31	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22175	618	0	10	18	372330						
32	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22181	624	0	10	24	769279						
33	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22248	691	0	11	31	559EC						
34	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22262	705	0	11	45	887999						
35	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22272	715	0	11	55	751796		T				
36	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22291	734	0	12	14	692185						
37	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22297	740	0	12	20	672993						
38	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22309	752	0	12	32	CAW10946						
39	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22312	755	0	12	35	761386						
40	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22341	784	0	13	4	774652						
41	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22342	785	0	13	5	36911						
42	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22343	786	0	13	6	339441						
43	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22352	795	0	13	15	898693						
44	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22357	800	0	13	20	283258						
45	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22363	806	0	13	26	105770						
46	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22374	817	0	13	37	439429						
47	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22378	821	0	13	41	730456						
48	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22397	840	0	14	0	92406						
49	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22421	864	0	14	24	257860		T				
50	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22425	868	0	14	28	906821						
51	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22430	873	0	14	33	146128						
52	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22435	878	0	14	38	658165						
53	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22474	917	0	15	17	GVX877G						
54	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22479	922	0	15	22	730792		T				
55	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22483	926	0	15	26	363969						
56	13-Nov-2006	Monday	1	1	LH	Sunny	06:00	06:15	22491	934	0	15	34	120826						
57	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22511	954	0	15	54	96241						
58	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22538	981	0	16	21	741701						
59	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22543	986	0	16	26	825950						
60	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22550	993	0	16	33	211618						
61	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22561	1004	0	16	44	169802						
62	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22574	1017	0	16	57	642939						
63	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22584	1027	0	17	7	582346						
64	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22596	1039	0	17	19	88867						
65	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22602	1045	0	17	25	716145						
66	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22607	1050	0	17	30	72269						
67	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22609	1052	0	17	32	541125						
68	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22619	1062	0	17	42	565051						
69	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22640	1083	0	18	3	114211						
70	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22657	1100	0	18	20	CY143406						
71	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22681	1124	0	18	44	788899						
72	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22685	1128	0	18	48	840057						
73	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22689	1132	0	18	52	12842						
74	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22692	1135	0	18	55	228501						
75	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22694	1137	0	18	57	114161		T				
76	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22697	1140	0	19	0	88409						
77	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22717	1160	0	19	20	223178		T				UTURN
78	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22755	1198	0	19	58	CY23368						
79	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22763	1206	0	20	6	680812						
80	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22787	1230	0	20	30	739230						
81	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22790	1233	0	20	33				WHITE	MAZDA	?	NOPLATE
82	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22794	1237	0	20	37	572328						
83	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22800	1243	0	20	43	198425						
84	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22809	1252	0	20	52	844006						
85	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22824	1267	0	21	7	88008						
86	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22829	1272	0	21	12	186126						
87	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22834	1277	0	21	17	342691						
88	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22852	1295	0	21	35	039EC						
89	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22866	1309	0	21	49	758730						
90	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22871	1314	0	21	54	198012						
91	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22875	1318	0	21	58	505807						
92	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22881	1324	0	22	4	276793						
93	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22884	1327	0	22	7	38467						
94	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22897	1340	0	22	20	386GP						
95	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22917	1360	0	22	40	233909		T				
96	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22922	1365	0	22	45	CCD14772						
97	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22937	1380	0	23	0	140573						
98	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22945	1388	0	23	8	592488						
99	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22948	1391	0	23	11	654784						
100	13-Nov-2006	Monday	1	1	LH	Sunny	06:15	06:30	22994	1437	0	23	57	793410						

APPENDIX 2 : TABLE TALK ARTICLE

Those 'suspicious' men are just logging traffic

Pam Fourie

If you live in the vicinity of Summer Greens and have noticed two "suspicious" looking men parked in a car next to the pedestrian hump on Summer Greens Road every morning from 6am till 10am while jotting down some "secret" information as if plotting some sinister coup – rest assured, there is no cause for alarm.

It's just Laurent Hermant and his assistant Duane Bowman, who will occupy that spot until Friday December 15 as part of Laurent's MSc research survey that he is conducting with the University of Stellenbosch to identify "traffic churn" doing normal weekdays and during school holidays. The survey is conducted in collaboration with Davey Patience of the City of Cape Town.

And those secret scribbles are vehicle registration numbers that the pair are jotting down.

"From previous studies done abroad, it can be concluded that while aggregated traffic streams on a day-to-day basis might be measured to have very little variability, variability does exist in individual travel behaviour, which is appropriately termed "traffic churn," explains Laurent.

He added that a recent study conducted on a major arterial entering the Cape Town CBD over a three-week period, revealed that almost 50% of individual vehicles appeared only once in the week and that less than 10% appeared on all five days of the week.

Summer Greens residents may already have noticed the two cameras put up on the street light pole and the traffic count loop on the exit road, which provide a continual traffic count record over the period when the number plates are recorded.

"The objective of this study is to compare the findings of the international literature and CBD study with this study, which is to be conducted over a controlled area and over a longer timeframe incorporating the school holiday period and to draw travel behaviour conclusions from the gathered data.

"Summer Greens was identified as the prime location for the survey as it is one of the very few residential areas that have only one exit route."

APPENDIX 3 : ANOVA TEST ANALYSIS RESULTS

ANOVA Test Calculation ***Appendix 3.1***

Test : Weekly trip volumes (Entire Dataset, all vehicles)

Method	k / n	1	2	3	4	5	m_i	$n_i.m_i$	$(m_i-m)^2$	$(x_1-m_i)^2$	$(x_2-m_i)^2$	$(x_3-m_i)^2$	$(x_4-m_i)^2$	$(x_5-m_i)^2$	$\Sigma(x_{ji}-m_i)^2$
Week 1	1	1744	1711	1740	1766	1802	1752.6	8763	89.1136	73.96	1730.56	158.76	179.56	2440.36	4583.2
Week 2	2	1750	1760	1803	1805	1798	1783.2	8916	1603.202	1102.24	538.24	392.04	475.24	219.04	2726.8
Week 3	3	1745	1769	1755	1831	1848	1789.6	8948	2156.674	1989.16	424.36	1197.16	1713.96	3410.56	8735.2
Week 4	4	1714	1689	1678	1690	1727	1699.6	8498	1897.474	207.36	112.36	466.56	92.16	750.76	1629.2
Week 5	5	1689	1691	1668	1670	1736	1690.8	8454	2741.57	3.24	0.04	519.84	432.64	2043.04	2998.8
								43579	8488.03						20673.20

k = 5 SS_M = 42440.16 SS_E = 20673.20

n_i = 5 df = 4 df = 20

n = 25 MS_M = 10610.04 MS_E = 1,033.66

m = 1743.16 F = MS_M/MS_E = 10.26

α = 5%

F_1-α,k-1,n-k = F0.95,4,20 = 2.87 *for a 5% level of significance*

Since F > F_1-α,k-1,n-k Hypothesis that means are equal is rejected

t_1-α/2,n-k = t0.975,20 = 2.086 *for a 5% level of significance*

$t_{1,2}$ = 1.50 Insignificant difference

$t_{1,3}$ = 1.82 Insignificant difference

$t_{1,4}$ = 2.61 Significant difference

$t_{1,5}$ = 3.04 Significant difference

$t_{2,3}$ = 0.31 Insignificant difference

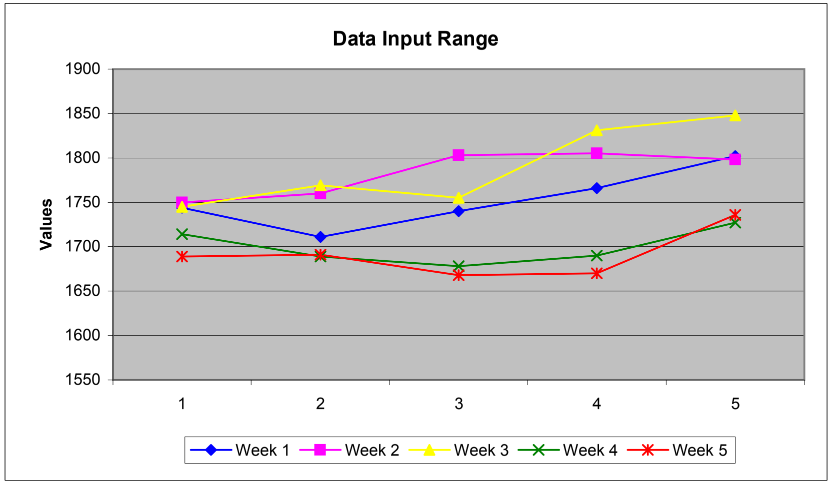
$t_{2,4}$ = 4.11 Significant difference

$t_{2,5}$ = 4.54 Significant difference

$t_{3,4}$ = 4.43 Significant difference

$t_{3,5}$ = 4.86 Significant difference

$t_{4,5}$ = 0.43 Insignificant difference



ANOVA Test Calculation ***Appendix 3.2***

Test : Weekly trip volumes (Peak hour Dataset, private cars only)

Method	k / n	1	2	3	4	5	m_i	$n_i.m_i$	$(m_i-m)^2$	$(x_1-m_i)^2$	$(x_2-m_i)^2$	$(x_3-m_i)^2$	$(x_4-m_i)^2$	$(x_5-m_i)^2$	$\Sigma(x_{ji}-m_i)^2$
Week 1	1	806	806	808	785	807	802.4	4012	3466.854	12.96	12.96	31.36	302.76	21.16	381.2
Week 2	2	817	808	821	813	782	808.2	4041	4183.502	77.44	0.04	163.84	23.04	686.44	950.8
Week 3	3	806	770	776	783	783	783.6	3918	1606.406	501.76	184.96	57.76	0.36	0.36	745.2
Week 4	4	678	663	690	654	676	672.2	3361	5086.542	33.64	84.64	316.84	331.24	14.44	780.8
Week 5	5	680	656	632	629	659	651.2	3256	8522.982	829.44	23.04	368.64	492.84	60.84	1774.8
								18588	22866.29						4632.80

$k =$ 5 $SS_M =$ 114331.44 $SS_E =$ 4632.80

$n_i =$ 5 df = 4 df = 20

$n =$ 25 $MS_M =$ 28582.86 $MS_E =$ 231.64

$m =$ 743.52 $F = MS_M/MS_E =$ 123.39

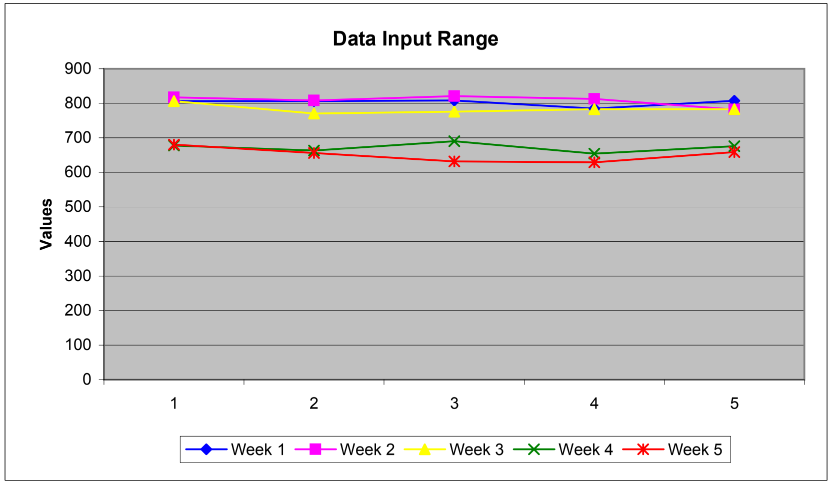
$\alpha =$ 5%

F_1-α,k-1,n-k = F0.95,4,20 = 2.87 *for a 5% level of significance*

Since F > F_1-α,k-1,n-k Hypothesis that means are equal is rejected

t_1-α/2,n-k = t0.975,20 = 2.086 *for a 5% level of significance*

$t_{1,2}$ =	0.60	Insignificant difference
$t_{1,3}$ =	1.95	Insignificant difference
$t_{1,4}$ =	13.53	Significant difference
$t_{1,5}$ =	15.71	Significant difference
$t_{2,3}$ =	2.56	Significant difference
$t_{2,4}$ =	14.13	Significant difference
$t_{2,5}$ =	16.31	Significant difference
$t_{3,4}$ =	11.57	Significant difference
$t_{3,5}$ =	13.75	Significant difference
$t_{4,5}$ =	2.18	Significant difference



ANOVA Test Calculation *Appendix 3.3*

Test : Day of Week variation (All Vehicles) - School Period only

Method	k / n	1	2	3	m_i	$n_i.m_i$	$(m_i-m)^2$	$(x_1-m_i)^2$	$(x_2-m_i)^2$	$(x_3-m_i)^2$	$(x_4-m_i)^2$	$(x_5-m_i)^2$	$\Sigma(x_{ji}-m_i)^2$
Monday	1	1744	1750	1745	1746.333	5239	829.44	5.444444	13.44444	1.777778			20.66666667
Tuesday	2	1711	1760	1769	1746.667	5240	810.3511	1272.111	177.7778	498.7778			1948.666667
Wednesday	3	1740	1803	1755	1766	5298	83.41778	676	1369	121			2166
Thursday	4	1766	1805	1831	1800.667	5402	651.9511	1201.778	18.77778	920.1111			2140.666667
Friday	5	1802	1798	1848	1816	5448	1670.084	196	324	1024			1544
						26627	4045.24						7820.00

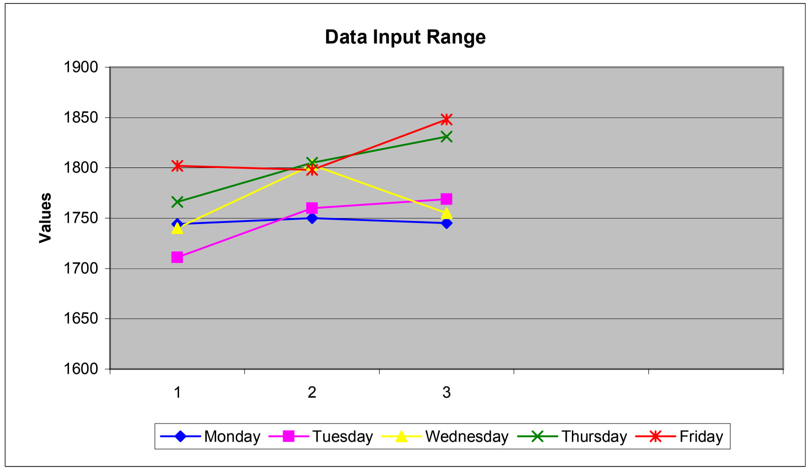
k =	5	SS_M =	12135.73	SS_E =	7820.00
n_i =	3	df =	4	df =	10
n =	15	MS_M =	3033.93	MS_E =	782.00
m =	1775.13			F = MS_M/MS_E =	3.88
α =	5%				

F_1-α,k-1,n-k = F0.95,4,10 = 3.48 *for a 5% level of significance*

Since F > F_1-α,k-1,n-k Hypothesis that means are equal is rejected

t_1-α/2,n-k = t0.975,10 = 2.228 *for a 5% level of significance*

$t_{1,2}$ =	0.01	Insignificant difference
$t_{1,3}$ =	0.86	Insignificant difference
$t_{1,4}$ =	2.38	Significant difference
$t_{1,5}$ =	3.05	Significant difference
$t_{2,3}$ =	0.85	Insignificant difference
$t_{2,4}$ =	2.37	Significant difference
$t_{2,5}$ =	3.04	Significant difference
$t_{3,4}$ =	1.52	Insignificant difference
$t_{3,5}$ =	2.19	Insignificant difference
$t_{4,5}$ =	0.67	Insignificant difference



ANOVA Test Calculation ***Appendix 3.4***

Test : Day of Week variation (All Vehicles) - Holiday Period only

Method	k / n	1	2	m_i	$n_i.m_i$	$(m_i-m)^2$	$(x_1-m_i)^2$	$(x_2-m_i)^2$	$(x_3-m_i)^2$	$(x_4-m_i)^2$	$(x_5-m_i)^2$	$\Sigma(x_{ji}-m_i)^2$
Monday	1	1714	1689	1701.5	3403	39.69	156.25	156.25				312.5
Tuesday	2	1689	1691	1690	3380	27.04	1	1				2
Wednesday	3	1678	1668	1673	3346	492.84	25	25				50
Thursday	4	1690	1670	1680	3360	231.04	100	100				200
Friday	5	1727	1736	1731.5	3463	1317.69	20.25	20.25				40.5
					16952	2108.30						605.00

k = 5 SS_M = 4216.60 SS_E = 605.00

n_i = 2 df = 4 df = 5

n = 10 MS_M = 1054.15 MS_E = 121.00

m = 1695.20 $F = MS_M/MS_E$ = 8.71

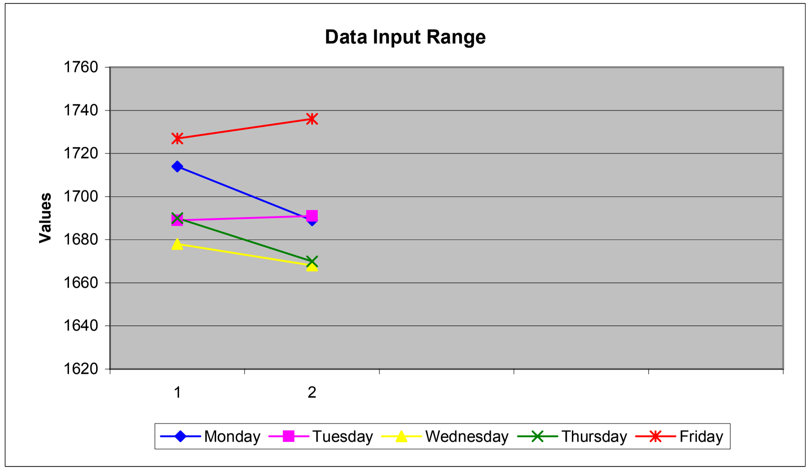
α = 5%

$F_{1-\alpha,k-1,n-k}$ = F0.95,4,5 = 5.19 *for a 5% level of significance*

Since F > $F_{1-\alpha,k-1,n-k}$ Hypothesis that means are equal is rejected

$t_{1-\alpha/2,n-k}$ = t0.975,5 = 2.571 *for a 5% level of significance*

$t_{1,2}$ =	1.05	Insignificant difference
$t_{1,3}$ =	2.59	Significant difference
$t_{1,4}$ =	1.95	Insignificant difference
$t_{1,5}$ =	2.73	Significant difference
$t_{2,3}$ =	1.55	Insignificant difference
$t_{2,4}$ =	0.91	Insignificant difference
$t_{2,5}$ =	3.77	Significant difference
$t_{3,4}$ =	0.64	Insignificant difference
$t_{3,5}$ =	5.32	Significant difference
$t_{4,5}$ =	4.68	Significant difference



ANOVA Test Calculation **Appendix 3.5**

Test : Frequency per week (All Vehicles) : Freq of Appearance

Method	k / n	1	2	3	4	5	m_i	$n_i.m_i$	$(m_i-m)^2$	$(x_1-m_i)^2$	$(x_2-m_i)^2$	$(x_3-m_i)^2$	$(x_4-m_i)^2$	$(x_5-m_i)^2$	$\Sigma(x_{ji}-m_i)^2$
Week 1	1	890	274	230	300	947	528.2	2641	319.6944	130899.2	64617.64	88923.24	52075.24	175393.4	511908.8
Week 2	2	994	299	218	350	920	556.2	2781	102.4144	191668.8	66151.84	114379.2	42518.44	132350.4	547068.8
Week 3	3	975	310	230	319	940	554.8	2774	76.0384	176568	59927.04	105495	55601.64	148379	545970.8
Week 4	4	971	331	268	302	855	545.4	2727	0.4624	181135.4	45967.36	76950.76	59243.56	95852.16	459149.2
Week 5	5	971	341	257	324	836	545.8	2729	0.0784	180795	41943.04	83405.44	49195.24	84216.04	439554.8
								13652	498.69						2503652.40

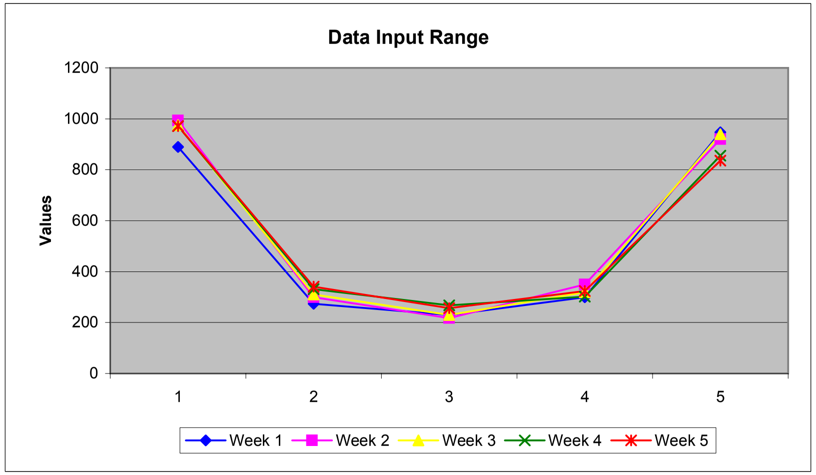
k =	5	SS_M =	2493.44	SS_E =	2503652.40
n_i =	5	df =	4	df =	20
n =	25	MS_M =	623.36	MS_E =	125,182.62
m =	546.08			F = MS_M/MS_E =	0.00
α =	5%				

F_1-α,k-1,n-k = F0.95,4,20 = 2.87 *for a 5% level of significance*

Since F < F_1-α,k-1,n-k Hypothesis that means are equal is accepted

t_1-α/2,n-k = t0.975,20 = 2.086 *for a 5% level of significance*

$t_{1,2}$ =	0.13	Insignificant difference
$t_{1,3}$ =	0.12	Insignificant difference
$t_{1,4}$ =	0.08	Insignificant difference
$t_{1,5}$ =	0.08	Insignificant difference
$t_{2,3}$ =	0.01	Insignificant difference
$t_{2,4}$ =	0.05	Insignificant difference
$t_{2,5}$ =	0.05	Insignificant difference
$t_{3,4}$ =	0.04	Insignificant difference
$t_{3,5}$ =	0.04	Insignificant difference
$t_{4,5}$ =	0.00	Insignificant difference



ANOVA Test Calculation ***Appendix 3.6***

Test : Frequency per week (All Vehicles) : % of trips wrt Freq of Appearance

Method	k / n	1	2	3	4	5	m_i	$n_i.m_i$	$(m_i-m)^2$	$(x_1-m_i)^2$	$(x_2-m_i)^2$	$(x_3-m_i)^2$	$(x_4-m_i)^2$	$(x_5-m_i)^2$	$\Sigma(x_{ji}-m_i)^2$
Week 1	1	927	592	748	1287	5209	1752.6	8763	89.1136	681615.4	1346992	1009221	216783.4	11946701	15201313.2
Week 2	2	1035	646	690	1511	5034	1783.2	8916	1603.202	559803.2	1293224	1195086	74092.84	10567701	13689906.8
Week 3	3	1023	655	741	1375	5154	1789.6	8948	2156.674	587675.6	1287317	1099562	171893.2	11319187	14465635.2
Week 4	4	1020	708	885	1284	4601	1699.6	8498	1897.474	461856.2	983270.6	663573.2	172723.4	8418122	10699545.2
Week 5	5	1010	728	828	1406	4482	1690.8	8454	2741.57	463488.6	926983.8	744423.8	81111.04	7790797	10006804.8
								43579	8488.03						64063205.20

$k =$ 5 $SS_M =$ 42440.16 $SS_E =$ 64063205.20

$n_i =$ 5 df = 4 df = 20

$n =$ 25 $MS_M =$ 10610.04 $MS_E =$ 3,203,160.26

$m =$ 1743.16 $F = MS_M/MS_E =$ 0.00

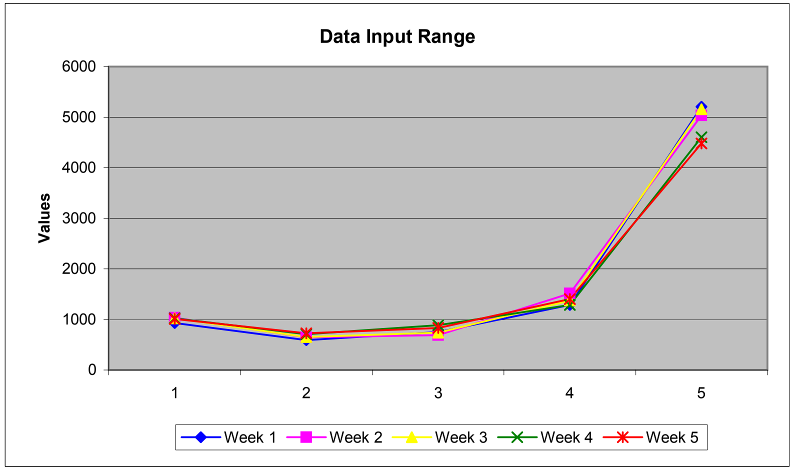
$\alpha =$ 5%

F_1-α,k-1,n-k = F0.95,4,20 = 2.87 *for a 5% level of significance*

Since F < F_1-α,k-1,n-k Hypothesis that means are equal is accepted

t_1-α/2,n-k = t0.975,20 = 2.086 *for a 5% level of significance*

$t_{1,2} =$	0.03	Insignificant difference
$t_{1,3} =$	0.03	Insignificant difference
$t_{1,4} =$	0.05	Insignificant difference
$t_{1,5} =$	0.05	Insignificant difference
$t_{2,3} =$	0.01	Insignificant difference
$t_{2,4} =$	0.07	Insignificant difference
$t_{2,5} =$	0.08	Insignificant difference
$t_{3,4} =$	0.08	Insignificant difference
$t_{3,5} =$	0.09	Insignificant difference
$t_{4,5} =$	0.01	Insignificant difference



ANVOA Test Calculation ***Appendix 3.7***

Test : First Departure Time across Weeks

Method	k / n	1	2	3	4	5	m_i	$n_i.m_i$	$(m_i-m)^2$	$(x_1-m_i)^2$	$(x_2-m_i)^2$	$(x_3-m_i)^2$	$(x_4-m_i)^2$	$(x_5-m_i)^2$	$\Sigma(x_{ji}-m_i)^2$
Week 1	1	27238.5809	27161.0189	27201.22	27274.871	27292.59	27233.66	136168.3	36002.994	24.25502	5276.14	1052.068	1698.684	3473.052	11524.2
Week 2	2	27049.6884	27082.3943	27185.503	27288.047	27398.07	27200.74	136003.7	49577.257	22816.87	14005.95	232.1874	7622.283	38939.64	83616.937
Week 3	3	27097.8508	27329.8064	27151.19	27376.945	27412.2	27273.6	136368	22440.653	30887.23	3159.335	14983.89	10680.42	19210.59	78921.466
Week 4	4	27634.9613	27533.578	27669.545	27635.403	27718.6	27638.42	138192.1	46232.492	11.94808	10991.4	968.8763	9.091044	6429.608	18410.923
Week 5	5	27731.4082	27544.1248	27763.752	27868.163	27945.5	27770.59	138852.9	120539.98	1535.147	51286.13	46.75047	9520.595	30593.25	92981.879
								685585	274793.38						285455.41

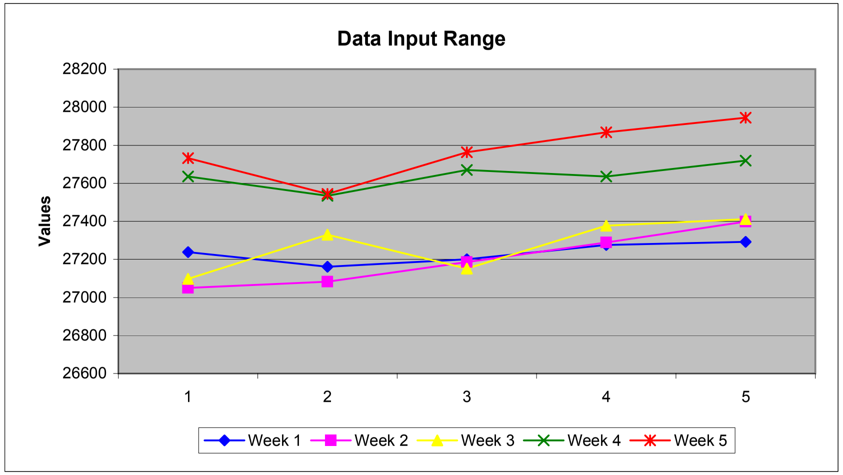
k =	5	SS_M =	1373966.89	SS_E =	285455.41
n_i =	5	df =	4	df =	20
n =	25	MS_M =	343491.72	MS_E =	14,272.77
m =	27423.40			F = MS_M/MS_E =	24.07
α =	5%				

F_1-α,k-1,n-k = F0.95,4,20 = 2.87 *for a 5% level of significance*

Since F > F_1-α,k-1,n-k Hypothesis that means are equal is rejected

t_1-α/2,n-k = t0.975,20 = 2.086 *for a 5% level of significance*

$t_{1,2}$ =	0.44	Insignificant difference
$t_{1,3}$ =	0.53	Insignificant difference
$t_{1,4}$ =	5.36	Significant difference
$t_{1,5}$ =	7.11	Significant difference
$t_{2,3}$ =	0.96	Insignificant difference
$t_{2,4}$ =	5.79	Significant difference
$t_{2,5}$ =	7.54	Significant difference
$t_{3,4}$ =	4.83	Significant difference
$t_{3,5}$ =	6.58	Significant difference
$t_{4,5}$ =	1.75	Insignificant difference



ANOVA Test Calculation — **Appendix 3.8**

Test : First Departure Time across Day of Week (school period only)

Method	k / n	1	2	3	m_i	$n_i.m_i$	$(m_i-m)^2$	$(x_1-m_i)^2$	$(x_2-m_i)^2$	$(x_3-m_i)^2$	$(x_4-m_i)^2$	$(x_5-m_i)^2$	$\Sigma(x_{ji}-m_i)^2$
Mon	1	27238.5809	27049.6884	27097.851	27128.71	81386.12	11511.52	12072.33	6243.888	952.0865			19268.31
Tues	2	27161.0189	27082.3943	27329.806	27191.07	81573.22	2018.2802	903.2601	11811.11	19246.91			31961.28
Wed	3	27201.2203	27185.5033	27151.19	27179.3	81537.91	3214.2096	480.3061	38.42547	790.4371			1309.169
Thur	4	27274.871	27288.0467	27376.945	27313.29	81939.86	5973.5851	1475.819	637.0958	4052.232			6165.146
Fri	5	27292.5886	27398.0723	27412.201	27367.62	82102.86	17324.365	5629.796	927.3104	1987.394			8544.5
						408540	40041.96						67248.40

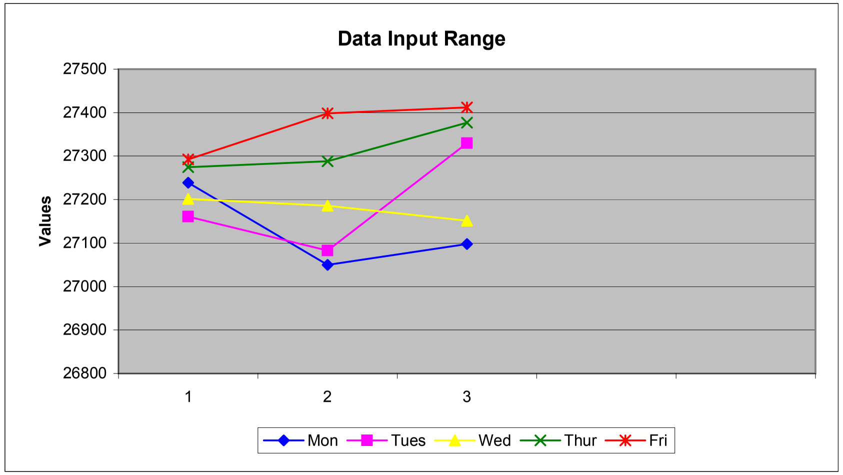
k =	5	SS_M =	120125.88	SS_E =	67248.40
n_i =	3	df =	4	df =	10
n =	15	MS_M =	30031.47	MS_E =	6,724.84
m =	27236.00			F = MS_M/MS_E =	4.47
α =	5%				

F_1-α,k-1,n-k = F0.95,4,10 = 3.48 *for a 5% level of significance*

Since F > F_1-α,k-1,n-k Hypothesis that means are equal is rejected

t_1-α/2,n-k = t0.975,10 = 2.228 *for a 5% level of significance*

$t_{1,2}$ =	0.93	Insignificant difference
$t_{1,3}$ =	0.76	Insignificant difference
$t_{1,4}$ =	2.76	Significant difference
$t_{1,5}$ =	3.57	Significant difference
$t_{2,3}$ =	0.18	Insignificant difference
$t_{2,4}$ =	1.83	Insignificant difference
$t_{2,5}$ =	2.64	Significant difference
$t_{3,4}$ =	2.00	Insignificant difference
$t_{3,5}$ =	2.81	Significant difference
$t_{4,5}$ =	0.81	Insignificant difference



ANOVA Test Calculation **Appendix 3.9**

Test : First Departure Time across Day of Week (holiday period only)

Method	k / n	1	2	m_i	$n_i.m_i$	$(m_i-m)^2$	$(x_1-m_i)^2$	$(x_2-m_i)^2$	$(x_3-m_i)^2$	$(x_4-m_i)^2$	$(x_5-m_i)^2$	$\Sigma(x_{ji}-m_i)^2$
Mon	1	27634.9613	27731.4082	27683.18	55366.37	454.49025	2325.501	2325.501				4651.003
Tues	2	27533.578	27544.1248	27538.85	55077.7	27440.634	27.8083	27.8083				55.61661
Wed	3	27669.5447	27763.7518	27716.65	55433.3	147.49308	2218.742	2218.742				4437.484
Thur	4	27635.4028	27868.1627	27751.78	55503.57	2235.3227	13544.3	13544.3				27088.59
Fri	5	27718.6028	27945.4985	27832.05	55664.1	16268.251	12870.41	12870.41				25740.83
					277045	46546.19						61973.52

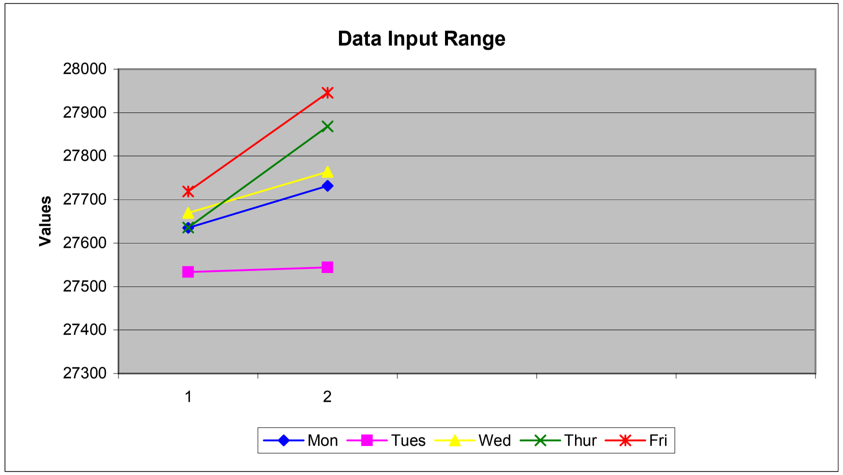
k =	5	SS_M =	93092.38	SS_E =	61973.52
n_i =	2	df =	4	df =	5
n =	10	MS_M =	23273.10	MS_E =	12,394.70
m =	27704.50			$F = MS_M/MS_E$ =	1.88
α =	5%				

F_1-α,k-1,n-k = F0.95,4,5 = 5.19 *for a 5% level of significance*

Since F < F_1-α,k-1,n-k Hypothesis that means are equal is accepted

t_1-α/2,n-k = t0.975,5 = 2.571 *for a 5% level of significance*

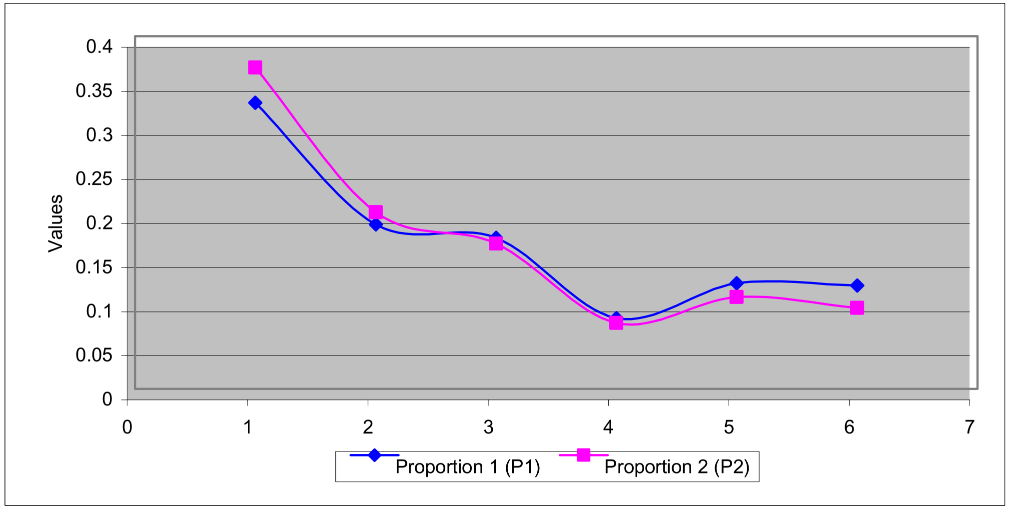
$t_{1,2}$ =	1.30	Insignificant difference
$t_{1,3}$ =	0.30	Insignificant difference
$t_{1,4}$ =	0.62	Insignificant difference
$t_{1,5}$ =	1.34	Insignificant difference
$t_{2,3}$ =	1.60	Insignificant difference
$t_{2,4}$ =	1.91	Insignificant difference
$t_{2,5}$ =	2.63	Significant difference
$t_{3,4}$ =	0.32	Insignificant difference
$t_{3,5}$ =	1.04	Insignificant difference
$t_{4,5}$ =	0.72	Insignificant difference



Proportions z-statistic test ***Appendix 3.10***

Test : Significance of Time period difference between school (P_1) and holiday (P_2) periods

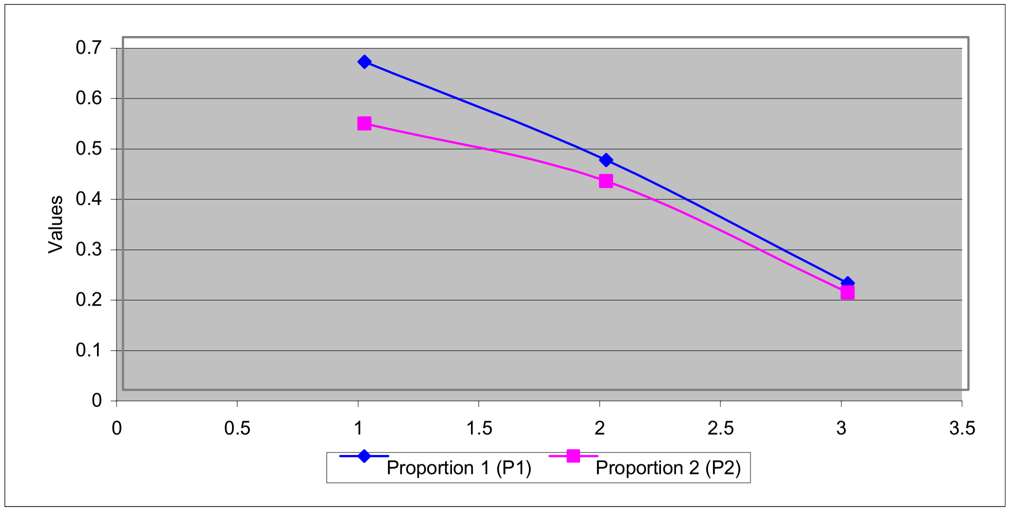
	Before		After							
Method/Event	Proportion 1 (P_1)	Sample 1 (n_1)	Proportion 2 (P_2)	Sample 2 (n_2)	P_o	s^2	SE	z	$z_{0.95}$	z-Test outcome
1	0.32464505	3064	0.364541172	5494	0.350257	0.227577	0.010756	3.709103	1.645	Significant
2	0.18658614	1761	0.20025214	3018	0.195216	0.157107	0.011886	1.149779	1.645	Not Significant
3	0.17143463	1618	0.164620795	2481	0.16731	0.139318	0.011927	0.571284	1.645	Not Significant
4	0.08020767	757	0.074646672	1125	0.076883	0.070972	0.012524	0.44404	1.645	Not Significant
5	0.11994067	1132	0.104040873	1568	0.110707	0.098451	0.012238	1.299259	1.645	Not Significant
6	0.11718584	1106	0.091898348	1385	0.103126	0.092491	0.012264	2.061919	1.645	Significant



Proportions z-statistic test ***Appendix 3.11***

Test : Significance of Time period difference between 5 week Summer Greens data (P_1) and Li, Geunsler, Ogle & Wang data (P2)

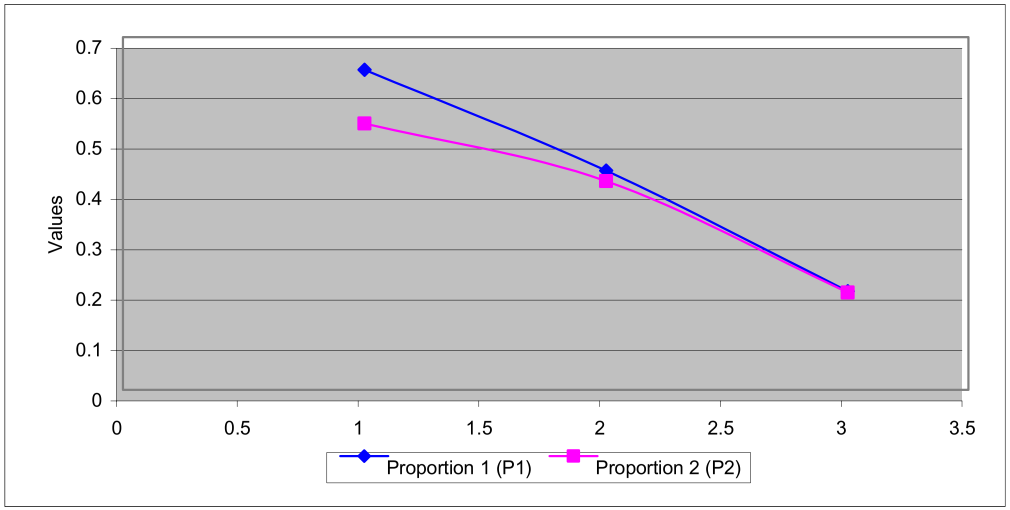
	Before		After							
Method/Event	Proportion 1 (P_1)	Sample 1 (n_1)	Proportion 2 (P_2)	Sample 2 (n_2)	P_o	s^2	SE	z	$z_{0.95}$	z-Test outcome
1	0.65082215	24509	0.528571429	280	0.649441	0.227667	0.028677	4.262981	1.645	Significant
2	0.45583255	24509	0.414285714	280	0.455363	0.248008	0.029931	1.388091	1.645	Not Significant
3	0.21179975	24509	0.192857143	280	0.211586	0.166817	0.024548	0.77167	1.645	Not Significant



Proportions z-statistic test ***Appendix 3.12***

Test : Significance of Time period difference between Summer Greens School (P_1) period and Li, Geunsler, Ogle & Wang data (P_2)

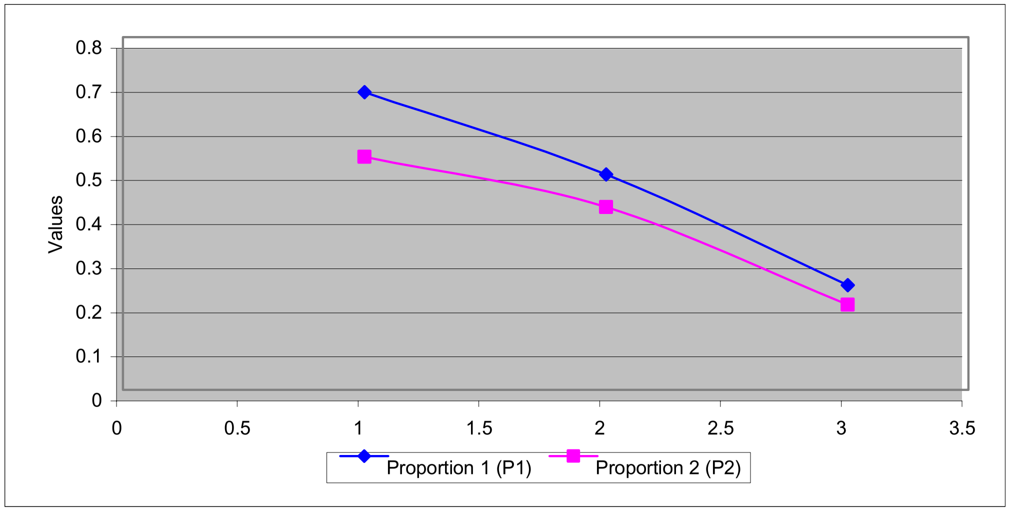
	Before		After							
Method/Event	Proportion 1 (P_1)	Sample 1 (n_1)	Proportion 2 (P_2)	Sample 2 (n_2)	P_o	s^2	SE	z	$z_{0.95}$	z-Test outcome
1	0.63545883	15071	0.528571429	280	0.633509	0.232175	0.029062	3.677903	1.645	Significant
2	0.43520669	15071	0.414285714	280	0.434825	0.245752	0.0299	0.699705	1.645	Not Significant
3	0.19593922	15071	0.192857143	280	0.195883	0.157513	0.023937	0.128756	1.645	Not Significant



Proportions z-statistic test **_Appendix 3.13_**

Test : Significance of Time period difference between Summer Greens Holiday (P_1) period and Li, Geunsler, Ogle & Wang data (P_2)

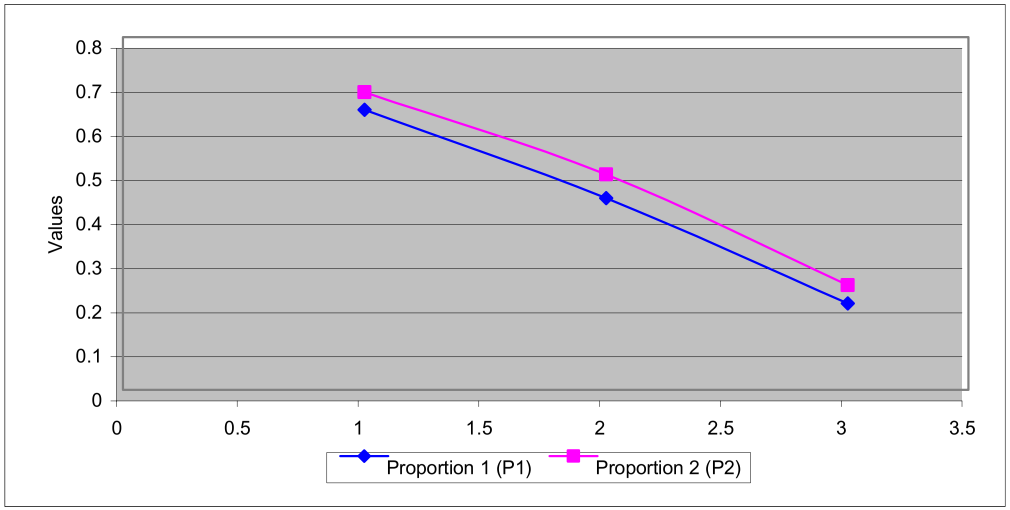
	Before		After							
Method/Event	Proportion 1 (P_1)	Sample 1 (n_1)	Proportion 2 (P_2)	Sample 2 (n_2)	P_o	s^2	SE	z	$z_{0.95}$	z-Test outcome
1	0.67535495	9438	0.528571429	280	0.671126	0.220716	0.02849	5.152179	1.645	Significant
2	0.48876881	9438	0.414285714	280	0.486623	0.249821	0.03031	2.457388	1.645	Significant
3	0.23712651	9438	0.192857143	280	0.235851	0.180225	0.025744	1.719594	1.645	Significant



Proportions z-statistic test ***Appendix 3.14***

Test : Significance of Time period difference between Summer Greens School (P_1) period and Holiday data (P_2)

	Before		After							
Method/Event	Proportion 1 (P_1)	Sample 1 (n_1)	Proportion 2 (P_2)	Sample 2 (n_2)	P_o	s^2	SE	z	$z_{0.95}$	z-Test outcome
1	0.63545883	15071	0.675354948	9438	0.650822	0.227253	0.006258	6.375649	1.645	Significant
2	0.43520669	15071	0.488768807	9438	0.455833	0.248049	0.006538	8.192888	1.645	Significant
3	0.19593922	15071	0.23712651	9438	0.2118	0.166941	0.005363	7.679455	1.645	Significant



ANVOA Test Calculation

Appendix 3.15

Test : Repetitious behaviour (Traveller makes same trip in subsequent week)

Method	k / n	1	2	3	4	5	m_i	$n_i.m_i$	$(m_i-m)^2$	$(x_1-m_i)^2$	$(x_2-m_i)^2$	$(x_3-m_i)^2$	$(x_4-m_i)^2$	$(x_5-m_i)^2$	$\Sigma(x_{ji}-m_i)^2$
Weeks 1 and 2	1	4070	268	181	194	304	1003.4	5017	21.777778	9404036	540813.2	676341.8	655128.4	489160.4	11765479.2
Weeks 2 and 3	2	4032	297	191	197	301	1003.6	5018	19.951111	9171207	499283.6	660318.8	650603.6	493646.8	11475059.2
Weeks 4 and 5	3	4097	320	197	195	277	1017.2	5086	83.417778	9485168	486087.8	672728	676012.8	547896	11867892.8
							0	0	0	0	0	0	0	0	0
							0	0	0	0	0	0	0	0	0
								15121	125.15						35108431.20

k = 3 SS_M = 625.73 SS_E = 35108431.20

n_i = 5 df = 2 df = 12

n = 15 MS_M = 312.87 MS_E = 2,925,702.60

m = 1008.07 F = MS_M/MS_E = 0.00

α = 5%

F_1-α,k-1,n-k = F0.95,2,12 = 3.26 *for a 5% level of significance*

Since F < F_1-α,k-1,n-k Hypothesis that means are equal is accepted

t_1-α/2,n-k = t0.975,12 = 2.179 *for a 5% level of significance*

$t_{1,2}$ = 0.00 Insignificant difference

$t_{1,3}$ = 0.01 Insignificant difference

$t_{1,4}$ = 0.00

$t_{1,5}$ = 0.00

$t_{2,3}$ = 0.01 Insignificant difference

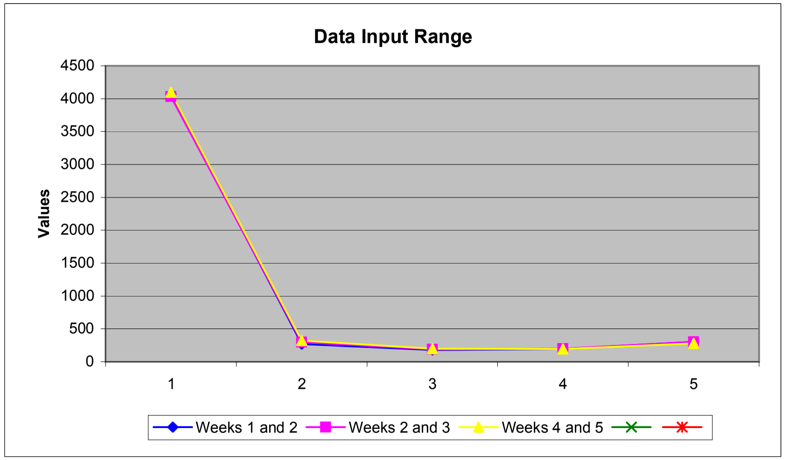
$t_{2,4}$ = 0.00

$t_{2,5}$ = 0.00

$t_{3,4}$ = 0.00

$t_{3,5}$ = 0.00

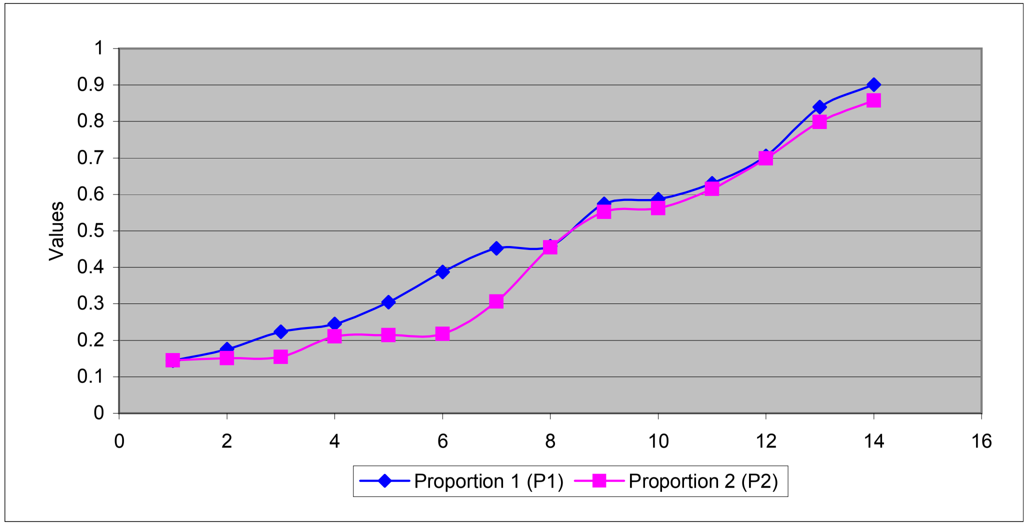
$t_{4,5}$ = 0.00



Proportions z-statistic test ***Appendix 3.16***

Test : Significance of Unique vehicle proportions for Summer Greens data (School & Holiday periods) for full time duration of survey

Method/Event	School Proportion 1 (P_1)	Sample 1 (n_1)	Holiday Proportion 2 (P_2)	Sample 2 (n_2)	P_o	s^2	SE	z	$z_{0.95}$	z-Test oucome
6:15-6:30	0.14379085	44	0.144680851	34	0.144179	0.123391	0.080209	0.011096	1.645	Not Significant
6:30-6:45	0.17564403	75	0.150769231	49	0.165814	0.13832	0.068316	0.364112	1.645	Not Significant
6:45-7:00	0.22384428	92	0.154098361	47	0.200261	0.160157	0.071752	0.972035	1.645	Not Significant
7:00-7:15	0.2452381	103	0.210526316	68	0.231435	0.177873	0.065899	0.526741	1.645	Not Significant
7:15-7:30	0.30461538	99	0.213740458	56	0.271783	0.197917	0.074387	1.221654	1.645	Not Significant
7:30-7:45	0.38745387	105	0.217898833	56	0.328478	0.22058	0.077715	2.181741	1.645	Significant
7:45-8:00	0.45217391	104	0.305936073	67	0.394876	0.238949	0.076577	1.909691	1.645	Significant
8:00-8:15	0.45853659	94	0.454545455	90	0.456584	0.248115	0.07346	0.054331	1.645	Not Significant
8:15-8:30	0.57432432	85	0.552325581	95	0.562714	0.246067	0.074061	0.297034	1.645	Not Significant
8:30-8:45	0.58741259	84	0.562043796	77	0.57528	0.244333	0.077986	0.325298	1.645	Not Significant
8:45-9:00	0.63087248	94	0.615384615	80	0.623752	0.234686	0.07369	0.210176	1.645	Not Significant
9:00-9:15	0.70542636	91	0.698529412	95	0.701904	0.209235	0.067095	0.102794	1.645	Not Significant
9:15-9:30	0.84	147	0.798319328	95	0.823638	0.145259	0.050172	0.830762	1.645	Not Significant
9:30-9:45	0.9010989	164	0.857142857	114	0.883074	0.103254	0.039183	1.121802	1.645	Not Significant
					#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1.645	#DIV/0!



ANOVA Test Calculation — ***Appendix 3.17***

Test : Area Space Bandwidths

Method	k / n	1	2	3	4	5	m_i	$n_i.m_i$	$(m_i-m)^2$	$(x_1-m_i)^2$	$(x_2-m_i)^2$	$(x_3-m_i)^2$	$(x_4-m_i)^2$	$(x_5-m_i)^2$	$\Sigma(x_{ji}-m_i)^2$
Week 1	1	4445	4377	4582	4609	4816	4565.45	22827.25	35789.072	14508.2	35702.1	257.6025	1874.89	62525	114867.8
Week 2	2	4258	4490	4477	4656	4658	4507.65	22538.25	60999.12	62575.02	329.4225	939.4225	22081.96	22605.12	108530.95
Week 3	3	4509	4596	4361	4701	4628	4558.9	22794.5	38310.233	2490.01	1376.41	39164.41	20192.41	4705.96	67929.2
Week 4	4	5036	4832	4939	5077	5098	4996.2	24981	58356.065	1544.49	27126.09	3271.84	6528.64	10363.24	48834.3
Week 5	5	4944	4961	5030	5232	5559	5144.95	25724.75	152349.7	40481.44	33837.6	13328.7	7577.703	171023.6	266249.05
								118865.8	345804.19						606411.30

k = 5 SS_M = 1729020.97 SS_E = 606411.30

n_i = 5 df = 4 df = 20

n = 25 MS_M = 432255.24 MS_E = 30,320.57

m = 4754.63 $F = MS_M/MS_E$ = 14.26

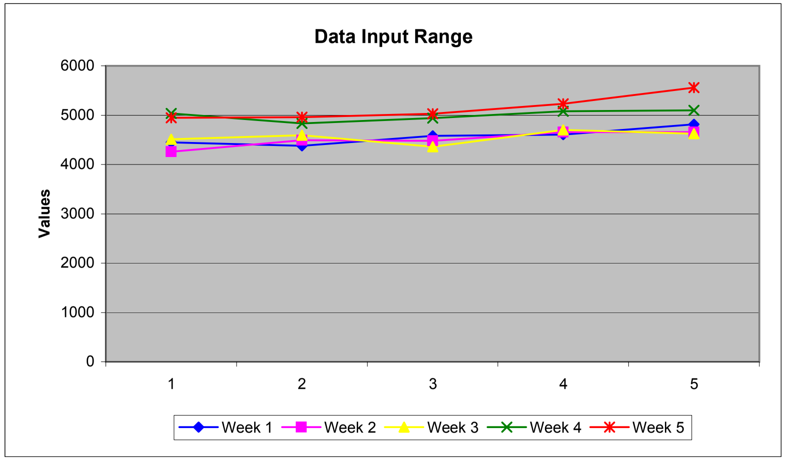
α = 5%

F_1-α,k-1,n-k = F0.95,4,20 = 2.87 *for a 5% level of significance*

Since F > F_1-α,k-1,n-k Hypothesis that means are equal is rejected

t_1-α/2,n-k = t0.975,20 = 2.086 *for a 5% level of significance*

$t_{1,2}$ =	0.52	Insignificant difference
$t_{1,3}$ =	0.06	Insignificant difference
$t_{1,4}$ =	3.91	Significant difference
$t_{1,5}$ =	5.26	Significant difference
$t_{2,3}$ =	0.47	Insignificant difference
$t_{2,4}$ =	4.44	Significant difference
$t_{2,5}$ =	5.79	Significant difference
$t_{3,4}$ =	3.97	Significant difference
$t_{3,5}$ =	5.32	Significant difference
$t_{4,5}$ =	1.35	Insignificant difference



ANOVA Test Calculation **Appendix 3.18**

Test : Area Space Median

Method	k / n	1	2	3	4	5	m_i	$n_i.m_i$	$(m_i-m)^2$	$(x_1-m_i)^2$	$(x_2-m_i)^2$	$(x_3-m_i)^2$	$(x_4-m_i)^2$	$(x_5-m_i)^2$	$\Sigma(x_{ji}-m_i)^2$
Week 1	1	26939	26831	26951	26924	27035	26935.9	134679.5	58660.84	9.61	11109.16	228.01	141.61	9820.81	21309.2
Week 2	2	26886	26833	26909	26992	27128	26949.6	134748	52212.25	4044.96	13595.56	1648.36	1797.76	31826.56	52913.2
Week 3	3	26774	26979	26919	27157	27177	27001.2	135006	31293.61	51619.84	492.84	6756.84	24273.64	30905.64	114048.8
Week 4	4	27421	27401	27358	27406	27541	27425.4	137127	61157.29	19.36	595.36	4542.76	376.36	13363.36	18897.2
Week 5	5	27521	27447	27552	27715	27658	27578.4	137892	160240.09	3352.41	17265.96	723.61	18659.56	6336.16	46337.7
								679452.5	363564.08						253506.10

k = 5 SS_M = 1817820.40 SS_E = 253506.10

n_i = 5   df = 4   df = 20

n = 25 MS_M = 454455.10 MS_E = 12,675.31

m = 27178.10 $F = MS_M/MS_E$ = 35.85

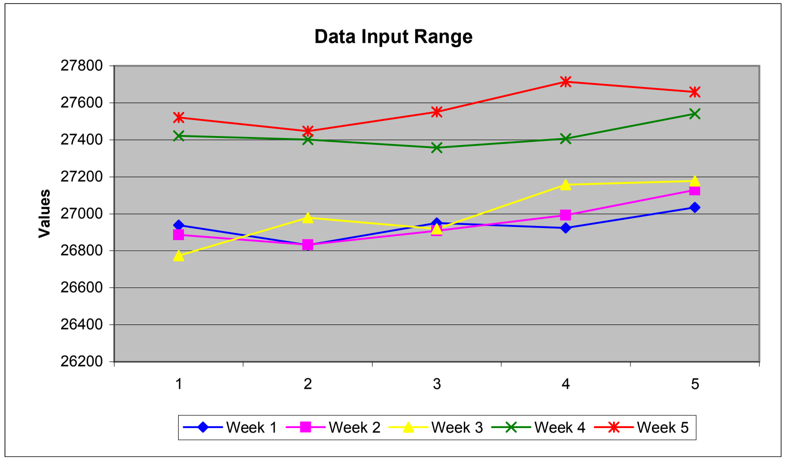
α = 5%

$F_{1-\alpha,k-1,n-k}$ = F0.95,4,20 = 2.87 *for a 5% level of significance*

Since F > $F_{1-\alpha,k-1,n-k}$ Hypothesis that means are equal is rejected

$t_{1-\alpha/2,n-k}$ = t0.975,20 = 2.086 *for a 5% level of significance*

$t_{1,2}$ =	0.19	Insignificant difference
$t_{1,3}$ =	0.92	Insignificant difference
$t_{1,4}$ =	6.87	Significant difference
$t_{1,5}$ =	9.02	Significant difference
$t_{2,3}$ =	0.72	Insignificant difference
$t_{2,4}$ =	6.68	Significant difference
$t_{2,5}$ =	8.83	Significant difference
$t_{3,4}$ =	5.96	Significant difference
$t_{3,5}$ =	8.11	Significant difference
$t_{4,5}$ =	2.15	Significant difference

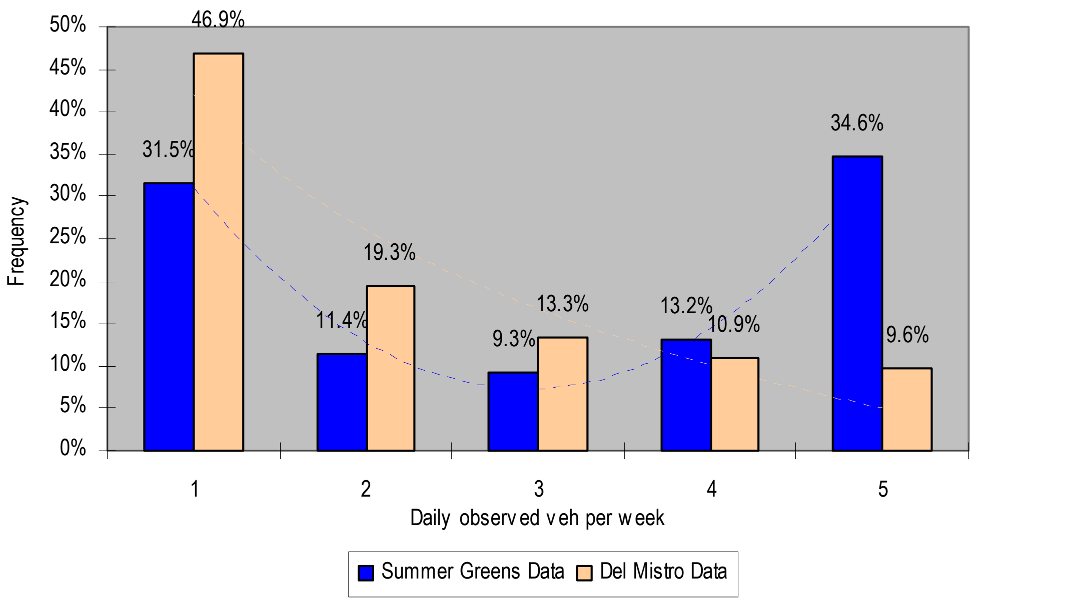


APPENDIX 4 : TRIP OBSERVATION FREQUENCY TABLES

Appendix 4.1 : Frequency of Appearance per week (5:45 to 9:00 period)						
Frequency of vehicles observed per week (No.)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
Vehicles not observed	*2342*	*2204*	*2197*	*2279*	*2300*	*2264*
1	653	764	784	*738*	*764*	741
2	249	245	263	*306*	*279*	268
3	206	222	195	*245*	*218*	217
4	291	323	314	*298*	*321*	309
5	871	854	859	*746*	*730*	812
Total	**4612**	**4612**	**4612**	**4612**	**4612**	**4612**
Frequency of vehicles observed per week (%)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
1	28.8%	31.7%	32.5%	31.6%	33.0%	31.5%
2	11.0%	10.2%	10.9%	13.1%	12.1%	11.4%
3	9.1%	9.2%	8.1%	10.5%	9.4%	9.3%
4	12.8%	13.4%	13.0%	12.8%	13.9%	13.2%
5	38.4%	35.5%	35.6%	32.0%	31.6%	34.6%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Figure A4.1 provides a plot of the average percentages of appearance frequencies across weeks.

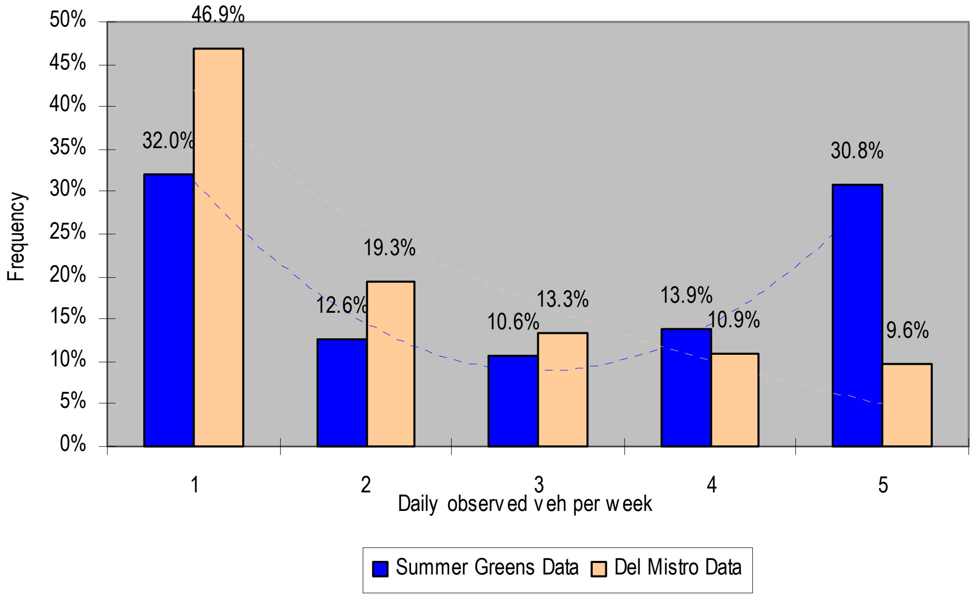
Figure A4.1 : Plot of Frequency of Appearance per week (5:45 to 9:00 period)



Appendix 4.2 : Frequency of Appearance per week (6:30 to 8:30 period)						
Frequency of vehicles observed per week (No.)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
Vehicles not observed	*1983*	*1902*	*1860*	*1971*	*2000*	*1943*
1	573	633	675	*632*	*660*	635
2	218	248	251	*270*	*260*	249
3	200	203	199	*228*	*219*	210
4	262	292	283	*273*	*272*	276
5	689	647	657	*551*	*514*	612
Total	**3925**	**3925**	**3925**	**3925**	**3925**	**3925**
Frequency of vehicles observed per week (%)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
1	29.5%	31.3%	32.7%	32.3%	34.3%	32.0%
2	11.2%	12.3%	12.2%	13.8%	13.5%	12.6%
3	10.3%	10.0%	9.6%	11.7%	11.4%	10.6%
4	13.5%	14.4%	13.7%	14.0%	14.1%	13.9%
5	35.5%	32.0%	31.8%	28.2%	26.7%	30.8%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Figure A4.2 provides a plot of the average percentages of appearance frequencies across weeks.

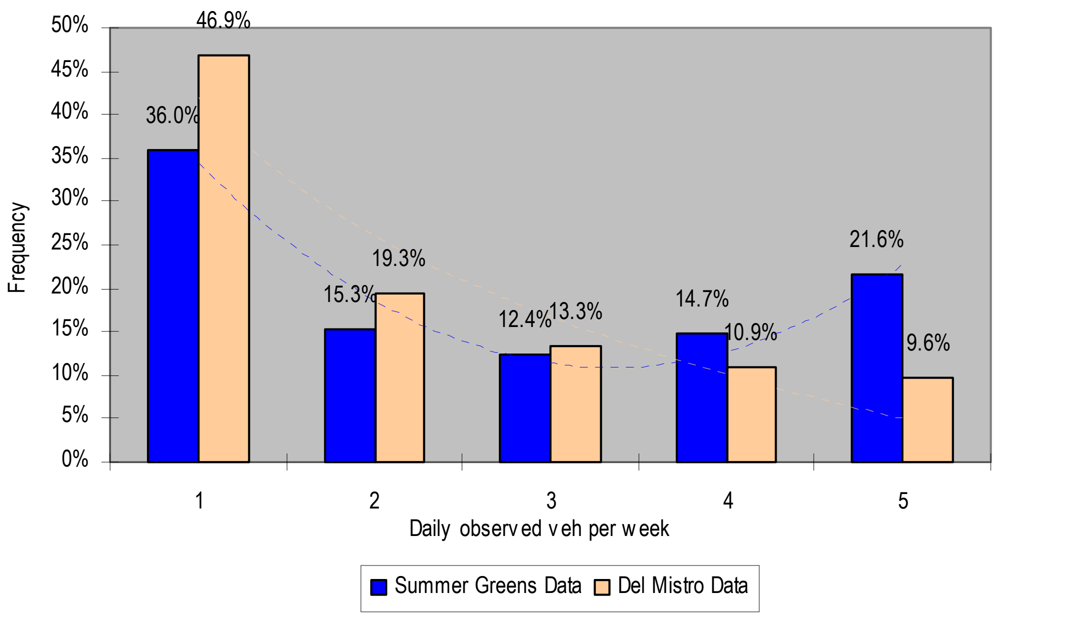
Figure A4.2 : Plot of Frequency of Appearance per week (6:30 to 8:30 period)



Appendix 4.3 : Frequency of Appearance per week (6:45 to 7:45 period)						
Frequency of vehicles observed per week (No.)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
Vehicles not observed	*1373*	*1322*	*1300*	*1479*	*1490*	*1393*
1	423	492	556	*467*	*493*	486
2	217	203	208	*208*	*195*	206
3	182	177	163	*158*	*157*	167
4	212	215	201	*189*	*179*	199
5	338	336	317	*244*	*231*	293
Total	**2745**	**2745**	**2745**	**2745**	**2745**	**2745**
Frequency of vehicles observed per week (%)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
1	30.8%	34.6%	38.5%	36.9%	39.3%	36.0%
2	15.8%	14.3%	14.4%	16.4%	15.5%	15.3%
3	13.3%	12.4%	11.3%	12.5%	12.5%	12.4%
4	15.5%	15.1%	13.9%	14.9%	14.3%	14.7%
5	24.6%	23.6%	21.9%	19.3%	18.4%	21.6%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Figure A4.3 provides a plot of the average percentages of appearance frequencies across weeks.

Figure A4.3 : Plot of Frequency of Appearance per week (6:45 to 7:45 period)

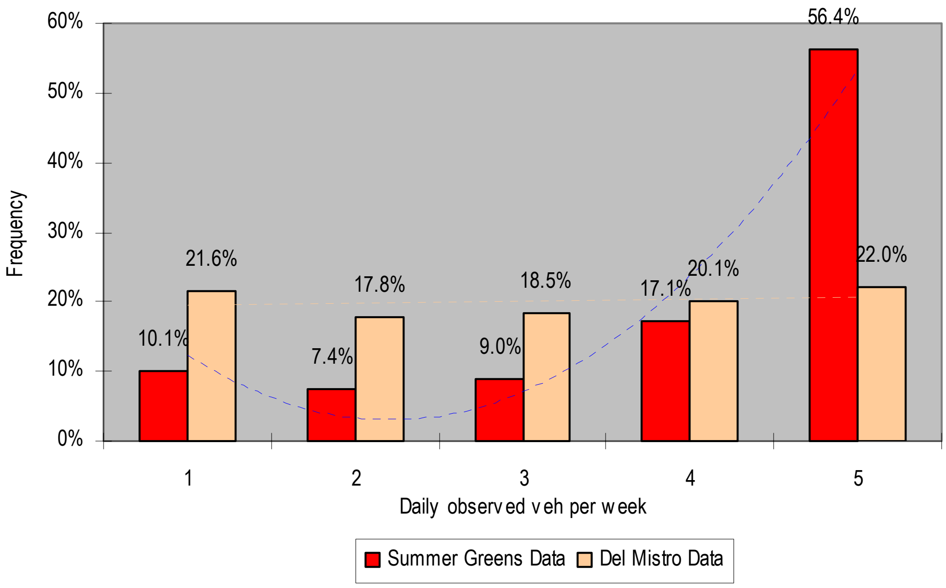


APPENDIX 5 : NO. OF TRIPS W.R.T TRIP OBSERVATION FREQUENCY TABLES

Appendix 5.1 : No. of trips w.r.t frequency of Appearance per week (5:45 – 9:00)						
Frequency of vehicles observed per week (No.)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
Vehicles not observed	*2342*	*2204*	*2197*	*2279*	*2300*	*2264*
1	669	793	809	*762*	*787*	764
2	522	517	548	*641*	*580*	562
3	648	685	606	*778*	*687*	681
4	1213	1360	1323	*1239*	*1355*	1298
5	4657	4526	4587	*3897*	*3796*	4293
Total	**7709**	**7881**	**7873**	***7317***	***7205***	**7597**
Frequency of vehicles observed per week (%)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
1	8.7%	10.1%	10.3%	10.4%	10.9%	10.1%
2	6.8%	6.6%	7.0%	8.8%	8.0%	7.4%
3	8.4%	8.7%	7.7%	10.6%	9.5%	9.0%
4	15.7%	17.3%	16.8%	16.9%	18.8%	17.1%
5	60.4%	57.4%	58.3%	53.3%	52.7%	56.4%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Figure A 5.1 provides a plot of the average percentage number of trips undertaken by the associated vehicle appearance frequency across weeks.

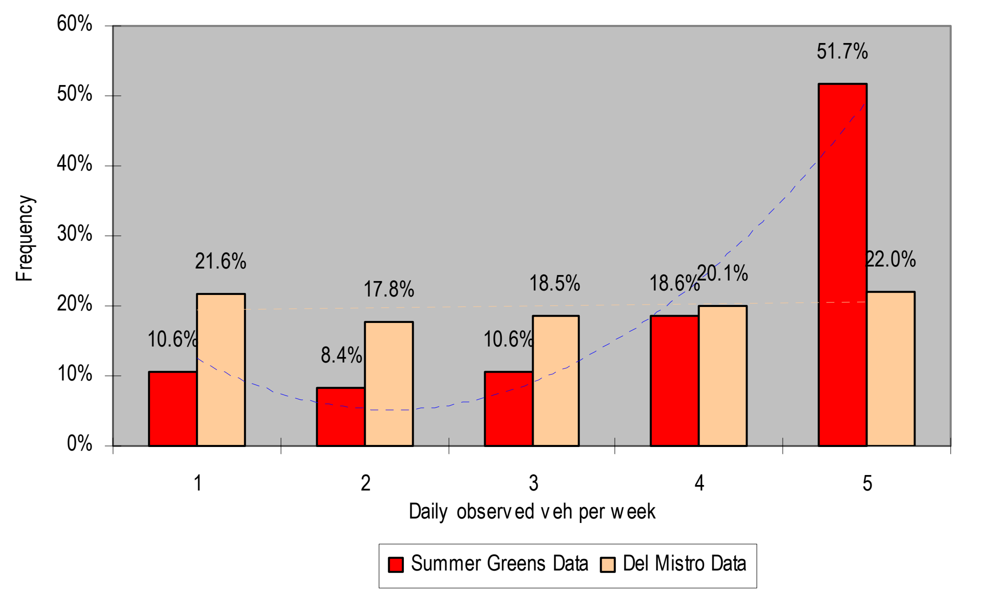
Figure A 5.1 : Plot of Percentage of trips w.r.t. Frequency of Appearances per week (5:45 – 9:00)



Appendix 5.2 : No. of trips w.r.t frequency of Appearance per week (6:30 – 8:30)						
Frequency of vehicles observed per week (No.)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
Vehicles not observed	*1983*	*1902*	*1860*	*1971*	*2000*	*1943*
1	586	643	693	*647*	*671*	648
2	449	510	516	*558*	*530*	513
3	618	622	608	*703*	*685*	647
4	1074	1201	1160	*1117*	*1125*	1135
5	3623	3370	3433	*2819*	*2627*	3174
Total	**6350**	**6346**	**6410**	***5844***	***5638***	**6118**
Frequency of vehicles observed per week (%)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
1	9.2%	10.1%	10.8%	11.1%	11.9%	10.6%
2	7.1%	8.0%	8.0%	9.5%	9.4%	8.4%
3	9.7%	9.8%	9.5%	12.0%	12.1%	10.6%
4	16.9%	18.9%	18.1%	19.1%	20.0%	18.6%
5	57.1%	53.1%	53.6%	48.2%	46.6%	51.7%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Figure A 5.1 provides a plot of the average percentage number of trips undertaken by the associated vehicle appearance frequency across weeks.

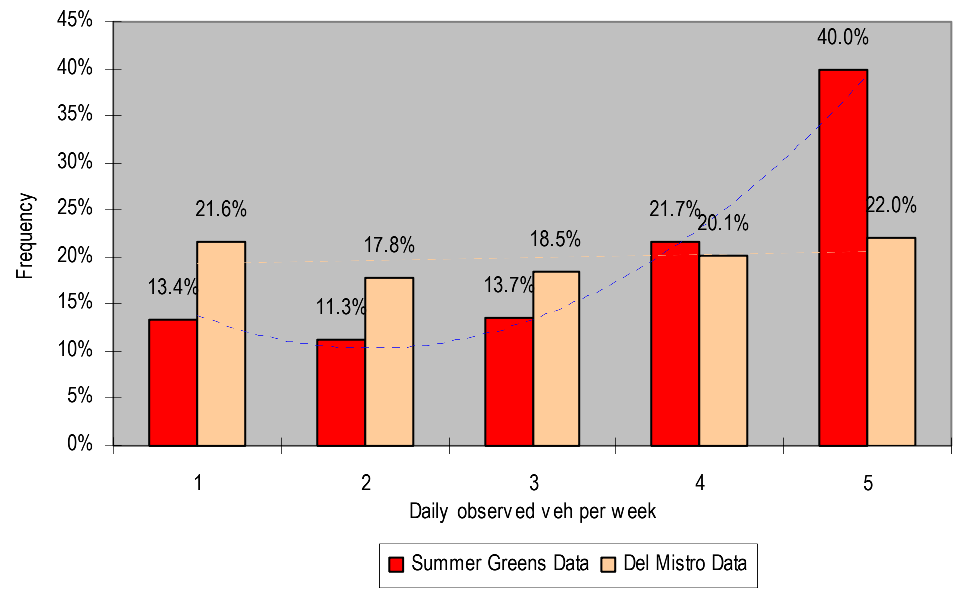
Figure A 5.2 : Plot of Percentage of trips w.r.t. Frequency of Appearances per week (6:30 – 8:30)



Appendix 5.3 : No. of trips w.r.t frequency of Appearance per week (6:45 – 7:45)						
Frequency of vehicles observed per week (No.)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
Vehicles not observed	*1373*	*1322*	*1300*	*1479*	*1490*	*1393*
1	428	501	563	*471*	*499*	492
2	439	412	420	*421*	*393*	417
3	550	537	492	*479*	*475*	507
4	857	870	811	*763*	*723*	805
5	1738	1721	1632	*1227*	*1166*	1497
Total	**4012**	**4041**	**3918**	***3361***	***3256***	**3718**
Frequency of vehicles observed per week (%)	Week 1	Week 2	Week 3	*Week 4*	*Week 5*	Average
1	10.7%	12.4%	14.4%	14.0%	15.3%	13.4%
2	10.9%	10.2%	10.7%	12.5%	12.1%	11.3%
3	13.7%	13.3%	12.6%	14.3%	14.6%	13.7%
4	21.4%	21.5%	20.7%	22.7%	22.2%	21.7%
5	43.3%	42.6%	41.7%	36.5%	35.8%	40.0%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Figure A 5.1 provides a plot of the average percentage number of trips undertaken by the associated vehicle appearance frequency across weeks.

Figure A 5.3 : Plot of Percentage of trips w.r.t. Frequency of Appearances per week (6:45 – 7:45)



APPENDIX 6 : FOLLOWING DAY REPEAT DATA TABLE

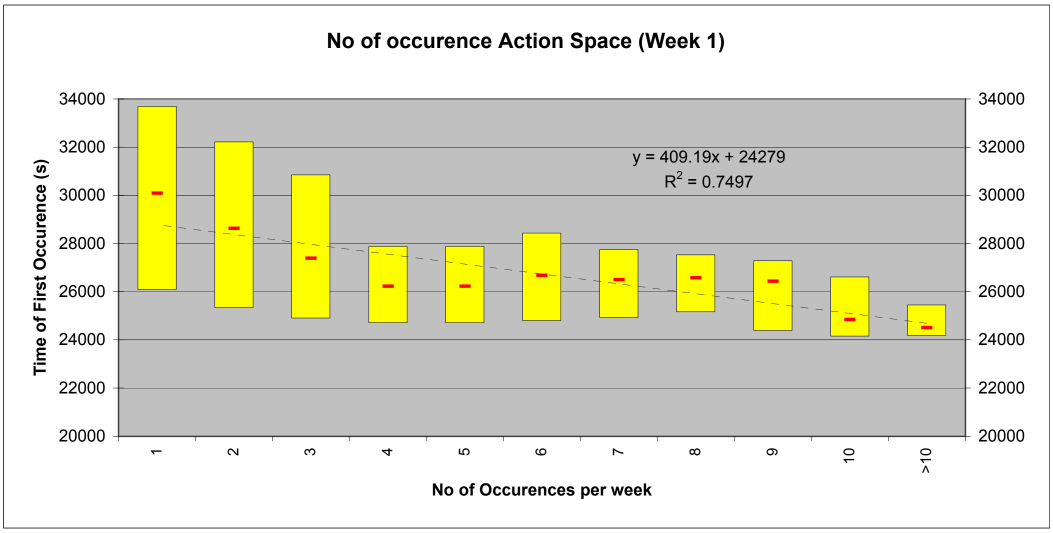
Appendix 6.1 : Following Day repeat data table

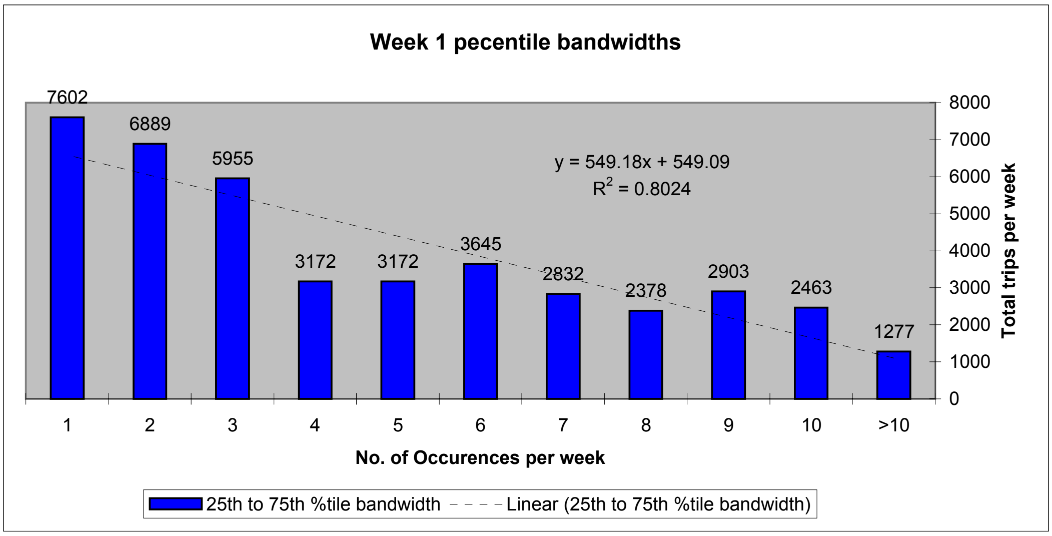
Sum of Min Count	Value of "Min count"				Percentage of Total records			
	Week 1							
	Mon-Tues	Tues-Wed	Wed-Thurs	Thurs-Fri	Mon-Tues	Tues-Wed	Wed-Thurs	Thurs-Fri
0	3747	3731	3708	3661				
1	672	703	723	759				
2	1258	1243	1246	1257	65.2%	63.9%	63.3%	62.4%
Total	5677	5677	5677	5677				
	Week 2							
	Mon-Tues	Tues-Wed	Wed-Thurs	Thurs-Fri	Mon-Tues	Tues-Wed	Wed-Thurs	Thurs-Fri
0	3652	3636	3624	3604				
1	806	775	764	815				
2	1219	1266	1289	1258	60.2%	62.0%	62.8%	60.7%
Total	5677	5677	5677	5677				
	Week 3							
	Mon-Tues	Tues-Wed	Wed-Thurs	Thurs-Fri	Mon-Tues	Tues-Wed	Wed-Thurs	Thurs-Fri
0	3665	3652	3657	3550				
1	769	758	723	887				
2	1243	1267	1297	1240	61.8%	62.6%	64.2%	58.3%
Total	5677	5677	5677	5677				
	Week 4							
	Mon-Tues	Tues-Wed	Wed-Thurs	Thurs-Fri	Mon-Tues	Tues-Wed	Wed-Thurs	Thurs-Fri
0	3703	3720	3706	3694				
1	769	772	797	791				
2	1205	1185	1174	1192	61.0%	60.6%	59.6%	60.1%
Total	5677	5677	5677	5677				
	Week 5							
	Mon-Tues	Tues-Wed	Wed-Thurs	Thurs-Fri	Mon-Tues	Tues-Wed	Wed-Thurs	Thurs-Fri
0	3704	3726	3722	3640				
1	795	760	778	896				
2	1178	1191	1177	1141	59.7%	61.0%	60.2%	56.0%
Total	5677	5677	5677	5677				

APPENDIX 7 : ACTION SPACE TABLES

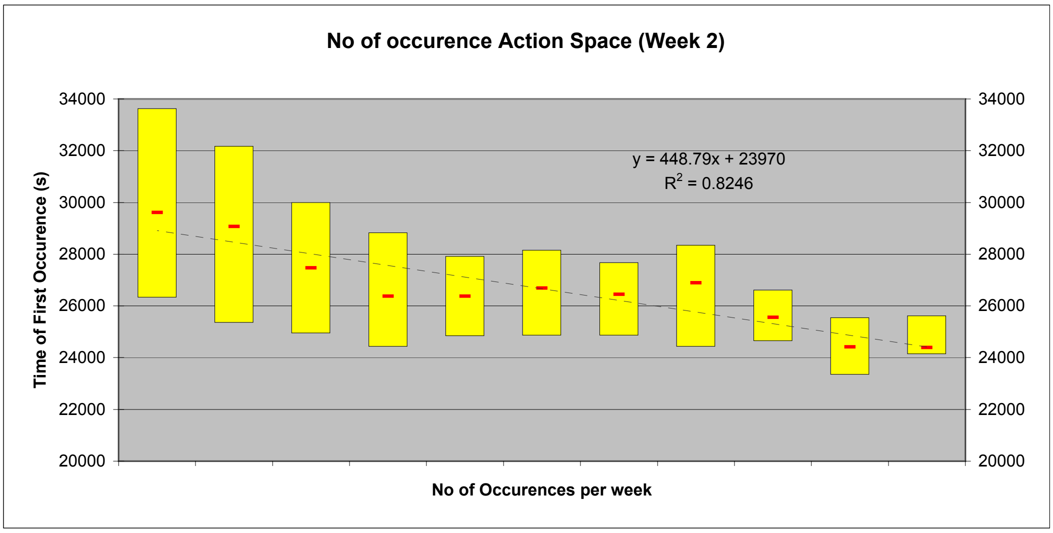
Action Space Data (week 1) ***Appendix 7.1***

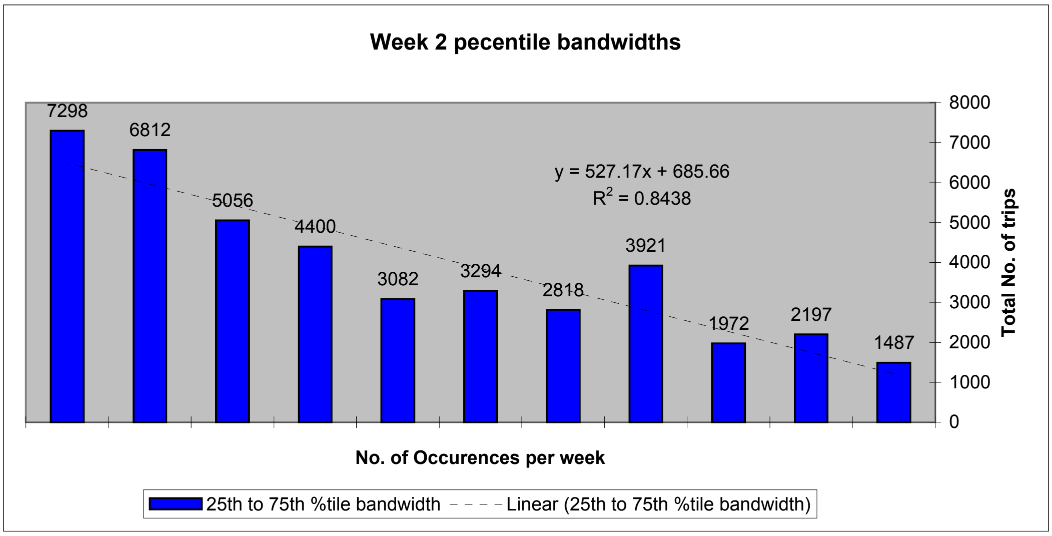
	No. of Occurences	>10	10	9	8	7	6	5	4	3	2	1
0	Min	21740	22561	22044	22136	21823	21210	21431	21431	21336	21220	21262
1	25th %tile	24178	24151	24381	25157	24915	24793	24708	24708	24899	25328	26089
2	50th %tile (Median)	24502	24841	26433	26575	26490	26671	26225	26225	27388	28632	30092
3	75th %tile	25455	26614	27284	27535	27747	28438	27879	27879	30853	32217	33691
4	Max	27094	27602	31357	35916	34833	35629	35979	35979	35963	35963	35996
	25th to 75th %tile	1277	2463	2903	2378	2832	3645	3172	3172	5955	6889	7602





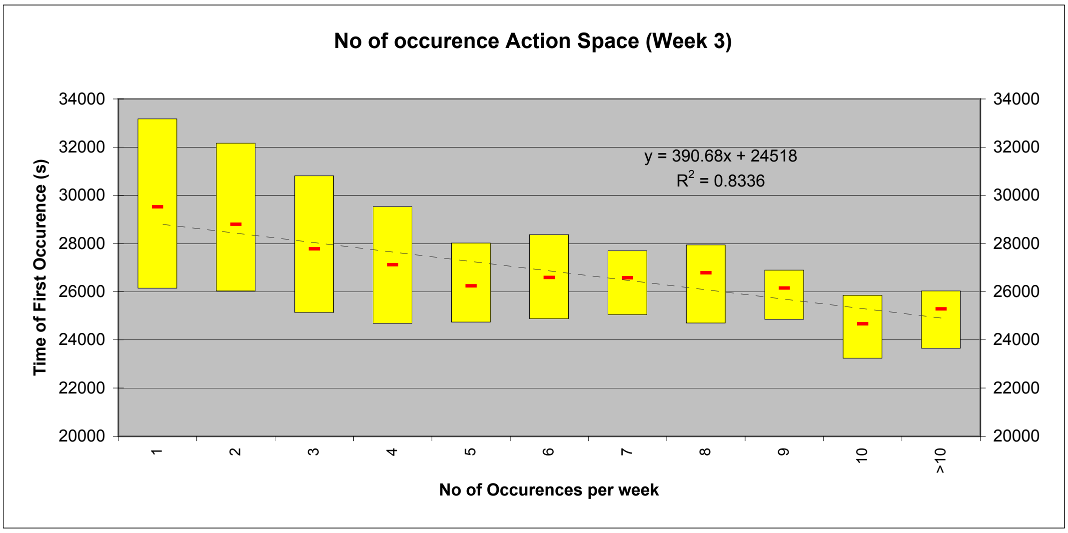
Action Space Data (week 2)											*Appendix 7.2*
	No. of Occurences	>10	10	9	8	7	6	5	4	3	2	1
0	Min	21416	21184	21131	21214	21143	21335	20919	20924	21011	21023	20926
1	25th %tile	24135	23347	24645	24422	24857	24857	24832	24429	24938	25357	26328
2	50th %tile (Median)	24386	24418	25561	26895	26446	26685	26370	26376	27471	29073	29612
3	75th %tile	25622	25544	26617	28342	27674	28150	27914	28829	29995	32168	33626
4	Max	31538	26852	35706	34252	35041	35940	35996	35829	35838	35976	36007
	25th to 75th %tile	1487	2197	1972	3921	2818	3294	3082	4400	5056	6812	7298

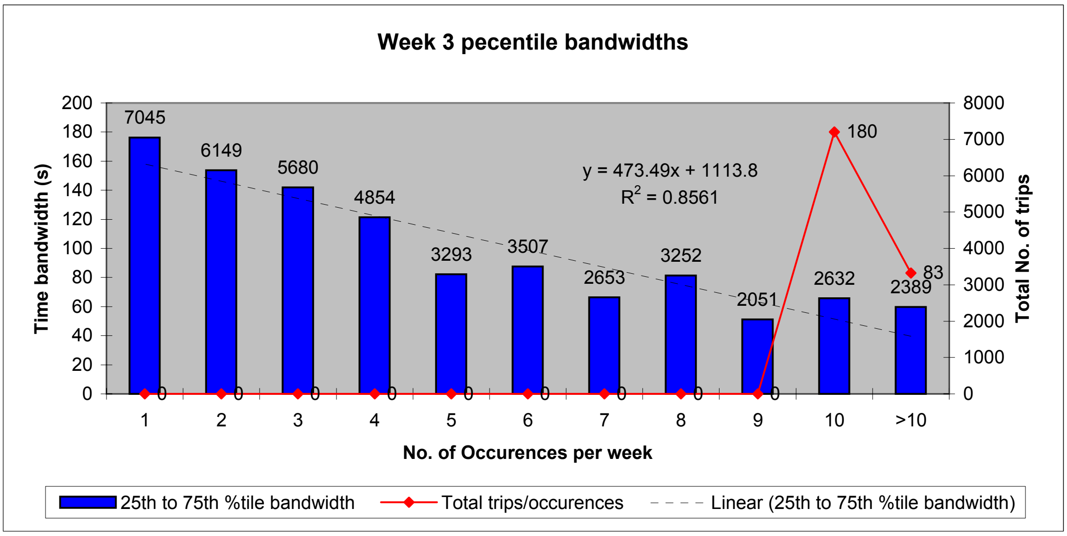




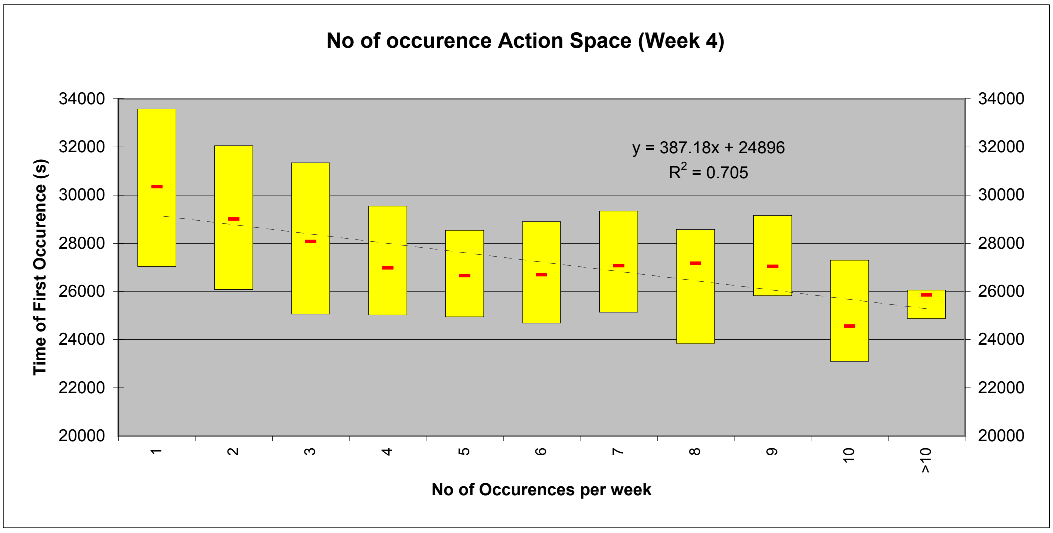
Action Space Data (week 3) | ***Appendix 7.3***

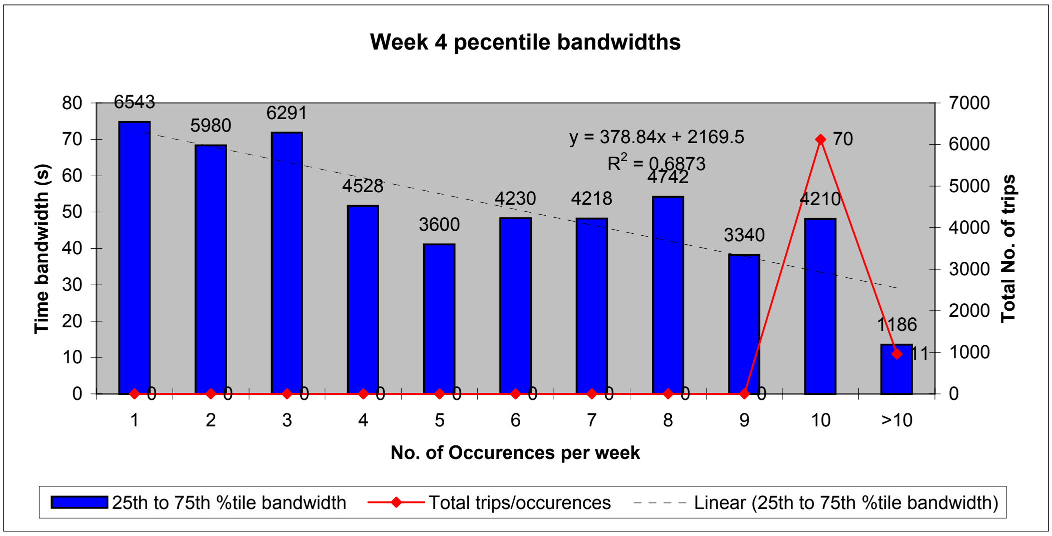
	No. of Occurences	>10	10	9	8	7	6	5	4	3	2	1
0	Min	22290	21269	22673	21202	21360	21154	21096	21026	21022	21037	21034
1	25th %tile	23638	23226	24844	24692	25039	24868	24729	24677	25129	26018	26134
2	50th %tile (Median)	25278	24664	26149	26778	26580	26590	26234	27117	27770	28801	29525
3	75th %tile	26026	25857	26895	27944	27692	28375	28022	29531	30809	32167	33179
4	Max	27515	28697	32759	33829	35152	35812	35952	35985	35970	35962	35963
	25th to 75th %tile	2389	2632	2051	3252	2653	3507	3293	4854	5680	6149	7045





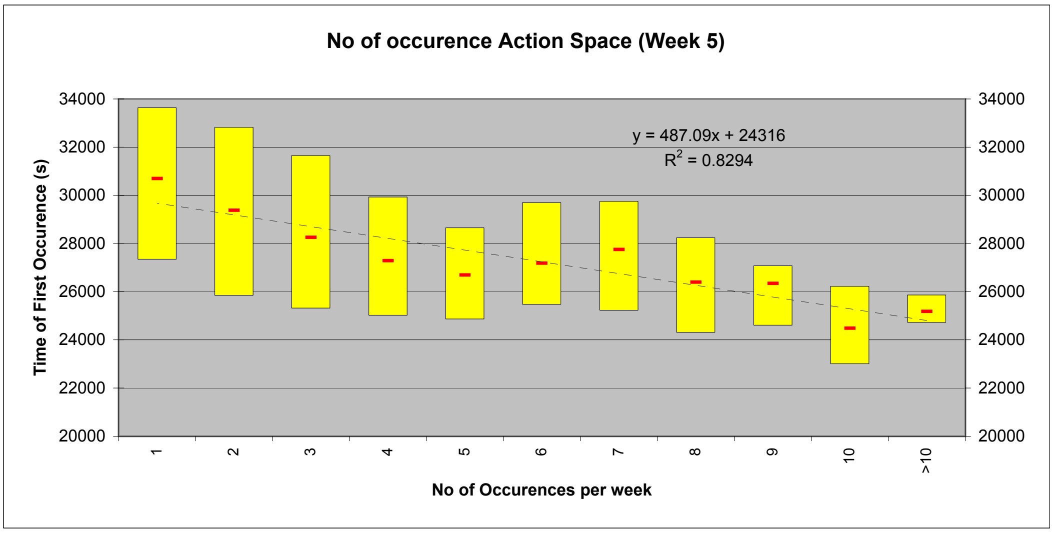
Action Space Data (week4)												*Appendix 7.4*
	No. of Occurences	>10	10	9	8	7	6	5	4	3	2	1
0	Min	24704	22632	21225	21331	21045	20975	21017	21059	21070	21032	20991
1	25th %tile	24875	23082	25816	23837	25121	24669	24936	25014	25049	26065	27027
2	50th %tile (Median)	25848	24555	27036	27174	27059	26685	26658	26975	28067	29007	30346
3	75th %tile	26061	27292	29156	28578	29339	28899	28536	29542	31340	32045	33570
4	Max	26103	30791	32592	35991	35052	35819	35972	35969	35983	35992	35989
	25th to 75th %tile	1186	4210	3340	4742	4218	4230	3600	4528	6291	5980	6543

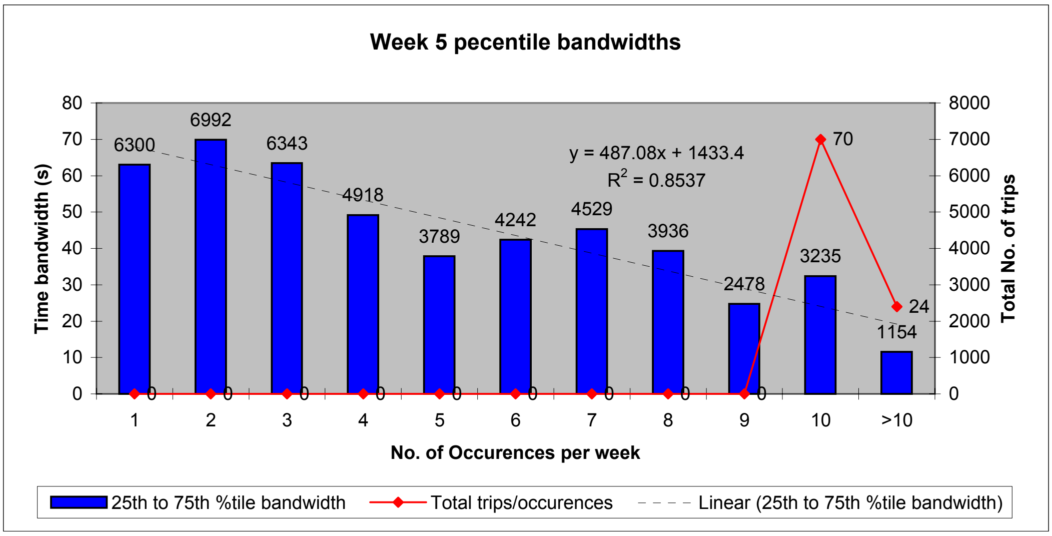




Action Space Data (week 5) **Appendix 7.5**

	No. of Occurences	>10	10	9	8	7	6	5	4	3	2	1
0	Min	23749	22152	22057	21279	21555	21272	21276	21197	20954	21003	20945
1	25th %tile	24709	22991	24599	24305	25218	25457	24861	25015	25313	25833	27339
2	50th %tile (Median)	25185	24482	26342	26394	27749	27180	26686	27282	28252	29376	30698
3	75th %tile	25863	26226	27076	28241	29746	29699	28650	29933	31656	32825	33639
4	Max	30792	29641	31474	34784	35697	35822	35992	35997	35999	35996	35998
	25th to 75th %tile	1154	3235	2478	3936	4529	4242	3789	4918	6343	6992	6300





DATA CD CONTAINING RAW DATA, SPREADSHEETS, AND DOCUMENTATION