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Estimating Mode Choice:

**A Discrete Choice Analysis of a Park and Ride System for
Florida Road, Durban**

by

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Dedication

To my wonderful parents, thank you for all the love and support throughout the years. And for never giving up on me!

To my best friend, I cannot begin to thank you for all you have done. But most importantly, for all those free meals and endless pep talks.

To the powers of the universe, thank you for giving me the patience, perseverance, and strength, to venture into new fields and challenge myself.

And lastly, to my professors Roger Behrens and Mark Zuidgeest. Thank you for introducing me to the wonderful world of discrete choice modelling, and support throughout this whole process.

Declaration

I,*N. BILALA*....., hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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List of Abbreviations

SC	Stated Choice	TDM	Travel Demand Management
P&R	Park and Ride	MLE	Maximum Likelihood Estimation
MNL	Multi Nomial Logit	CBD	Central Business District
DCE	Discrete Choice Experiment	VMT	Vehicle Miles Travelled
DCM	Discrete Choice Methods	RP	Revealed Preference
PT	Public Transport	RUM	Random Utility Model
NMT	Non-Motorised Transport	GEV	General Extreme Value
TMS	Traffic Management System	ASC	Alternative Specific Constant
CAPI	Computer Aided Personal Interview		

Dissertation Title

Estimating Mode Choice:

A Discrete Choice Analysis on The Impact of Introducing a Park And Ride System To Florida Road, Morningside, Durban

Abstract

The majority of roads in Southern Africa have been designed primarily for private vehicle usage, with alternative modes such as public transport and non-motorised transport being largely neglected, and this is also true of Florida Road. Florida Road is located in Morningside, Durban, and has become an iconic landmark street known for its buzzing day and night life. However, due to the lack of adequate parking provision, coupled with increased traffic volumes, this street is plagued by traffic congestion, drivers performing unsafe vehicle manoeuvres as well as illegal parking, contributing to increased driver frustration and the increased possibility of car accidents. In this study, the feasibility of introducing a Park and Ride (P&R) system to Florida Road (from Greyville Racecourse) was investigated. Previous studies have shown that P&R systems can have a positive impact on traffic congestion on the local road network, however, there are not many studies that document the travel impacts and demand for P&R systems of this type – smaller P&R that do not link to major bus or rail public transport systems, but rather operate as “express bus” systems.

This dissertation investigated the predicted travel behaviour responses of car users to the introduction of a P&R system to Florida Road from Greyville Racecourse. By doing so, the demand for the service, in terms of choice probabilities, was forecast. Another interest in this study was to examine the influence of current travel behaviour patterns as well as socio demographic characteristics on the predicted demand for the service.

A stated preference survey was designed and implemented, which presented respondents with hypothetical choice scenarios involving three modes considered available – car, P&R and Uber with varying levels of service attributes i.e. travel cost, time spent parking, security and headway. A questionnaire asking respondents about their current travel patterns and personal characteristics was also administered. A discrete choice experiment was then carried out. A discrete choice experiment models the stated choices of respondents and provides a relative evaluation on the attributes presented, based on their responses. A multinomial logit model was then used in this experiment, to estimate the results.

The results of the discrete choice experiment show that travel cost is one of the most important factors in mode choice evaluation by users of Florida Road. In particular to the P&R system, the service headway as well as presence of car guards/ security at the P&R facility were critical determinants of choice. Employment status was found to have a significant impact on the perceived costs of a trip, particularly trips made by respondent's private vehicle. Respondents also displayed a preference for P&R for social trips, and work trips, over other modes. The time users spent parking at Florida Road was found to not be a significant deterrent to car usage. Socio – demographic variables such as age and gender were not found to have a significant bearing on mode choice probabilities.

To ensure a sustainable demand for the P&R system, P&R service characteristics should be optimised, and the utility of using the P&R service should be higher than that of the other modes considered. From the data analysis, it was evident that for a higher patronage, the cost of using the P&R service should be low, or ideally, the service should be free. Shorter headways between pick – ups/ drop – offs should be maintained. Another important aspect is that, to promote the service, adequate advertising on social media is recommended. Aspects such as parking facility location, bus schedules, costs etc should be highly publicised. A high - quality shuttle bus service should also be provided, to further attract prospective users to the service.

For the P&R system to be truly successful, P&R should be also introduced with measures to discourage use of parking bays on Florida, and encourage the use of the P&R service. An option considered is to start charging parking costs for the bays on Florida Road, thereby discouraging the use of this parking. The promotion of public transport, coupled with measures that actively discourage private vehicle usage would add to the attraction of the P&R system.

1 INTRODUCTION

The purpose of this chapter was to present the framework upon which this research was structured. In this Chapter, the motivation for this research will be described, followed by the aims and objectives of this study. The motivation details the reasons behind conducting this study, as well the reasons behind choosing Florida Road as a study area. The aims and objectives then provide a breakdown of the study goals, and well as the approach taken to achieve these. The structure of this study is also described followed by the methodology undertaken.

1.1 Motivation for Research

Many cities suffer from traffic congestion, brought about by the recent surge of private vehicles onto the road network. With limited infrastructure, increasing traffic congestion leads to many problems, including increased driver frustration and deterioration of the quality of life (Islam *et al.*, 2015). Florida Road, the study area for this research has been plagued by similar concerns, which brought this research into conception.

Florida Road is located in Morningside, Durban, and has become an iconic landmark street in eThekweni, known for its busy day and night life. Florida Road provides an interesting case study due to the unique context it presents. It combines multiple land uses on a 1.5 km stretch of road, and encompasses different facets of social and economic importance. Due to the variety of land uses, Florida Road serves a different demographic, both day and night, leading to increased pedestrian as well as vehicle movement at these times. There is limited parking on this road with parking provisions being mostly on street parallel parking bays on the main road, as well as some side roads. This form of parking lends itself to many traffic issues, including increased congestion during peak periods and unsafe driver behaviour in certain conditions. These are generally caused by delays experienced by drivers while looking for parking bays, waiting for a vehicle to enter/ exit a parking bay, vehicles performing unsafe manoeuvres (u-turning, waiting for parking on the main road etc.) The current traffic problems experienced on Florida Road revolve around the lack of adequate parking facilities, increased vehicular traffic as well as a lack of pedestrian infrastructure required for safe crossing and general pedestrian movement.

Because of these congestion related concerns, countries around the world are turning towards Travel Demand Management (TDM) measures, as a way to reduce traffic congestion (Islam *et al.*, 2015). In broad terms, TDM refers to the application of strategies aimed at reducing or redistributing travel demand. The addition of a Park and Ride (P&R) system for Florida Road will aim to address all these issues. P&R is a TDM measure currently in use internationally to address the problem of congestion in urban areas (Memon, 2014).

For Florida Road, implementing a P&R would assist in realising the goal of decreased vehicle travel on this heavily pedestrian trafficked road. There has been a history of underutilisation of P&R spaces in Durban, and research into the feasibility of implementing such systems should be thoroughly investigated. However, projects of this scale are normally dependent on governmental funding, with high capital and operational expenditure. Determining the feasibility of such a system prior to implementation is therefore a critical step in the evaluative process. There is only very limited research into travel demand estimation, and hence traveller response, as it pertains to P&R and park-and-pool facilities (Pratt, 2013).

Research on P&R systems has also not been thoroughly documented, under the South African context, although there is evidence of research into the fields of Stated choice (SC) and Discrete Choice Experiments (DCE) (Van Zyl *et al.*, 2001; Van Zyl and Venter, 2009) .

This research will provide insight into travel behaviour responses as it pertains to P&R systems, as well as investigate the relevant theoretical background and methodology required to achieve this.

1.2 Aims and Research Objectives

This study used Stated Choice (SC) and Discrete Choice Experiments (DCE) methods to analyse mode choice behaviour in users of Florida Road, upon the introduction of a P&R system to the area. The aims and objectives presented below highlight the general intention of this research, as well as emphasises the desired outcomes.

Aims

The aim of this study was to investigate predicted travel behaviour responses of car users to the introduction of a P&R system from Florida Road to Greyville Racecourse. By doing so, the demand for the service could be quantified, in terms of choice probabilities. A DCE, encompassing SC survey data was carried out to achieve this aim. Another aim of this study was to gain knowledge in the field of SC and DCE, to effectively implement these aspects, and produce significant results. Of interest in this study was also to examine the relative influence of mode attributes on the decision maker's choice, as well as analyse how personal characteristics affect individual decision making.

The demand for the P&R service will be based on user's hypothetical preferences as well as their current socio – demographic and travel characteristics.

Research Objectives

The research objectives presented below assisted in structuring the research carried out. Using the aims above, the research objectives segmented the study into achievable objectives or milestones, as described below.

- ◆ The identification of attributes that influence mode choice for users of Florida Road – it was important to evaluate mode attributes of importance to Florida Road users, as these attributes were used in the design of the SC survey.
- ◆ The identification and modelling of mode choice behaviour in users of Florida Road – the SC survey was used as data in the discrete choice analysis, which analysed and predicted mode choice behaviour.
- ◆ Determination of the effect of user's socio - demographic characteristics on the demand for the P&R service i.e. age, gender, employment status.
- ◆ Determination of the effect of user's current travel characteristics on the demand for the P&R service i.e. time spent and trip purpose.
- ◆ Determination of the effect of each mode's respective service attributes on mode choice.

- ◆ Determination of the factors that influence trade-off behaviour between cost and P&R service characteristics.

This was carried out by:

- ◆ Gathering all information available on Florida Road, relevant to this research,
- ◆ Documenting and applying research in the field of stated choice survey, design and discrete choice modelling,
- ◆ Gathering preference data in the form of stated choice surveys, and
- ◆ Analysing data using discrete choice models to make inferences on current and predicted user preferences (for transport mode) and overall mode shares.

Respondents were asked to value various service attributes for the proposed P&R, Uber and their current private vehicle trip. This study will reveal an understanding of whether visitors to Florida Road are willing to use the P&R service, and the reasoning behind their choices.

1.3 Structure of Dissertation

This dissertation has been divided into 6 parts, following the methodology regarding DCE's.

Chapter One details the motivation for this research as well as the aims and objectives the study attempted to achieve. The reasoning behind using Florida Road for the DCE is also detailed. This chapter provides a brief background into the framework of the research undertaken, and breaks down the study into attainable goals and objectives.

Chapter Two moves on to the literature review, where the main themes running through this research were investigated. Aspects included in the literature review were P&R systems and their operations, the development of SC surveys and experimental design, as well as Discrete Choice Methods (DCM) and model estimation.

The research problem will then be explored in greater detail in Chapter Three, where the context of the study, and study area are discussed. The study area was broken down into the travel components relevant to evaluating P&R demand, and further investigated, to better inform the SC survey design. The focus of this chapter was to investigate the various reasons for the traffic issues experienced on Florida Road, as well as evaluate on a high-level basis whether a P&R system was a suitable traffic reduction measure.

Chapter Four describes how the SC survey and survey instrument was developed, and covers the process of SC design and implementation. This chapter also covers how alternatives, attributes and their respective levels were derived as well as the process by which the final choice sets posed to survey respondents were determined.

Chapter Five describes the framework behind the discrete choice analysis methodology, gives some background into the theory behind DCM's, and presents the results of model estimation, using the SC survey data.

Chapter Six begins with a discussion of the data analysis and gives a summary of the overall data output from model estimation and scenarios tested.

And finally, Chapter Seven concludes the research with a summary on the overall research method and subsequent data analysis and results, and gives recommendations for further research as well as P&R service implementation.

1.4 Research Approach

The following schematic shows the process carried out in the development and implementation of this research. At this point, it should be noted that the research approach described here refers to the general approach taken to this study. The data collection (SC survey) and data analysis (discrete choice analysis) chapters both start off with a detailed description of the research approach, regarding the specifics pertaining to each chapter.

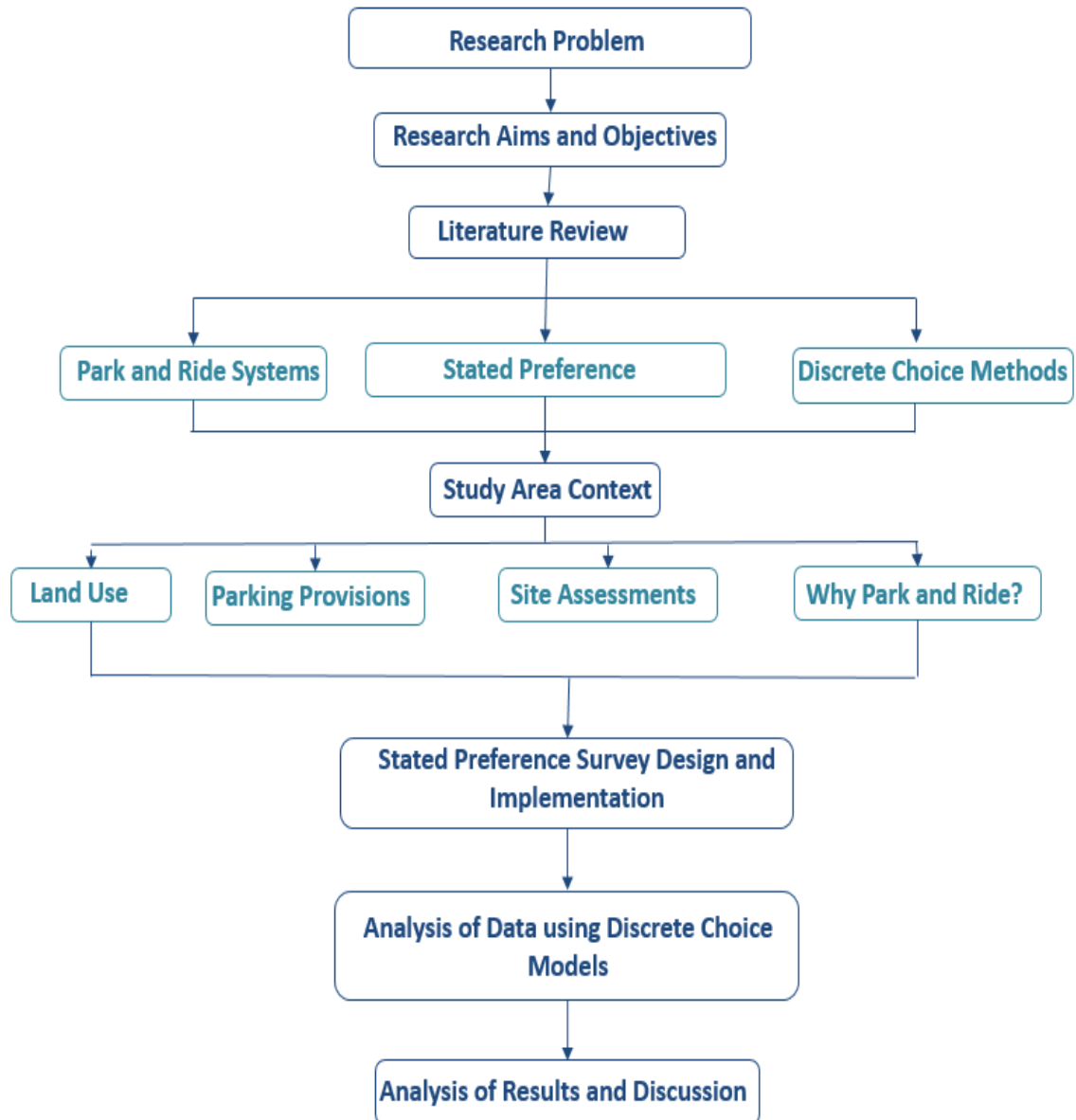


Figure 1 : Flow diagram Showing Research Approach

The research problem was initially identified. This was an important step in the research process as it provided a framework for the aims and objectives to be accurately defined and quantified. Florida Road has numerous congestion problems, which are brought on by the lack of inadequate parking facilities. Congestion reduction measures in urban areas such as TDM measures were researched. A P&R system was concluded to be the most suitable measure that could potentially assist in regulating parking and traffic management for Florida Road.

The aims and objectives for this study were then developed in response to the research problem. The aims defined the overall goals that this study attempted to achieve, while the objectives defined the specific aspects that need to be investigated to support the aims of this study. The main aim of this research was to estimate the demand for the proposed P&R service for Florida Road. Objectives to support the aim included the determination of attributes that influence mode choice in Florida Road users, as well as model mode choice behaviour for the same demographic. Further to this, the effect of the new service attributes, current trip characteristics as well as some socio – demographic variables were analysed. Previous research identified DCM's as the most applicable method to analyse data and successfully carry out this research (Hensher, 1994; Kenneth E Train, 2009; Minal, 2014; Johnston *et al.*, 2017). Given that the P&R system is not in existence, a SC survey was considered the most appropriate method to gather data on potential user's mode choice preferences.

A thorough literature review was conducted to gain sufficient knowledge on the methods identified. The literature review reviewed past literature on various research involving the main themes presented in this study – P&R systems, SC theory as well as DCM theory. Research relevant to the theoretical background, as well as implementation of these methods was reviewed. Case studies were also investigated. The literature review and focus group discussions were carried out to inform on the variables to use in the SC design.

The study area was then investigated to gain a qualitative understanding of the research problem, as well as to assist in the development of attributes and levels (used in the SC survey) that showed a high correlation to the real-life situation. Aspects that were considered important to the research include the land uses on Florida Road, parking provisions as well as site assessments.

The SC survey was then designed, describing various levels of travel time, travel cost, security and headway (for the P&R service) for the modes (car, P&R and Uber) considered in this study. Respondents were presented with 9 choice sets, and then

asked to indicate their preferred modes of travel under some hypothetical scenarios. One of the key deterrents to the use of SC surveys relies in its reliability, as what respondents state that they would do, and what they do, may sometimes differ (Hensher, 1994). Even though there are question marks regarding the validity of SC results to represent real life, there is still a high demand for the method (Johnston *et al.*, 2017). The survey was implemented by means of a paper and pencil survey, over the weekend evening period. University students were used in the implementation of the survey. The survey results were then coded for use in the DCE. DCE's were used to analyse the survey data. In broad terms, DCE's are considered a quantitative technique for eliciting preferences in individuals (Kenneth E Train, 2009). The survey results were used to estimate an MNL model. Logit models are used to determine choice probabilities, given set SP data and the appropriate logit model formulation. Multinomial refers to the cases in which there are more than two variables used in the modelling process. In this study, a Multinomial Logit (MNL) model was used to determine the likelihood that users of Florida Road would use the new P&R service under different scenarios of travel cost, travel time, security and headway. Taste preferences for attributes were determined using utility theory, MNL theory as well as maximum likelihood estimation (MLE) techniques. There is a vast literature on DCE used in transportation which provides a good understanding of DCE's and how models work, as well as how they can be used in transportation engineering (Ben-Akiva and Bierlaire, 2003; Hensher, Rose and Greene, 2005; Wittink, 2011; Olaru *et al.*, 2014)

In summary, a SC survey was carried out to obtain data which was analysed in a DCE. This approach was chosen as to evaluate the impact of inclusion of a P&R service to Florida Road, as a potential TDM measure. The DCE results were then analysed, to gain insights into mode choice behaviour of users of Florida Road, as well as determine the factors that influence mode choice.

Scenarios in which the P&R service attributes were varied were also investigated, to gain a greater understanding of the sample populations responsiveness to changes in mode attributes. These results are then collaborated and discussed, and recommendations for potential P&R facilities are given.

2 LITERATURE REVIEW

2.1 Introduction

The purpose of this literature review was to review literature that would assist in meeting the objectives of this study, as well as in understanding and implementing the methods involved in carrying out this research. This included research into the fields of Park and Ride (P&R) systems, Stated Choice (SC) surveys, as well as Discrete Choice Experiments (DCE's), which are main themes that run through this research.

In the first section, the basic concepts regarding P&R systems and their operations are discussed. The main traffic impacts of implementing these systems are described, as well as some of the unintended induced traffic impacts that have been seen to occur. The typical profile of a P&R user is also investigated.

The next section covers SC methods and survey design. The history behind the development of SC research is briefly discussed, as well as the basic theories unpinning SC survey design. Previous research regarding the derivation of alternatives, attributes and levels is detailed, and statistical good design practice methods are described.

Following this, literature forming the basis of the analysis is presented, and deals with the DCE. The theory behind DCE's are discussed, followed by a brief discussion on the different types of models and their characteristics, as used in the transportation context. The Multinomial Logit Model (MNL) and its respective properties were investigated. Choice theory was also discussed, and more specifically, the influence of choice on utility and its estimation. Finally, the model estimation procedure as well as methods on improving specifications are described. Case studies relevant to this research are also documented.

Finally, the chapter concludes with a summary of the key findings from the literature review.

2.2 Park and Ride

This section focussed on identifying the main operational aspects regarding P&R systems, and well as their predicted impacts on travel and the local road network. Both the advantages and disadvantages of using such systems were explored. Potential P&R users and their various transport needs were also highlighted.

2.2.1 Introduction

As car ownership has risen over the last few decades, traffic congestion has become a serious problem plaguing large cities, both in South Africa, as well as internationally. As such, innovative travel modes and services have been developed, to counteract these negative effects (Yang, 2010).

P&R forms an important component of parking management strategies. These systems have grown in popularity since their introduction in the late 1970's (Parkhurst, 1995). P&R facilities have been developed as a solution to reduce traffic congestion and improve accessibility to areas of congestion. According to the AASHTO Geometric Guidelines for Transit Facilities on Highways and streets, a P&R system can be defined broadly as a facility which provides a place where people can park their vehicles, and use public transit or carpool services to reach their final destinations.

P&R systems have been developed to cater for a range of transportation needs, and offer travellers the option of mixed mode travel. They allow travellers to use a low occupancy mode, generally their private vehicle, to access a transfer location, whereby a higher occupancy mode (generally public transport – in the form of rail, buses etc.) to their respective destinations can be utilised. Areas in which P&R systems are most warranted, are generally the outskirts of urban areas or CBD's (Central Business Districts) where travel densities and congestion and perhaps parking charges are higher, and higher occupancy modes of travel become more convenient forms of access (Pratt, 2013). There are a variety of P&R systems researched in previous studies, as well as currently available. P&R facilities can range in form, from multi-storey parking garages, to simple surfaced parking lots, depending on the intended use. In a similar sense, the purpose for the introduction of a P&R service can vary, from serving a major intermodal transportation hub, to merely facilitating car pool trips (Pratt, 2013).

P&R is unique in the sense that it combines the use of your own vehicle, as well as public transport (Chen *et al.*, 2017). Abdul Hamid, Mohamad and Karim (2008) states that in order for P&R to be attractive to potential users, there needs to be cost as well as time savings, when compared to the alternative modes of transport.

2.2.2 The Travel Impacts of Park and Ride Systems

Litman (2013) gives a good summary of the travel related impacts of implementing P&R systems on various transportation elements such as traffic, the use of alternative modes as well as accessibility. The main travel impact of these services is increased public transport ridership and ridesharing. P&R also supports the use of public transport, as most trips to these facilities were carried out with the intention to use some form of public transport. They also reduce the number of trips made during the peak periods, by reducing the number of vehicles on the road, due to public transport usage. In a similar sense, P&R systems reduce the overall car trips made. P&R systems should in general, lead to a decrease in traffic congestion, as they encourage users to switch from their private vehicle to a public transport system. P&R also increases the availability of alternatives to driving alone by providing travellers with an opportunity to transfer from a low to high occupancy mode (Pratt, 2013).

There are also other factors to consider, that influence the impact that P&R systems have on traffic volumes and Vehicle Kilometres Travelled (VKT) (Chen, Liu, Hua, & Kim, 2017). These include the mode of access and trip length to the P&R facility, the distance between the facility and the major activity centre, as well as the benefits that can be derived from using the P&R facility. The competitiveness of P&R when compared to other current modes of travel would also provide an indication with regards to the demand for the service (Pratt, 2013).

As discussed, P&R systems have been created to primarily deal with the issue of increased congestion and travel costs associated with higher density activity centres within a city. There are also other objectives of these systems, as they cater for convenience, when using higher occupancy modes. It also increases **travellers'** alternatives to driving alone, and allows a smooth transition from low- to high-occupancy modes, and vice versa. P&R systems also contribute to the reduction of VKT and possible harmful gas emissions.

It is worth noting at this point that the type of P&R system described in this study is not that of a typical P&R system as detailed in many research papers. The P&R that is the subject of investigation does not link to a mass public transport system, but rather one with a smaller demand and service offering, that is operated by shuttle busses, serving a single development. Pratt (2013) refers to this type of P&R as express/ local bus P&R facilities.

P&R systems can also provide increased revenue (or reduced costs) for public transport providers along these routes from increased ridership (Olaru *et al.*, 2014). These systems are also an efficient alternative for travellers to access the various public transport modes, in a low-density environment, which would generally not occur.

Research has also been carried out, into the potential negative effects of P&R systems. One of the main drawbacks of these schemes is the amount of space taken by parking facilities, which could otherwise be used to promote more compact development (Pratt, 2013).

2.2.3 The Induced Impacts of Park and Ride Systems

P&R systems can have many positive travel impacts, as has been discussed. Parkhurst (1995, 2000a) was one of the first to introduce the concept of the “unintended effects” - referring to the induced traffic impacts of P&R. He suggested that P&R schemes cause a spatial redistribution of traffic along the adjacent road network, rather than an overall traffic reduction.

Meek *et al.* (2009) also suggested that P&R systems can have counter-productive goals, and in particular, goals counter-productive to car use reduction. He hypothesized that car use within urban areas would increase, in the presence of P&R schemes. He also categorised these “unintended effects” into four major aspects, as shown below:

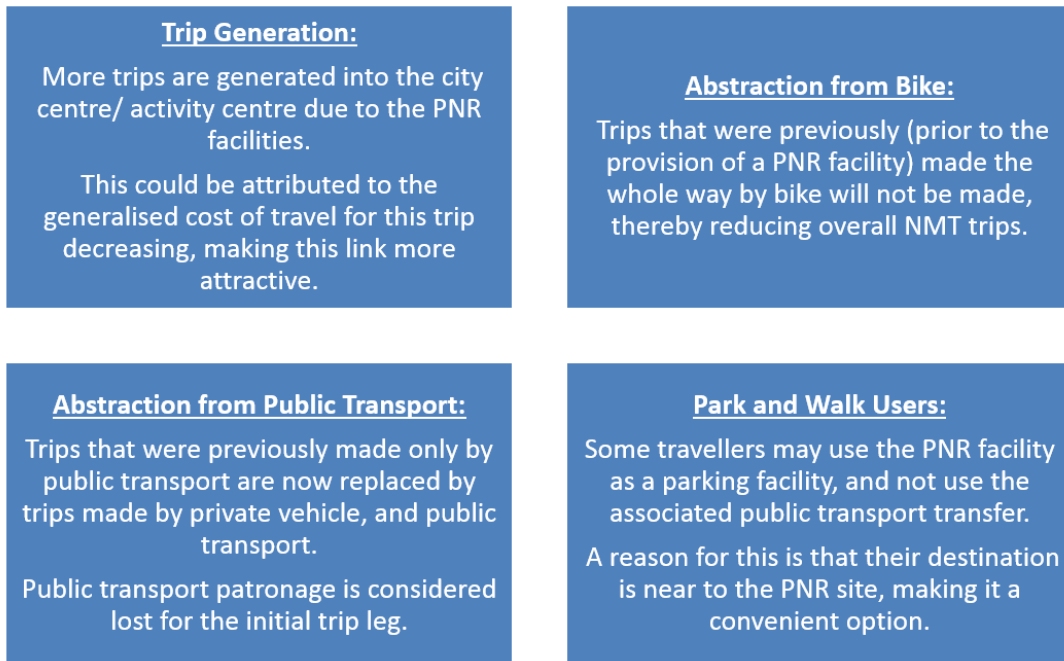


Figure 2 : Some of the "unintended effects" of P&R systems

In a study carried out by Parkhurst (1995), it was found that P&R users who had switched from other modes were making additional trips, that were attracted by the new opportunity of the P&R service. Levels of congestion in the cities studied remained the same, and there was concern that total travel increased. The study concluded that for P&R schemes to be successful, measures aimed at increasing the use of public transport should be targeted, along with the promotion of the P&R service.

2.2.4 The Profile of a Park and Ride User

To develop the attributes and levels used in the SC survey, an in-depth understanding of potential P&R users as well as the factors that affect the usage of P&R systems was required.

One of the defining characteristics of a P&R user is that they are trip makers with choices. These users have private vehicles because they are able to use this for a portion of their trip, and have the ability to utilise it for their entire trip length. Users can therefore be classified as choice users, and not “captive” public transport users (Pratt, 2013). For this reason, the demand for P&R systems will only increase, once the overall cost of a trip with using the P&R facility, is less than the generalised cost of using their private vehicle, for the same trip. The extent of this depends on the circumstance. To a potential user, running vehicle costs can be offset by parking costs at their destination, for example, or longer travel times.

Prospective P&R users would evaluate the utility of the option of driving, against the utility concerning all three aspects of the mixed- mode trip – access to the P&R facility, transfer to transit to the stop/ destination and access to the final destination. According to Pratt (2013) the main aspects considered by trip makers are the time and costs associated with each portion of the trip, as well as the availability of parking at the P&R facility.

Contextual factors that contribute to the use of P&R systems include congested traffic conditions at the destination, lack of parking at the destination, as well as reliable transit availability (Pratt, 2013). Cost and travel saving opportunities are also major contributors to the usage of P&R facilities. Softer issues such as the avoidance of driving stress was also considered a contributor.

In terms of facility location, Pratt (2013) states that users prefer facilities to be located closer to their residence than their destination, or in advance of congested areas. The most important attributes of these services considered by users were found to be safety, service and shelter. Safety was ranked high in terms of importance, but was not considered to affect travel choices in a major way, unless safety was severely compromised in some way. Factors such as facility amenities are “nice to have”, but do not influence facility use in a major way.

2.3 Stated Choice Methods

SC techniques, and their application to DCE's will be discussed here. Previous research was explored here to gather a grasp on the process of choosing alternatives, attributes and levels. The statistical design method was then covered, which included the concepts of fractional factorials and orthogonal design. Lastly, statistical good practice principles were investigated.

2.3.1 Introduction

Louviere *et al.*, (2000) uses a simple definition of an SC survey as any form of data collection that involves the elicitation of preferences and/ or choices from samples of respondents.

SC methods have been in existence since the early 1920's , and have grown extensively in many different fields (Cherchi and Hensher, 2015). Sanko (2001) gives a good summary of the origins of SC research as well as the development of SC research in the transportation field. Most research encountered introduced Thurstone and Hensher as the fathers of SC design (Louviere, 1988; Ahern and Tapley, 2008; Hess and Rose, 2009; Olaru *et al.*, 2014; Johnston *et al.*, 2017)).

SC surveys are now used in many disciplines including marketing, geography, science and tourism, and many of these fields have contributed to its early development (Hensher, 1994). Early stages of SC research only involved ranking and rating (Sanko, 2001). Models then began to evolve in approach and complexity. Louviere and Hensher (1983) were the first to show how a choice experiment can be used with varying choice sets, to enable estimation of a DCM, and therefore predict probability of usage or market share of an alternative. Researchers such as Morikawa (1989) have also made developments on the advantages of combining revealed and stated choice data to better estimate DCM's.

In recent years, SC surveys have gained increasing popularity in the transportation and planning sector. These methods are especially useful when there is a need to assess consumers' behaviour when a new product/service is introduced or there is a substantial change in its attributes (Louviere and Hensher, 1983). The results of these surveys are used to build travel models, aimed at predicting future travel behaviour. It is not exactly clear on the ultimate origins of SC design in the transport field.

Technological developments have also played a pivotal role in SC research. Computerised surveys goes back to the 1980s (Sanko, 2001). Orthogonal designs have been superseded by more efficient methods – such as D-efficient designs (Hensher, 1994; Sanko, 2001; ChoiceMetrics, 2012; Smith *et al.*, 2015) which appear to be more superior. The vast use and expansion of SC through the years shows its relevance and applicability to many research fields.

2.3.2 Revealed Preference vs Stated Choice

The applicable data types explored for this study were revealed preference (RP) and SC. With regards to experiments, RP data refers to data associated with what an individual actually did i.e. it relies on data regarding an action that has been already carried out (Sanko, 2001). SC however, deals with hypothetical contexts/ situations, and usually asks individuals what their action or response would be, given a specific circumstance.

The table below also gives a good detailed comparison of RP and SC data sets characteristics in terms of the type of preference information, alternatives and attributes considered as well as the choice set and number of responses that are possible(adapted from Sanko (2001)):

Table 1: Comparison of SC and RP Data Characteristics(adapted from Sanko (2001))

	RP Data	SC Data
Preference Information	Actual behaviour is recorded	Predicted behaviour under a hypothetical situation
	Behaviour carried out is what is revealed in the real market	There is a possibility behaviour might not be consistent with the actual market
	Results is one choice	Result is a rating/ ranking of alternatives – provides more information
Alternatives	Considers only existing alternatives	Considers both existing and non-existing alternatives, and allow us to look at potential changes
Attributes	There can exist a degree of measurement error	There is no measurement error
	Limited range of attribute levels due to lack of variability in the market place	Vast range of attribute levels can be used
	Possibility of correlation among attributes	Correlation between attributes can be controlled
Choice Set	No clear definition of choice set	Clear definition of choice set
Number of Responses	One response per respondent	More than one response per respondent

Products that are not traded in the actual market can be analysed. RP data does not exist for this situation. For transportation, this is an advantage as the demand for new alternatives can be forecasted. Revealed preference cannot collect data on hypothetical / new services or products. Attributes also have little variability in the market place. In real markets, the value of attributes of products / services is rarely varied, offering little information on the trade-off behaviour in individuals when attribute levels are varied. With SC, attributes can be varied upon the researchers discretion and hypothetical scenarios. Attribute levels are also highly correlated in the market place. For example, travel cost and travel time are generally correlated. An increase in travel cost is normally related to an increase in travel time, and vice versa. Bias in estimation is reduced as one attribute may have an influence on the other. Stated choice data collection is also more economical and more information can be captured per respondent. RP data collection is time and cost intensive (Sanko, 2001).

2.3.3 Stated Choice Reliability

The main disadvantage debated by researchers of the use of SC data lies in its reliability. In SC surveys, the respondents state what he would prefer, which has the potential to differ from what the individual eventually does do. In RP, the choice made by respondents has known outcomes, even though they are dependent on the respondent's perceptions of attribute levels (Hensher, 1994). The main biases in SC data are due to respondents trying to justify their actual behaviour, or respondents trying to control policies. One of the solutions to this was discovered by Morikawa (1989), who introduced the method of combining revealed and SC data, to obtain more accurate results. Even though there are question marks regarding the validity of SC results to represent real life, there is still a high demand for the method (Johnston *et al.*, 2017).

In this literature review, we will focus on two main aspects relating to SC survey design – the design of alternatives, attributes and levels, as well as the survey statistical design. Statistical design refers to the methods used to formulate the final choice sets posed to respondents. Best practices regarding survey design will also be investigated.

2.3.4 Design of Alternatives, Attributes and Levels

One of the most important elements of SC design is the setting and combining of attributes and attribute levels. The motivation behind conducting experiments in general terms is to determine the independent influence of different variables, on some observed outcome (ChoiceMetrics, 2012). In SC studies, experiments are designed to determine the influence of design attributes upon choices that are made by the respondents being sampled.

The distribution of attributes and levels play a big role in whether inferences can be made on the influence of individual levels on the respondent's decision-making skills. The allocation of attribute levels can also have an impact on the statistical power of the experimental design. This is most prominent upon its ability to detect statistical relations within the data set. With larger sample sets, this is not a big consideration. However with smaller, realistic sample sets, this could lead to poor design and less accurate results (ChoiceMetrics, 2012).

2.3.4.1 Choosing Relevant Attributes and Levels

The design of SC surveys is informed by many factors including the objectives of the study, previous research on the specific application and well as knowledge gained through the survey design process (Johnston et al., 2017). Johnston et al. (2017) also suggests that attributes and levels should be chosen based on the objectives of the study, feasibility of implementation, plausibility to respondents as well as statistical efficiency.

There are vast amounts of literature detailing the choice of attributes and attribute levels for use in SC designs. However, only a few were found to contain this information for shuttle P&R services, or smaller P&R systems (that are not linked to major public transport systems such as rail). The attributes and levels described below provided a good understanding of factors that influence mode choice for potential P&R users.

It is generally good practice to make use of only the most relevant attributes. In transport mode choice modelling, the most commonly considered attributes are travel time and travel cost (Adamowicz, Louviere and Swait, 1998; Shiftan, Vary and Geyer, 2006; Kenneth E Train, 2009; Olaru *et al.*, 2014). Other popular attributes include various travel time components, reliability, comfort etc. (Hess and Rose,

2009). Having attributes directly linked to alternatives aids in making the alternative presented more believable to respondents.

A study carried out by Shiftan, Vary and Geyer (2006) examined the potential of implementing shuttle bus services within a national park, with the objective of decreasing vehicle use on the park roads. This study used an SC survey and DCM's to quantify the effect of various service characteristics on visitor's mode choice and on reducing car travel in the parks. Attributes included in this study were private vehicle drive time, private vehicle walk time (for private vehicle use) and fare and headway for shuttle service use.

Hole (2004a) carried out a similar study to the research topic. The research used SC data to forecast the demand for an employee P&R service for a University. The experiment contained only two attributes; P&R door-to-door travel time and cost, which were varied over three levels relative to the individuals' current commute.

Abdul Hamid, Mohamad and Karim (2008) carried out research on the factors that influence P&R usage. The study found that in terms of trip characteristics, trip purpose, total time taken from origin to destination, total cost incurred (from origin to destination) and number of transfers made were most important to current users. In terms of parking characteristics, P&R service charges, frequency of P&R use and the availability of parking at the P&R facility were also important considerations.

Attributes such as travel cost and travel time are generally well understood by respondents, especially in relation to their current trip. However, attributes such as comfort and service quality for example, can be tricky to describe. It is therefore good practice that the researcher present these attributes in a meaningful way, so that it can be easily understood (Hess and Rose, 2009).

Another important consideration in the choosing of attribute levels, is that the choice set generated by the experimental design, accurately represent the real life trade-off behaviour experienced by respondents (Sanko, 2001). The ranges used in attribute levels should necessitate the trade-off thought processes between the alternatives posed, but not be too broad, so that they result in unrealistic combinations.

According to Hess and Rose (2009), the more levels used in a survey design, the less efficient a design is. The reasoning behind this lies in the fact that the statistical efficiency of a design is a function of the choice probabilities. The paper states that the more attribute levels used, the more constrained the design will be in terms of the possible choice probabilities that can be achieved.

2.3.5 Statistical Design

So far, the process of defining attributes and attribute levels has been reviewed. Statistical design refers to the process whereby attributes and attribute levels are combined, to produce alternatives and choice sets that are presented to respondents (Smith et al., 2015). This is considered one of the critical elements of SC survey design.

2.3.6 Full Factorial and Fractional Factorial Design

A full factorial design represents the full range of combinations (each attribute level combined with every other attribute level) that can be generated from the attributes and attribute levels specified. Full factorials have some advantages over their fractional factorial counterparts. Full factorials guarantee that all attribute effects are independent of one another (Louviere *et al.*, 2000). This implies that no correlation effects are regarded in full factorials.

There are also some disadvantages regarding the use of full factorials. The full factorial design produces too many choice sets, which become unrealistic as too many tasks are presented to respondents (Sanko, 2001). Respondents can experience respondent fatigue, which has the possibility of leading to responses errors, and respondents “brushing through” choice sets. Since the full factorial consists of a complete spectrum of choice set combinations, dominant scenarios may exist. Dominant scenarios refer to choice sets whereby one alternative scenario is always chosen (Smith *et al.*, 2015). Dominant scenarios can also result in unrealistic situations, which do not give meaningful information on trade-off behaviour.

Full factorials are most applicable to SC studies with a small number of attributes and levels. As the number of alternatives, attributes and levels increase, the number of choice sets increase considerably (Smith et al., 2015).

Fractional factorial designs were developed to reduce the number of choice sets presented to respondents, while still maintaining the required number of attributes and attribute levels. Previous research has indicated that this is the most commonly used solution (Sanko, 2001; ChoiceMetrics, 2012). A fractional factorial design only shows respondents a subset of the full factorial, thereby reducing the respondent (as well as researcher burden). Orthogonal design will be explored in the following section.

According to Sanko (2001), interactions and their inclusions affects the type of design procedure used. For example, if you are interested in all interactions, you would need to use the full factorial. If you are only interested in some interactions, a fractional factorial that only considers them can be used. The paper suggests that interactions be ignored as far as possible, unless there is good reason to include them.

2.3.7 Orthogonal Design

Orthogonal designs refer to designs that most importantly satisfy attribute level balance and one whereby all parameters are independently estimable. By default, this implies that attribute levels are uncorrelated with each other (ChoiceMetrics, 2012) . Hensher (1994) states that this property is a major advantage of SC as it allows the researcher to undertake statistical tests regarding main effects and interactions within the experiment. The most commonly found design is the orthogonal fractional factorial (Yang, 2010). Louviere *et al.* (2000) suggests that there are two main types of orthogonal design; simultaneous and sequential orthogonal design. The differences in the two methods relate to how the orthogonal design is carried out. Simultaneous orthogonal design generates a design that is orthogonal both within and between alternatives, while sequential orthogonal design generates an orthogonal design for the first alternative, then adds subsequent alternatives, and generates another orthogonal design.

Finding an orthogonal design may not always be possible (ChoiceMetrics, 2012). There are tables of orthogonal arrays available, using specific numbers of attributes and levels. Sometimes, it is possible that an orthogonal array for a specific situation cannot be determined.

Attribute level balance occurs when each attribute level in an experiment occurs the same number of times as every other attribute level. The rationale behind this property is that it can reduce respondent bias, by not showing one (or more) levels more than the rest. In other words, respondents are not only subjected to too many low or high attribute levels, but rather an equal range of levels (Hess and Rose, 2009). Respondents are expected to react objectively to all attribute levels(Hess and Rose, 2009). However, there may be some undesirable properties of attribute level balance and they may result in large experimental designs. This becomes more critical when there are odd and even attribute levels used. Hess and Rose (2009) also suggests that

attribute level balance also imposes a constraint on the statistical design, thereby leading to less efficient designs.

Collins, Bliemer and Rose (2014) states that orthogonality is an important characteristics in linear models, and are less important to nonlinear models such as DCM's, and this idea is supported by other researchers (Hensher, 1994; Adamowicz, Louviere and Swait, 1998; Louviere *et al.*, 2000; Wittink, 2011).

Reasons for moving away from orthogonal designs include the inclusion of implausible scenarios as well as, sometimes orthogonality cannot be maintain due to context constraints and the introduction of more efficient designs (Schmid, 2016).

2.3.7.1 Other Designs

Majority of experimental designs used to date involve orthogonal designs, or are orthogonal in nature. However, SC designs have evolved to match the complexities of advancement in DCM's. More recent designs are moving away from the concepts underpinning orthogonality, in favour of optimality and efficiency measures (Smith *et al.*, 2015).

The purpose of efficient designs is to produce reliable parameter estimates using only a fractional factorial design. One of the challenges of these designs is knowledge of estimated parameters as these need to be known prior to estimation. In some cases, parameters can be set to 0, or set to values based on the researchers experience (Smith *et al.*, 2015). Hess and Rose (2009) suggests that the advantages of these designs lie in their ability to produce more robust results, with smaller sample sizes.

2.3.8 Statistical Design Good Practice

Smith *et al.*(2015) refers to a good statistical design as one that has a rich set of attributes and choice sets, and enough variation in attribute levels to produce meaningful explanations to behaviour. Almost every step in the statistical design of an SC survey has a critical impact on the statistical robustness of the models eventually realised. In this part of the literature review, the main aspects that contribute to good statistical design, particularly with regards to the research problem and this specific SC survey design, was investigated.

There was a vast array of literature found regarding survey design objectives, and statistical good practice principles. Some of the more commonly found aspects are summarised here.

2.3.8.1 How Many Is Too Much?

To reduce the number of choice sets posed to respondents, the number of attributes and corresponding attribute levels should be kept to a minimum. The main reason behind this is to avoid respondent burden. A limit of between 6- 7 attributes was suggested, and this number should be decreased if alternatives are new to respondents, or perhaps complicated to define Permain et al. (1991) through (Sanko, 2001). In the same breath, the number of attributes presented should not be too low, as this can sometimes be considered as bearing little resemblance to actual choice decisions made by respondents (Hess and Rose, 2009). Some papers suggest a maximum of 9-10 attributes per alternative (Smith *et al.*, 2015).

A common assumption is that more choice tasks produce greater variability, which essentially assists in better model estimation and model outcomes (Hess and Rose, 2009). Hess and Rose (2009) also cited a paper by Bliemer et al. (2009) who compared the results of two survey designs – an efficient design with 18 and an orthogonal design with 108 choice sets. He showed that the smaller design outperformed the larger design, in terms of producing much smaller standard errors upon estimation. What was important however is how much information can be gathered from choice sets, regarding trade-off behaviour (Hess and Rose, 2009) .

2.3.8.2 Generating Choice Sets

The number of choice sets in the orthogonal design is generally too large to pose to all respondents, and should be minimised. In Sanko (2001), guidelines were given into the process of removing irrelevant choice sets. It should be noted that combinations and choice sets need to be realistic, but sometimes it is not possible to have all combinations within the individuals experience (Hensher, Rose and Greene, 2005).

Sanko (2001) suggests that if the survey intention is to aim at reality, you can remove choice sets which pose contextual constraints, or choice sets that are trivial. Implausible scenarios can also be removed, and this refers to the situation where the choice sets posed represent scenarios that are unlikely to occur in reality. Trivial

games refer to choice sets where the choice decision is an obvious one, and one alternative (and attributes) is dominant over the others. Realism is also improved by removing dominant alternatives (Smith *et al.*, 2015).

2.3.8.3 Blocking

Sometimes, the number of choice sets generated by a statistical design is too many to pose to each respondent. To counteract this, blocking is generally used. This refers to the process whereby choice sets are divided into subsets, and subsets are allocated to different respondents (Hess and Rose, 2009). Each block is not orthogonal by itself, but the combination of all blocks is orthogonal. Attribute level balance however, is satisfied in blocking (ChoiceMetrics, 2012).

Another paper written by Hess et al. (2008) documented the results of three different experimental designs – an orthogonal design with random choice assignment, an orthogonal design with orthogonal blocking column and an efficient design. The design with the worst performance was the orthogonal design with random choice assignment. However, it was interesting to note that the efficient design only performed marginally better than the orthogonal design with orthogonal blocking. The paper concluded that blocking was a far more critical to SC than the experimental design.

2.3.8.4 The Inclusion of Additional Questions

SC surveys should include additional questions over and above the SC survey experiment. These questions are generally required to enhance the validity of the SC experiment being carried out as well as to assist in evaluating the validity of responses to questions (Johnston *et al.*, 2017).

Hess and Rose (2009) suggest the inclusion of socio – demographic data, attitudinal data as well as data regarding how respondents process their choices. The paper also suggests that researchers should be cautioned when asking questions of a personal nature (when carrying out the SC survey) to avoid influencing behaviour. Preference heterogeneity can also be captured with the use of personal characteristics and attitudinal data, by means of trade-off behaviour.

2.3.8.5 Enhancing the Validity of the Statistical Experiment

Some important points came to the fore upon researching the formulation of attributes and levels for use in DCM's. Attributes should be designed to be realistic, and believable to respondents, adding to the realism of the study. The rationale behind realism is that respondents are asked to analyse similar situations that they would be faced with in real life. Realism can be lost if the experiment does not accurately portray the real life circumstance (Hess and Rose, 2009). In most cases, it is also advantageous if the attributes relate to the respondent's actual experience with the alternative (Sanko, 2001). Another important aspect is that attributes allow for trade-off behaviour from respondents. Depending on the study objectives, mirroring real life behaviour involves trade-off between attributes is often a key consideration. Numerous studies have for example, used trade-off behaviour in product evaluation as well as product elasticities. The use of pivoting has also been a way to increase the realism effects (Hess and Rose, 2009).

2.4 Discrete Choice Theory

The purpose of this section was to explore the theory underlying Discrete Choice Experiments (DCE's) as well as delve into model design and estimation principles. DCE's are an SC method that involves the generation and analysis of choice data (Lancsar, Fiebig and Hole, 2017). The SC survey data described in the previous sections highlighted the process involved in the generation of the data. The focus of this chapter will be on the analysis of this data. DCM's can also be referred to as disaggregate models, as the decision maker is assumed to be the individual.

The main outcome of DCE's is to predict the decision-making behaviour of individuals as well as determine the relative influence of attributes of alternatives to individuals when choices are made (Koppelman and Bhat, 2006). DCE's are also useful in analysing choice behaviour for segments of the population. DCE's and survey experimental design are intimately linked. There is a vast literature on DCE's used in transportation which provides a good understanding of how these models work, as well as how they can be used (Hensher, 1994; Ben-Akiva and Bierlaire, 2003; Koppelman and Bhat, 2006).

2.4.1 The Theoretical Foundations of Discrete Choice Models

This section will focus on describing the theoretical principles that underpin DCM's, and their estimation. Understanding choice behaviour and the framework under which decisions are made, is a key step in conducting a DCE. The main topics discussed here are choice theory as well as utility theory and random utility models (RUM's).

2.4.1.1 Choice Theory

It can be said that all, if not most of the decisions we make in life, involve a choice. We choose what to have for breakfast, how to get to work, whether to go the gym etc. The theory of how choices are made has become an interest to society. If the process behind how choices are made can be quantified to some degree, then it is possible for researchers to pick up patterns in behaviour, predict demand or adjust current economic levels to suit consumer demand (Wittink, 2011).

In this section, the process of decision - making as postulated by Ben-Akiva and Lerman (1985) will be described, as well as the essential components of the decision-making process.

2.4.1.1.1 The Decision-Making Framework

Ben-Akiva and Lerman (1985) defined the decision-making process as a series of sequential steps consisting of the following:

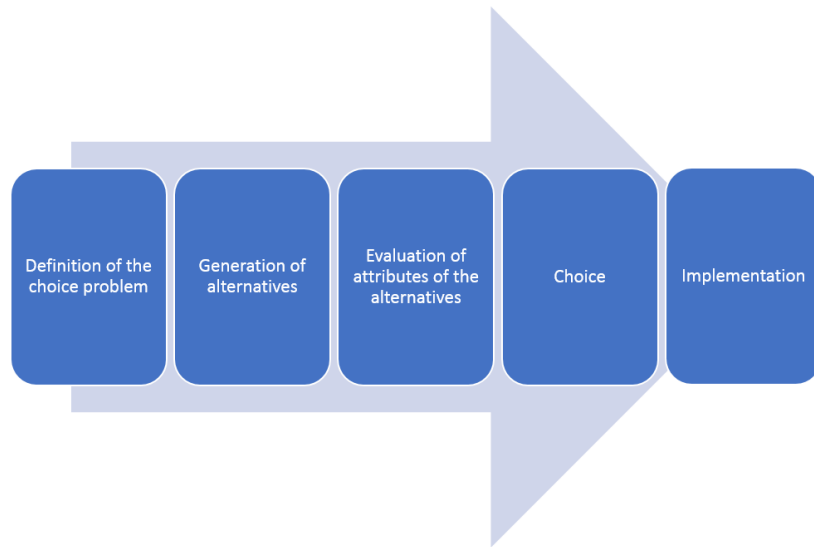


Figure 3: The Decision-Making Framework as proposed by Ben - Akiva and Lerman (1985)

It is generally easier to observe an individual's end choice, then to gather information on how individuals arrived at a specific choice. The proposed framework states that an individual first tries to understand the choice problem at hand, and makes sense of what is required. The individual then determines the alternatives that are available to them. Not every potential alternative can be included in an individual's choice set, due to contextual constraints regarding the individual's environment, or the individual themselves. The next step in the process is to then evaluate each alternative that is available, in terms of its attributes relevant to the choice context. An individual then uses a specific decision rule to evaluate alternatives, and select a choice (Ben-Akiva and Lerman,1985). Some of these elements will be discussed briefly in the section to follow.

2.4.1.1.2 Elements of the Decision- Making Process

The elements forming part of the decision-making framework are discussed in greater detail to provide some clarity on the basic concepts underlying DCE. The concepts of a decision maker, alternatives and attributes as well as the decision rule, are introduced.

Decision - Maker

The decision - maker in each choice situation varies, but generally represents an individual, group or institution with the responsibility to make the decision being considered (Ben-Akiva and Bierlaire, 2003; Kenneth E Train, 2009). On an individual level, each decision – maker’s choice situation, or context is different and so is the taste variations (for products/ services) inherent to every individual. Taste variations refer to the concept that individuals value attributes differently. An example given in Koppelman and Bhat (2006) refers to a situation in which two individuals are faced with a mode choice decision. If these individuals have different income levels and residential locations for example, they may have differing choice sets, and may weigh the importance of transport mode service attributes (such as trip time, trip cost etc) differently. Socio – demographic characteristics (such as age, employment status, income etc) of respondents should be included in DCMs to assist in explaining these taste preferences better (Ben-Akiva and Bierlaire, 2003).

Alternatives and Attributes

Individuals generally make a choice given the set of alternatives that is available to them. The set of alternatives available does not always consist of every alternative possible, due to a combination of environmental and personal constraints. In most choice contexts, individuals only consider a subset of the actual choice set, presenting alternatives that are feasible to the individual (Koppelman and Bhat, 2006).

The alternatives in a choice situation are characterised by attributes. The attractiveness of an alternative is determined by the attractiveness of its attributes, to the individual (Koppelman and Bhat, 2006). The identification of available alternatives to the individual is a complex process, and is referred to as choice generation. Ben-Akiva and Bierlaire (2003) also make an interesting point – that a respondent’s awareness of the alternative can also affect the choice set.

The Decision Rule

The decision rule is the process by which an individual evaluates the relevant alternatives (and their subsequent attributes), and formulates a decision, or choice. An individual is thought to usually use some type of decision rule which assists in selecting the chosen alternative.

Slovic (1977) and Svenson (1979) cited via (Wittink, 2011) gives decision rules that can be classified into four categories:

- ◆ Dominance measures
- ◆ Level of satisfaction measures
- ◆ Lexicographical rules
- ◆ Utility

Dominance measures refer to a situation where one alternative is found to be better than another alternative when at least one attribute is better, all else being equal. However, in most situations, this does not lead to one unique choice. Satisfaction measures give every alternative a “level of satisfaction” to the individual, and the one chosen is the most attainable. Lexicographical rules refer to decision rules that order alternatives according to level of importance. Utility was used in this research. Utility uses the attractiveness of attributes of alternatives, as a measure of value to an individual. Maximisation theory assures that utility is an aspect an individual tries to maximise in the decision-making process.

Most transport or travel behaviour models are based on utility theory, which will be discussed in the sections to follow. As human behaviour and choice making is a complex process, it is generally recommended that a probabilistic component be included in the decision rule. Some researchers may choose to consider only the deterministic (observed traits/ variables), and assume that the uncertainty is derived from the researchers inability to capture all aspects that affect the decision making process (Ben-Akiva and Bierlaire, 2003).

The Choice Set

The choice set combines attributes and levels in a form that is recognisable to the individual. According to Kenneth E Train (2009) the choice set should have the following three properties; 1) the alternatives need to be mutually exclusive, 2) the choice set needs to be exhaustive and 3) the number of alternatives need to be finite. Mutual exclusivity in terms of alternatives means that each alternative has no

relation to every other alternative. An exhaustive choice set refers to one in which all possible alternatives are included. A finite choice set is one that has a defined number of alternatives.

2.4.1.2 Utility Theory and Random Utility Models

Utility theory forms the theoretical basis for DCM's. Choosing is a "ubiquitous state of activity in all societies" (Louviere et al. 2000) and individuals choose between different things based on their preferences/liking, personal situations, and experiences, accounting for their constraints and habits or inertia (Smith *et al.*, 2015).

Utility theory can be found in numerous publications, and is not limited to use in DCM's. Utility theory has its underpinnings in economic consumer theory (Ben-Akiva and Bierlaire, 2003). Literature suggests that Thurstone (1927) originally developed the theory, following Marschak (1960) who formalised the approach (Hensher, Rose and Greene, 2005). The most simplistic definition of utility was found in a paper by Koppelman and Bhat (2006) who described utility as an indicator of value to an individual. Utility is derived from the attributes of alternatives, and the alternatives are dependent on the choice being undertaken. Utility, as a constructed measure of well-being, has no natural level or scale. The rule of utility is utility maximisation, states that an individual will choose the alternative (from the given choice set) that aims to maximise the utility of the individual. Thus, if the utility of an alternative is greater than the rest of the utilities, this alternative will be chosen (Ben-Akiva and Bierlaire, 2003).

However, in reality, it is not just the attributes of alternatives that influence an individual's choice. There are several elements that factor into the decision-making process, such as personal characteristics as well as contextual constraints. The components of the utility is known to the decision-maker, but not to the researcher, as he only observes some of the attributes of the alternatives, and some of the characteristics of the decision maker (Ben-Akiva and Bierlaire, 2003; Koppelman and Bhat, 2006; Wittink, 2011). From a researcher's perspective, only some attributes can be measured – these are called observed variables. Personal characteristics, socio – demographics and contextual constraints contribute to some of the unobserved variables that researchers come across, and hence, uncertainty in the researchers experiment. Louviere *et al* (2000) states that the random component of the utility

function does not mean that individuals make decisions in a random fashion, but rather that the unobserved influences on choices can be characterised by a distribution in the sampled population. The main evaluation point of utility functions is that only differences in utilities matter, and whether that difference is positive or negative (Koppelman and Bhat, 2006).

Models derived from utility theory are called random utility models (RUM's). RUM's describe the relation of the explanatory variables used on the choice outcome, without reference as to how a choice is made (Wittink, 2011). Mode choice models based on utility theory take into account the researcher's lack of understanding i.e. unobserved variables. Errors are observed as inaccuracies on the researcher's side. The utility function, as formalised by Manski (1977) via Ben-Akiva and Bierlaire (2003) encompasses these aspects as is presented below. Ben-Akiva and Bierlaire (2003) also states that utility theory can be made operational by 1) separating the utility into the deterministic and random components of the function; 2) specifying the deterministic component and 3) specifying the random component. Utility is considered a random function, due to the uncertainty that exists within parts of the utility function.

The general utility function is shown:

$$U_{int} = V_{int} + \varepsilon_{int} \quad (1)$$

Where

U_{int} is the utility of the individual n in choice set t for the i alternative,

V_{int} refers to the deterministic part of the utility which comprises of the attributes of the alternatives, as well as the characteristics of the decision maker (it is also the part of the utility that is observed by the researcher) and

ε_{int} is referred to as the random term, and captures the uncertainty and elements that cannot be observed by the researcher.

The deterministic portion of the function (V_{int}) is a function of the attributes of the alternatives itself, as well as known characteristics of the decision - maker i.e. $V_{int} = (z_{in}, S_n)$ where z_{in} is the vector of attributes as perceived by individual n for alternative i , and S_n is the vector of characteristics of individual n , which are combined to form a new vector X_{int} . Then, the linear parameters β_{in} are introduced to the function as representative utility is usually specified to be linear in parameters. The deterministic term of the utility is therefore fully specified by the vector of parameters β .

$$U_{int} = \beta_{in}X_{int} + \varepsilon_{int} \quad (2)$$

The final utility function can then be given by:

$$U_{int} = \beta_1X_{int} + \beta_2X_{int} + \beta_3X_{int} + \dots + \beta_kX_{ink} + \varepsilon_{int} \quad (3)$$

Where β_1 represents the unknown taste parameters for the first attribute etc.

Manski (1977) via (Ben-Akiva and Bierlaire, 2003) gives four sources of the error term:

Unobserved taste variations: Taste variations or preferences within the population or groups of individuals cannot be measured, and the researcher is unaware of the taste variations that do exist.

Unobserved attributes: The complete list of attributes that affect the decision-making process is not known to the researcher. It is physically impossible to observe all relevant attributes.

Instrumental variables: Some elements of the vector of attributes are not observable. Therefore, the utility function is derived as a function of observed variables.

Measurement errors: The attributes of alternatives are not physically observed by the researcher, they are designed within the SC context (in this study). In a sense, the researcher estimates the attributes, and it is in this process that measurement errors resulting from inaccurate measurements can be found.

The distribution of the error term is normally specified by the researcher, and informs what model will be used. Kenneth E. Train (2009) gives a good explanation of the distribution of the error term. He considers a population of people who have the same observed utility. Within this population however, the unobserved factors differ (from person to person). The density function $f(\epsilon_n)$ represents the distribution of the unobserved utility factors throughout the population.

2.4.2 Choosing a Choice Model

Disaggregate choice models have become the most popular type of travel demand models (Jara-Díaz, 1998). The utility of an alternative has been defined, and is used in combination with socio – demographic variables to predict, and help analyse and explain choice behaviour. Model specification now becomes an important part of the experiment and provides the framework for the structure of decision - making, the distribution of the unknown portion of the utility, the functional form of the observed part as well as the type and form of the variables to be used (Jara-Díaz, 1998).

There are three general families of models that are used today; Logit model, Probit Model and General Extreme Value (GEV) Model. The point of differentiation between models is generally in the distribution of the error term, or rather, under different specifications of the density of the unobserved factors $f(\varepsilon_n)$. A researcher therefore must choose a model whose distribution most meets the terms of the study being considered. The logit model is considered the most widely used DCM.

DCM's attempt to model individual preferences using disaggregate data. However, when modelling population (or group) behaviour, individual preferences can vary greatly across the population. This variability in taste preference is referred to as heterogeneity (Hensher, Rose and Greene, 2005). Heterogeneity is generally not an observed characteristic.

There are two types of commonly used binary choice models; binary Logit and binary Probit models. Binary models refer to models whereby only two alternatives are considered.

Logit and Probit models are very similar in nature, however logit models have a closed form integral for the choice probabilities, making them computationally more efficient, and more popular in use (Wittink, 2011). Logit models are based on a probability distribution function of the maximum of a series of random variables, introduced by Gumbel (1958). With logit models, it is assumed that the error term is logistically distributed. Logistic distribution resembles the normal distribution, but has fatter tails. However, the logit model has its limitations, as it cannot represent random taste variations, as well as the Independence of Irrelevant Alternatives (IIA) property. This property implies that the ratio of choice probabilities between any pair of alternatives is unaffected by the presence/ absence of any other alternative present in the choice set. In other words, all pairs of alternatives have no impact

upon each other, and are treated as equally similar/ dissimilar (Hensher, Rose and Greene, 2005).

Probit models assume that the unobserved factors are distributed jointly normal, motivated by the central limit theorem. This theory states that the sampling distribution of the mean for a variable, will approximate a normal distribution, regardless of the variables distribution in the population (Wittink, 2011). Probit models also have an open model form for predicting choice probabilities, making these models difficult to estimate (Wittink, 2011). The main advantage of the Probit family of models lies in its ability to accurately capture correlations among alternatives and between time (Ben-Akiva and Bierlaire, 2003; Kenneth E. Train, 2009). The only limitation of Probit models lies in its reliance on a normal distribution, and in some situations, the unobserved factors. Utility is still decomposed into the observed and unobserved parts, however, the density of ε_n is represented by (Ben-Akiva and Bierlaire, 2003):

$$\phi(\varepsilon_n) = \frac{1}{(2\pi)^{\frac{J}{2}} |\Omega|^{\frac{1}{2}}} e^{-\frac{1}{2} \varepsilon_n' \Omega^{-1} \varepsilon_n} \quad (4)$$

Where Ω represents the covariance structure of the model.

The MNL and NL models form part of the family of GEV models. The main defining component of GEV models is that the unobserved components (i.e. the error term) is jointly distributed, as a generalised extreme value, allowing for correlations between alternatives. If these correlations are set to 0, then the GEV model transforms into the standard logit model (Wittink, 2011).

The last model to be discussed is the nested logit model. This is the most popular model that does not incorporate the IIA assumptions (Louviere *et al.*, 2000). Nested logit models group alternatives into nests, and preserves the independence assumption across alternatives, with it being relaxed to an extent within nest structures. Nested logit is said to be a set of hierarchical MNL models, linked by conditional relationships (Louviere *et al.*, 2000). As with the MNL model, the error terms of MNL are independent and identically Gumbel distributed. These models also have a closed form solution, and are relatively easy to estimate.

Minal (2014) gives some disadvantages of using nested logit models. As the number of alternatives increases, so too does the number of structures to be tested. In some cases, the competitiveness of modes cannot be accurately represented.

2.4.2.1 Multi-Nomial Logit Models (MNL)

The Logit family consist of many models such as multinomial logit, nested logit, heteroscedastic extreme value logit and random parameter or mixed logit (Louviere *et al.*, 2000). The MNL model was first introduced for binary choice, where the logistic distribution was used (Ben-Akiva and Bierlaire, 2003). The most important characteristic of Logit models is that the error term is Independently and Identically Distributed (IID) extreme value. The main characteristics of this assumption is that the unobserved factors are uncorrelated over alternatives, as well as the variances for all alternatives is the same. This assumption leads to the convenience and popularity of the Logit models (Kenneth E Train, 2009).

Louviere *et al* (2000) gives some good advantages of using MNL models. MNL models are easy to estimate, and provide unique parameter estimates. There is also a vast array of software packages available to estimate Logit models. The error term in MNL models is assumed to be logistically distributed, using a Gumbel distribution (Wittink, 2011). The distribution is shown below. That is, for every ε_{in} , this function is given by:

$$F(\varepsilon_n) = e^{-e^{-\mu(\varepsilon_n - \eta)}} \quad (5)$$

$$f(\varepsilon_n) = \mu e^{-\mu(\varepsilon_n - \eta)} e^{-e^{-\mu(\varepsilon_n - \eta)}} \quad (6)$$

Where η is the location parameter and μ is a positive scale parameter.

One of the defining properties of the MNL model is the Independence of Irrelevant Alternatives property (IIA). Another way of stating this property is that the ratio of the probabilities of any two alternatives is independent of the choice set (Wittink, 2011).

There are three main assumptions underlying the formulation of MNL models and the distribution of the unobserved utility (error term). The first assumption is that the error (or random) components of the utilities are identically and independently distributed, with a Type I extreme value (Gumbel) distribution. This implies that there are no common unobserved factors that affect the utilities of alternatives.

Sometimes this assumption can be violated, when a decision- maker starts to group alternatives according to common attributes. For example, a decision maker may group public transport modes, and assign a higher utility to these, as they prefer the social aspects of these modes, when compared to travelling alone (Bhat, 2002). According to Koppelman and Bhat (2006), the Gumbel distribution has computational advantages when it comes to maximisation, and closely resembles a normal distribution.

The second assumption is that error components are independently distributed across alternatives. This means that there is no correlation across alternatives, and homogeneity is maintained. It should be noted here that the MNL model does not allow for taste sensitivities in the unobserved variables in a model (Bhat, 2002).

The last assumption is that the error components are identically distributed across observations/ alternatives i.e. the amount of “noise” is the same across alternatives (Koppelman and Bhat, 2006). This assumption can sometimes be violated, when for example, transit modes offer different levels of comfort on different routes. In this case, the “noise” will vary across individuals, across the two routes (Bhat and Koppelman, 1999). The three assumptions lead to the closed form structure of the MNL model.

The development of other models has risen largely to avoid the independence assumption associated with logit models, as sometimes independence may be inappropriate. Ben-Akiva and Lerman (1985) state that the problem does not per se lie with the IIA property, but rather every model that has an underlying assumption that the disturbances are mutually independent state similar results. Another implication of this property is that changes in one probability, equally affects changes in the probabilities of the other alternatives (Minal, 2014).

MNL models use utility theory and the functional form given by:

$$U_{int} = \beta_1 X_{int} + \beta_2 X_{int} + \beta_3 X_{int} + \dots + \beta_k X_{ink} + \varepsilon_{int} \quad (3)$$

The general expression used for the probability of choosing an alternative is given by:

$$P_{jnt} = \frac{\exp(V_{jnt})}{\sum_{j=1}^j \exp(V_{jnt})} \quad (7)$$

Where V_{jnt} represents the summation of all utilities for each mode.

MNL models are also simple to estimate due to the closed form specification, and model estimation leads to unique parameter estimates. There are also known tests to test the efficiency of models such as overall goodness of fit and t – statistics. There are also many computer estimation packages available, to assist in model estimation.

2.4.3 Model Estimation

Most mode choice models use the process of Maximum Likelihood Estimation (MLE) to estimate the β parameters from the utility function. Because of the closed form of logit models, MLE can be used. There are two steps involved in the process of MLE; the development of the joint probability density function of the observed sample, and the estimation of parameter values that maximises the likelihood function (Koppelman and Bhat, 2006).

Using the log – likelihood function for logit models given by:

$$L(\beta) = \prod_{n=1}^N \prod_i (P_{ni})^{y_{ni}} \quad (8)$$

Where $y_{ni} = 1$ if person n chose alternative i and 0 otherwise,

P_{ni} represents the probability of person n chose alternative i and

β represents a vector containing the parameters of the model.

The log – likelihood function is then:

$$LL(\beta) = \sum_{n=1}^N \sum_i y_{ni} \ln P_{ni} \quad (9)$$

And the estimator is the value of β that maximises this function. At the maximum of the likelihood function, the derivative with respect to each of the parameters is 0.

$$\frac{d LL(\beta)}{d\beta} = 0 \quad (10)$$

This equation is then solved, and β parameters are estimated. The β parameters are then used in the utility functions per alternative, to calculate the choice utilities. Once the choice probabilities for each respondent in each choice situation is calculated, the probabilities are summed, and then averaged over the number of decision- makers, to produce the final choice probabilities.

2.4.4 Improving Specification

There are many methods used in DCM's to test the statistical significance of models and help improve specification. There are some informal tests that can be carried out, as well as more formal tests. Some of these that have been used in this research will be discussed here.

2.4.4.1 Informal Tests

Informal tests give an indication as to whether models are accurately representing the real-life situation, and whether the parameters estimated, make sense. One of the key informal tests is to check whether all coefficients are of the expected sign. In most cases, the sign of coefficients should be obvious to the researcher, prior to estimation, based on theory, judgement and intuition. A negative value indicates a level of disutility to the user, while a positive value indicates a level of satisfaction, or utility. For example, aspects such as travel cost or PT service waiting times typically have negative utilities, inferring a dislike of these aspects by individuals. The order of magnitude of individual coefficients should also be intuitive to the researcher. This is of more importance when considered relative to all alternatives used. For example, the relative dislike of travel cost for individuals regarding different travel modes considered should make intuitive sense to the researcher. Socio - demographic segmentations and the subsequent results should also make sense to the researcher (Koppelman and Bhat, 2006).

2.4.4.2 Hypothesis Testing and Goodness of Fit

The process of testing how good a sample parameter is in comparison to the population parameter, is referred to as hypothesis testing. According to Kenneth E. Train (2009), hypothesis testing relies heavily on the assumptions the researcher makes on the distribution of the random variable.

In hypothesis testing, there are only two outcomes; the hypothesis is either rejected based on some observed outcome, or the hypothesis is not rejected, based on the same outcome (Ben-Akiva and Bierlaire, 2003). The null hypothesis can be defined as the outcome of the hypothesis test that the researcher does not want to observe. The alternative hypothesis represents the outcome of the hypothesis that the

researcher would like to support. Following this, Type I and Type II errors can also be defined. A Type I error is defined as occurring when we reject the null hypothesis when it is true. A Type II error is said to occur when we fail to reject the null hypothesis when it is false (Kenneth E. Train, 2009). The probability of making a Type I error is defined as α . The probability of making a Type II error is defined as β . This can be shown in the table below.

Table 2 The relationship between H_0 , Type I errors and Type II errors

		Decision	
		<i>Accept H_0</i>	<i>Reject H_0</i>
Truth	<i>H_0 True</i>		Type I error probability α
	<i>H_0 False</i>	Type II error probability β	

Researchers then use p – values to determine the relative significance of the test. The p – value can be described as the probability of getting the observed value of the test statistic, or a value with even greater evidence against H_0 , if the null hypothesis is actually true. The smaller the p – value, the greater the evidence against the null hypothesis. With a given significance level α , then:

Reject H_0 if the p – value $\leq \alpha$

For the test, you need a p-value less than 0.05 to accept the model when using a confidence level of 95 %.

The t – test statistic will be the last test parameter discussed. Most statistical software packages today include the t – test statistic as part of the analysis.

The t – statistic is given by:

$$t - statistic = \frac{\beta_k - B_k}{S_k} \tag{11}$$

Where β_k is the estimate for the k^{th} parameter,

B_k is the hypothesised value for the k^{th} parameter and

S_k is the estimate standard error

Rejecting the null hypothesis implies that the variables created have a significant impact on modal utilities, and should be retained. Low values of the t – statistic implies that the variable does not contribute significantly to the explanatory power of the model, and should be excluded. Selection of the critical value for t is dependent on the researchers judgement, and allowance of error the researcher is willing to make (Koppelman and Bhat, 2006). The selection of critical t – values fixes the rejection region of the test (Kenneth E. Train, 2009). There are tables citing critical t- values for different confidence intervals. In this study, a confidence interval of 90% was considered, which links to a critical t value of 1.645.

Table 3: Table showing Critical t - values for Various Confidence Intervals (cited via Koppelman and Bhat (2006))

Confidence Level	Critical t-value (two-tailed test)
90%	1.645
95%	1.960
99%	2.576
99.5%	2.810
99.9%	3.290

Goodness of fit

The last statistic that will be discussed is called the log – likelihood ratio ρ^2 – value.

This statistic is defined as

$$\rho^2 = 1 - \frac{LL(\beta)}{LL(0)} \quad (12)$$

where $LL(\beta)$ is the value of the log-likelihood function at the estimated parameters $LL(0)$ is its value when all the parameters are set equal to zero. The ρ^2 value is a function of the sample data, choice set size as well as number of parameters included.

When $\rho^2 = 0$, then the new model performs the same as the zero-parameter model, while when $\rho^2 = 1$, this infers that the new model is able to predict choices perfectly. The log likelihood value ranges from 0 to 1. Kenneth E. Train (2009)states that there is no interpretable meaning for values that lie between 0 and 1, although it can be said that a higher value ρ fits the data better. Models estimated with different

samples, or a different set of alternatives cannot be compared with this statistic (Koppelman and Bhat, 2006).

2.5 Case Studies

This section will entail the review of case studies relevant to the context of this research. No South African studies were found, regarding P&R demand analysis performed using DCM's. However, there were studies carried out documenting the use of SC data and DCM's to analyse and predict mode choice probabilities, which will be discussed. There was also very little information found regarding international express bus P&R studies, using DCE methods. Most discrete choice analysis studies found revolved around large scale P&R systems. However, two similar studies are discussed here.

2.5.1 The South African Experience

SP and DCE studies have been carried out under the South African context, however, there were no studies found that focused around the use of P&R systems. Some of the research pertaining to SC and DCE methods that have been carried out in South Africa are reviewed here. Two papers using SC and DCE methods to predict PT choice probabilities were reviewed.

A case study was undertaken by Van Zyl and Venter (2009) that aimed to estimate factors that influence mode choice in bus and private transport users, in the City of Johannesburg. The study covered the design and implementation of SC methods, as well as calibration of DCMs, and concluded with a sensitivity analysis regarding the factors that influence mode choice. The sampled respondents included 200 car users, and 100 bus users. Variables included in the survey were walk time (from home to bus), waiting times for bus, in vehicle travel time, travel cost as well as parking cost. The study found that factors that influence the choice between car and bus related to travel time, travel cost and affordability factors. Another influential factor was users previous experience with the bus service, which influenced the choice probabilities negatively.

Another study carried out by Zyl and Hugo (2002) evaluated modal attributes with SC data amongst private and public transport usage in Cape Town. The study used revealed and stated choice data to calibrate DCM's. The main objectives of this study were to determine the trade-off respondents were willing to make regarding choice of travel mode (including a restructured PT system) as well as to calibrate DCMs and calculate resulting demand elasticities. Scenarios which entailed the improvement of certain PT aspects were tested. Aspects such as PT fares, method of payment, door

– to – door travel time, in – vehicle time, levels of crowding etc were included in the SC survey. The study found that fare and cost attributes were the most significant, followed by aspects such as train security and crowding. Conclusions were also drawn on segments of the population, against these factors. The study concluded that combined SC – RP data calibration was required, to accurately determine elasticities and test policies.

In a study carried out by Van Zyl, Lombard and Lamprecht (year unknown), the success of stated choice techniques under the South African context was evaluated. Four SC studies previously carried out were reviewed and evaluated in terms of the methods used, complexity and size of experiments, quality of responses as well as model performance. The study found that SC surveys used in DCM's in South Africa among the less literature have been met with a reasonable degree of success, with some data requirements for these models not always being fulfilled. It also states that no formal research has been carried out in South Africa to identify best practice principles for local circumstances, especially as it pertains to low – income public transport (PT) users. The study also states that further research is required on the transferability of SC techniques, to the South African context.

2.5.1.1 Park and Ride Case Studies

There were not many studies found documenting the use of DCE's for P&R shuttle services. Most P&R studies encompass P&R facilities on a much larger scale, and those that are based around larger public transport systems.

One study however, was found to be of a similar nature to the research carried out. The study, conducted by Hole (2004a) analysed commuter preferences for a P&R service for a University (in the USA). Lack of inadequate parking lead to the motivation for this study. The experiment contained only two attributes; P&R door-to-door travel time and cost, which were varied over three levels relative to the individuals' current commute. Nine choice sets were posed to respondents. A binomial logit model was used in estimation. Some of the model estimation findings are documented below.

The P&R ASC was positive and significant. Females were more likely to switch to P&R than males. Low-income academics are significantly more likely to switch to P&R than individuals in the other income categories. The likelihood of switching to P&R decreases significantly when the number of cars in the household increases. The

coefficients for travel time and cost were also strongly significant. Individuals who work in buildings with relatively poor on-site parking were significantly more likely to use P&R. An employee P&R service seems to have the potential to be effective in reducing the demand for on-site parking when supported by measures to deter parking on-site.

Another study carried out by Islam *et al* (2015) investigated the mode change behaviour of P&R users, to analyse the effect of P&R sites on commuters travel mode, for various P&R facilities in Melbourne. The main objective of this study was to investigate the key factors in the mode change behaviour of P&R users. This study found that PT travel and transfer time at P&R stations were the main influencing factors of P&R usage. Another interesting find was that lower parking fares in the city has a positive effect on private vehicle usage.

2.6 Literature Review Summary

In summary, this literature review was undertaken to gain an understanding in the theories underpinning SC and DCE design, as well as gather best practice principles for carrying out the analysis. This literature review delved into the critical aspects required to carry out this research; P&R systems and their operations, SC survey design and implementation, DCM's and model estimation, as well as case studies documenting previous P&R research both in South Africa, and internationally.

P&R systems and their basic operations were discussed. In particular, the P&R system specific to this research (shuttle express bus services) was introduced. The main travel impacts of implementing P&R systems on travel behaviour as well as the local road network was also investigated. It was found that while majority of the reviews are positive, there are also mixed reviews towards the overall impacts of P&R. Some research documents the positive impacts of P&R such as congestion reduction and reduced harmful vehicle emissions, while some research focusses on the more "unintended effects" of P&R. These unintended effects mainly focus around the increase of VKT, due to the lowered general perceived costs of travel. Overall, there is limited research as it pertains to P&R express bus services. Lastly in this section, the profile of a P&R user was identified. P&R users are choice users and in order for P&R to become an attractive option, the cost (as well as time aspects) of using the P&R should be lower than that for using a private vehicle, given the same trip.

The SC section of the literature reviewed focussed around the SC method, and implementation. The design of alternatives attributes and levels were also discussed, as this plays a critical role in SC design. These elements are context dependent, and fully rely on the aims and objectives the study in question aims to achieve. Full and fractional factorials as well as orthogonal design along with their relative advantages and disadvantages were discussed. Fractional factorials have an advantage over their full factorial counterparts as they present less choice sets to respondents, thereby decreasing respondent burden. Orthogonal designs have been favoured for many years, but are now being superseded by more efficient designs. Finally, elements that bring the SC survey together such as choice set generation, blocking and the inclusion of additional questions were reviewed.

The theory behind DCM's, choice theory, probabilistic theory and utility theory were then discussed. Most models have the assumption of rational behaviour and utility-maximizing behaviour, which forms the basis of RUM's. The concepts of logit models and their underlying characteristics were also introduced. Other model structures such as Probit models and GEV models were also considered and compared to the Logit, to choose the most appropriate model for estimation. MNL models and their main assumptions were researched, to gather an overview of the MNL model development and implementation. The theory behind model estimation is also discussed. Specifications testing and improving model specification using hypothesis testing and goodness of fit measures was also discussed at length.

Finally, case studies regarding the South African as well as international experience with SC, DCE as well as P&R is reviewed. No South African studies were found, regarding P&R demand analysis performed using DCM's. However, there were studies carried out documenting the use of SC data and DCM's to analyse and predict mode choice probabilities. There was also very little information found regarding international express bus P&R studies, using DCE methods. Most discrete choice analysis studies found revolved around large scale P&R systems.

3 DEFINITION OF THE CHOICE PROBLEM – THE STUDY AREA CONTEXT

3.1 Background

This section will answer the question, “why Florida Road?” as well as delve into characteristics of this area that were important to this study. To gain a greater understanding of the context of the study, the background to Florida Road was researched and visual site assessments were carried out. In this section, the traffic characteristics of Florida Road were investigated. The users of Florida Road were also determined, as well as the various land uses on the stretch of roadway and traffic operations at different times of day. Understanding the context of the study assisted in the formulation of alternatives, attributes and levels, which is of critical importance, when trying to base research on a real-life situation.

Florida Road has become an iconic street in Durban due to its diverse range of land uses and bustling day and night life. Florida Road is found in Windermere, a popular residential suburb in Durban, in close proximity to the Moses Mabhida Soccer Stadium. Activity centres such as Florida Road are generally located near city centres, or hubs of activity. However, Florida Road is situated within a residential suburb, adding to the mix of traffic within the area. Generally, those who visit Florida Road live nearby, or within the same area. There are many different land uses on this stretch of road, which attracts users with differing trip purposes, for example, there are those who go to Florida Road to use the banking facilities, those that go to Florida Road for grocery shopping, as well as those who visit the restaurants etc. The study area for this research can be seen in the Figure on the next page:



Figure 4 : The Florida Road Study Area (Google Earth, 2017)

3.2 Study Area Data

The three aspects that will be discussed in this section are the land uses on Florida Road, parking provisions, as well as visual site assessments of the area. Land uses on this stretch of road give a good indication of the traffic generation, as well as where the busier portions of Florida Road are located. The parking provisions were also examined to get an indication of the magnitude of the parking demand, in relation to the parking supply. Lastly, site assessments were carried out to confirm the above observations, as well as determine any other contextual constraints relevant to this study.

3.2.1 Land Uses on Florida Road

The land uses on Florida Road assisted in gaining a better understanding of the traffic characteristics on this stretch of roadway. Land use can be used as an indicator of the type of traffic generation caused by this area, and also give an indication of the type of users of Florida Road. **Figure 5 shows the** variety of land uses present on Florida Road.

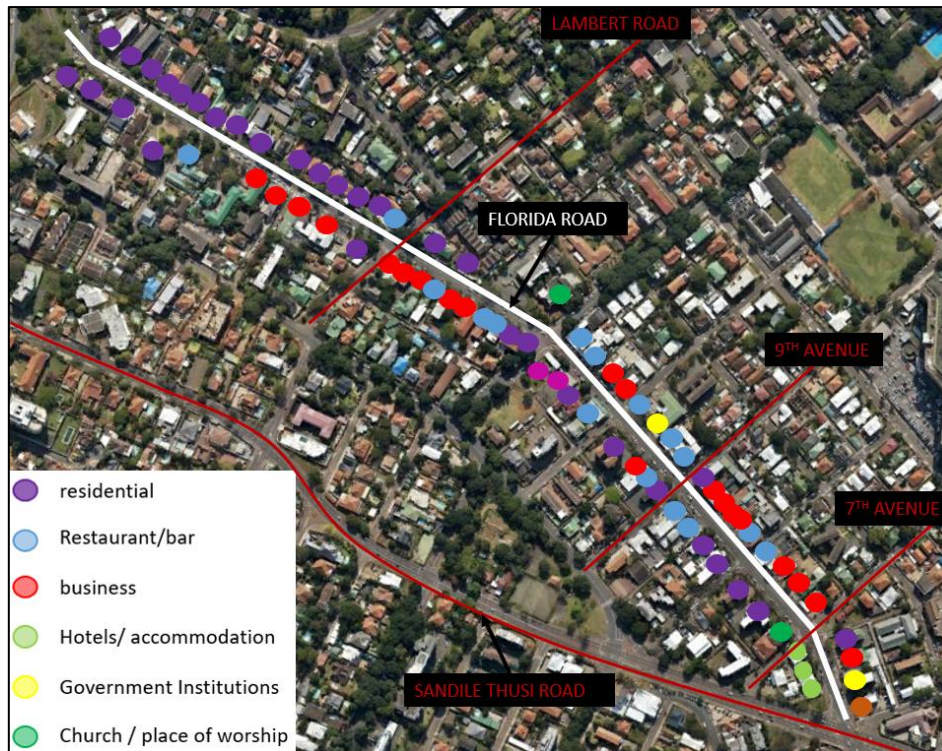


Figure 5: Land Uses on Florida Road (Google Earth, 2017)

The following land uses were found to be the most common:

- ◆ Residential apartments/ flats
- ◆ Restaurants, pubs and bars (Spiga, Capello, Dropkick Murphy's, Taco Zulu, Café Vacca Matta etc.)
- ◆ Different types of businesses including banking offices, grocery stores, retail, private companies etc.
- ◆ Hotels and backpacker's accommodation
- ◆ Government institutions such as Durban Tourism and GO! Durban offices
- ◆ Churches and places of worship

Given the diversity of land uses found on this 1,5 km stretch of road, a range of travellers (with different travel needs) within the study area exist. The variety of land uses also induce an assortment of transport needs in terms of trip generation, and in particular, dictate when peak periods occur. Different land uses generate traffic during different peak periods, and these are seen to vary, during the weekday and weekend periods as well.

The buzzing nightlife is a major attraction to those who visit Florida Road. Most restaurants and bars are situated between 9th Avenue and Lambert Road, and it is in this section that Florida Road has the busiest vehicle traffic. Parking on this

section is always utilised and it is difficult for individuals to find a parking bay. The restaurants on this stretch have usual business hours, except for a few that close between 12am and 2am on weekend periods. The morning, lunch and evening peaks typical of restaurants are more prominent on weekends than on weekdays. The restaurants on Florida Road are the biggest generators of traffic here.

The business on Florida Road varies, from petrol stations to small boutique stores to consulting firms, and attracts a range of different travellers from day to day employees to day visitors. Most businesses were found to have undercover basement parking for employees, but visitors had on - street public parking facilities. Residential apartments are scattered throughout Florida Road, and have a higher concentration towards the north (between Lambert Road and Musgrave Road). The concentration of residential apartments to the north of Florida Road can clearly be seen.

3.2.2 Parking Provisions on Florida Road

The traffic on Florida Road is primarily vehicular traffic. Parking on Florida Road is mainly provided by parallel on - street parking that spans the length of Florida Road, as well as on most side roads that intersect with Florida Road.

Public parking spaces were counted using Google Earth images, and surprisingly, amounted to a total of 373 parking spaces. These parking bays were scattered throughout, and located on Florida Road and some of the side roads, and shown in the figure below. Even though there appears to be a large amount of parking available, most of the parking bays located to the north (in the vicinity of the residential apartments) were underutilised. Most of the restaurants are located further south on Florida Road, which is a distance away from these parking bays, which could be a possible reason for this.



Figure 6 : Parking Bay Locations on Florida Road and Adjacent Roads (Google Earth, 2017)

The land uses present on Florida Road lend themselves to significant amounts of generated traffic. As described, most “prime” parking is located further south of Florida Road, in the vicinity of the main restaurants, which is also where most of the illegal parking manoeuvres occur, as well as accidents occur.

3.2.3 Site Observations

Site observations were carried out, to help gather information on when the peak periods occur, their duration as well as the traffic experienced and potential traffic issues during these periods. This information provided insight into the reasons behind congestion on Florida Road and potentially, whether a P&R service can counteract these negative effects. These visits were carried out on two weekends; 13 – January 2018 as well as 24-25 February 2018. Weekends during different periods of the month were considered, primarily to ascertain whether traffic volumes fluctuate at different times of the month. Weekday traffic flows were also looked at, based on the researchers experience with the area.

Peak Period Observations

Traffic volumes on Florida Road in the weekday mornings were not too high; the traffic here mainly consists of employees coming into Florida Road, through traffic

from daily work commutes as well as restaurant patrons visiting Florida Road for breakfast. There are still many on street parking bays available in the morning peak. During the lunch period, traffic volumes pick up slightly (when compared to the morning). This traffic consists of generally those going out for lunch/ getting take-away, those having lunch meetings, through traffic from surrounding schools etc. the banking facilities are also busy at this time. The afternoon (from 3pm to 6pm) periods are not generally too busy on weekdays, with mainly those returning from work, again, those getting an early supper etc. Weekends are the busiest time for Florida Road, as this is the time the restaurants get the most patrons. The peaks over the entire day generally, on both Saturdays and Sundays.

In the table below, users were categorised by time of day (and week) in which they visit Florida Road, as well as the duration of the visit. These observations were obtained by general observations while being on Florida Road.

Table 4 : Florida Road User Characteristics

Time of Week	General User Type	Typical Trip Purpose	Typical Visit Duration
Weekends	Visitors to the grocery stores or banking facilities	Shopping	15 mins to 30 min
	Patrons to the various restaurants / bars	Social	30 mins to 3 hours
	Patrons to the churches located on Florida Road	Social	1 to 2 hours
	Residents on Florida Road and surrounds visiting the various restaurants there	Social	30 mins to 3 hours
	Patrons to the various restaurants / bars	Social	30 mins to 3 hours
Weekdays	Patrons to the various restaurants	Social	30 mins to 3 hours
	People who work on Florida Road and do not have off street parking	Work	Min 6 hours
	People who have meetings etc. on Florida Road	Work	30 mins to 3 hours
	Patrons to the various restaurants / bars	Social / Work	30 mins to 2 hours
	Patrons to the various restaurants / bars	Social	30 mins to 3 hours

The following observations were made regarding the peak weekend period traffic on Florida Road:

Too Little Parking to Cater for Land Uses

The parking demand for Florida Road appears to exceed the supply of parking. The restaurants and night entertainment generate large amounts of traffic, particularly over the weekend evening periods. The mix of traffic generated has many implications on the resulting traffic conditions at Florida Road, such as increased driver frustrations, increased traffic congestion as well as illegal parking actions that affect pedestrian safety. There have been many accidents over recent years, which has prompted the eThekweni Municipality to introduce speed bumps to the south section of Florida Road. Drivers were also observed to spend between 5-15 minutes, looking for a parking bay during peak periods.

Illegal Parking Manoeuvres

As a result of an inadequate number of parking bays, many drivers on Florida Road perform illegal manoeuvres, while searching or waiting for a parking bay. Some of these manoeuvres documented include double (sometimes triple) parking outside restaurant fronts, double parking at intersections, stopping on the road to pick up/drop off passengers as well as drivers “looping” around Florida Road to find a parking bay.

3.3 So, Why A Park and Ride?

Through site assessments and study area analysis, conclusions were made regarding the traffic concerns for Florida Road. The parking demand appears to outweigh the parking supply. Even though it is difficult to be certain of the demand for parking at this location, from observations it was clear that parking demand exceeded the supply. During the peak periods, in the busy areas, there were no available parking bays, and people wait for bays to become available, thereby resulting in illegal parking manoeuvres being performed. Of the many side roads prevalent on Florida Road, only those in close proximity to the restaurants etc were utilised as parking. Pedestrian safety is decreased due to increased traffic/ vehicular movement and unsafe traffic situations caused by people looking for parking, stopping on the road.

Since it is not possible to increase the number of parking bays on Florida Road due to the lack of adequate space, as well as the fact that increased parking bays may compound the problem, rather than assist in its reduction, a P&R system for the area was proposed.

Parking management is a critical component of any transportation system, as parking is always required at every destination (Litman, 2013). Koppelman and Bhat (2006) states that an increase in traffic congestion can result in driver frustration, longer travel times, increased accidents, greater fuel consumption and a deterioration in air quality. The main travel impact of P&R services is increased public transport ridership and ridesharing. P&R supports the use of public transport, as most trips to these facilities are carried out with the intention to use some form of public transport. They also reduce the number of trips made during the peak periods, by reducing the number of vehicles on the road, due to public transport usage (Pratt, 2013). P&R systems form part of parking management strategies as they relocate parking to the outskirts of activity centres, decreasing traffic congestion.

Memon *et al* (2014) gives a good description of the role of P&R systems in the traffic reduction context, as seen in the figure below. To induce travel reduction, one can either aim at encouraging the use of alternative modes of transport, or, discourage the use of private vehicles. A P&R in the traditional sense is aimed at supporting public transport, and providing users with an option of using their private vehicle for the first leg of the trip. It reduces the need for parking at major activity centres, and promotes the use of public transport.



Figure 7 : The Role of P&R in Travel Reduction (as cited in Memon et al., 2014)

The hypothetical P&R system was designed, that would be posed to respondents of the SC survey, and would be included in the survey as an alternative transport option, to the existing transport options. System elements were designed with the primary user (those who use their private vehicles) in mind.

4 DATA COLLECTION – STATED PREFERENCE SURVEY

4.1 Motivation for a Stated Preference Survey

The purpose of conducting an experiment is to measure the independent influence of different variables, on some observed outcome (Kenneth E Train, 2009). In Stated Choice (SC) studies, experiments are designed to determine the influence of design attributes upon choices that are made by the respondents being sampled.

SC surveys are an efficient method to analyse consumer behaviour, in terms of evaluating alternative attributes which contain hypothetical choice alternatives and new attributes. Respondents are presented with choice sets, and asked to choose between a range of alternatives. In this study, the alternatives are the new P&R system, Uber as well as respondent's private vehicle. As the P&R system is not in existence, an SC study coupled with discrete choice analysis assisted in assessing the predicted demand for such a service. Each alternative will be described to respondents by its attributes, and these attributes will be further described, by a range of levels, allowing the attributes to vary. Varying attributes and levels assists in understanding how and why individuals make choices, and in this research, how and why people choose a specific transport mode for their trip to Florida road. SC data has many advantages over its RP counterpart, as has been described in the literature review.

The methodology undertaken for the SC design will be discussed in the next section.

4.2 Survey Design Approach

The survey method was developed through a process of reviewing previous research on the subject and extracting and collating aspects relevant to this study. There are no set rules for survey design, however a few themes that formed a common thread through literature was used as a basis for the survey method described below. The flow diagram presented shows the general process that was followed.

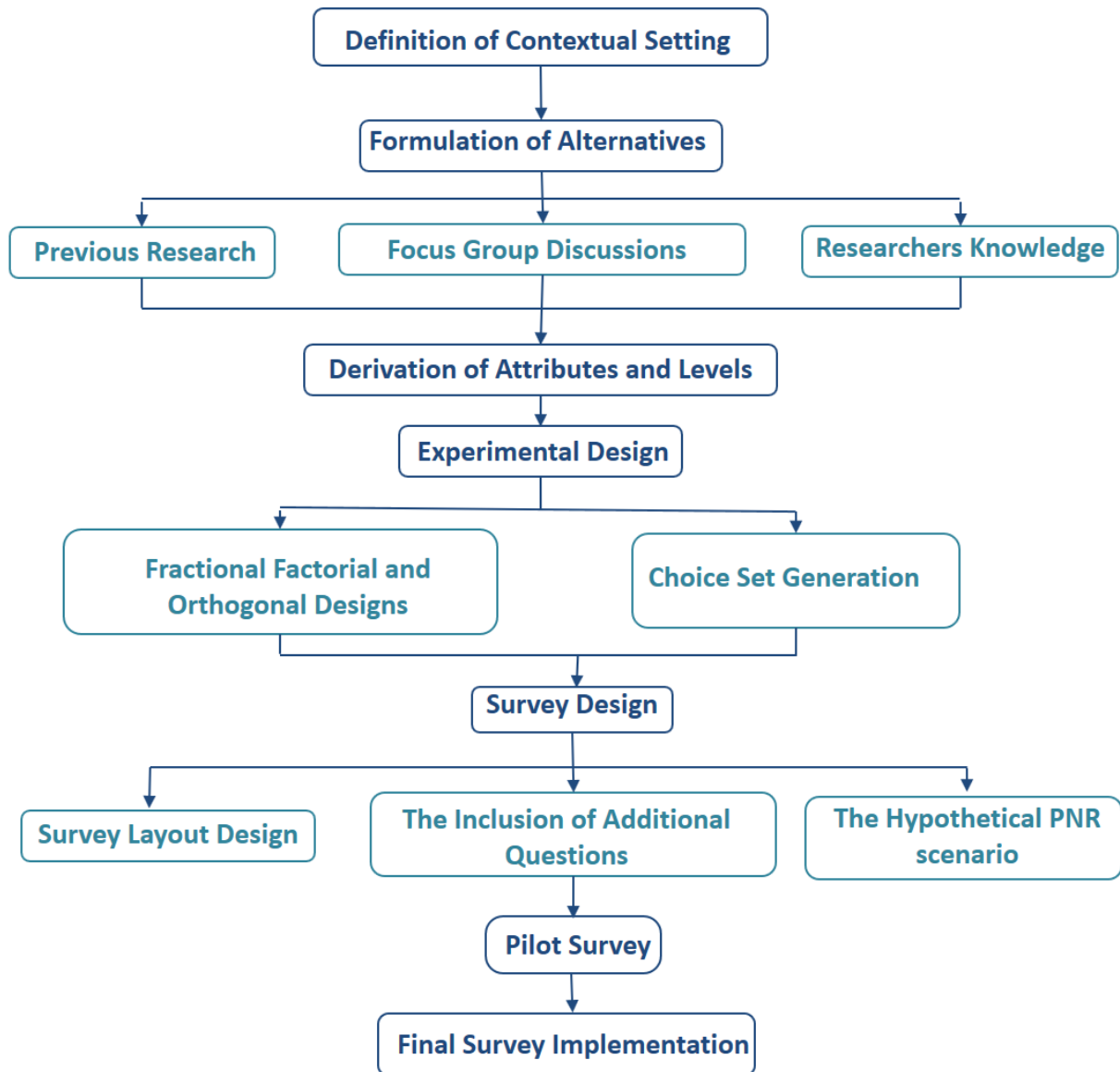


Figure 8: Flow diagram Showing the Stated Choice Approach undertaken

To produce DCM's data is required, regarding the sample population, and in line with the aims and objectives of the study that was carried out. Since there was no P&R system in existence, there was no Revealed Preference (RP) data regarding this transport mode that could be used in model estimation. Although the car alternative and Uber are available to users, there was no current data available for this study. For this reason, an SC survey was required. As discussed in the literature review, one of the advantages of using SC designs lies in the methods ability to handle new alternatives, and provided variability in attributes and levels, that is not generally seen in the market place.

One of the most important steps in this survey design was defining the contextual setting for the survey, as well as establishment of the main survey requirements. Examining the contextual setting allowed for the determination of constraints to the survey, alternatives to be included as well as allowed for a better understanding of the study area. The main survey requirements refer to the sample size required, type of survey to be implemented, days of survey etc. The method of sampling used was simple random sampling. Random sampling eliminates any bias, by giving all individuals an equal chance of being surveyed, and is said to be a good representation of population characteristics. Weekend evenings were chosen as the best time to implement the survey, and this was found to be the busiest times for Florida Road, and would give a good indication of the peak demand for the service, on the Florida Road area.

Alternatives, attributes and levels were then formulated through a combination of previous research, focus group discussions with users of Florida Road, as well as general knowledge of the study area. Lancsar, Fiebig and Hole (2017) suggests that undertaking reviews of relevant literature and qualitative work to generate alternatives, attributes and levels is common practice. Focus group discussions were also used in order to better understand the study area context, as well as determine what is reasonable in the minds of decision makers (Smith *et al.*, 2015). Levels are generated by using values that closely simulate real life, by basing levels on real – life examples. Good practice principles regarding the number and type of attributes and levels to use were also considered.

Once the alternatives, attributes and levels were defined, the experimental design was carried out. Experimental design refers to the process whereby attributes and attribute levels are combined, to produce alternatives and choice sets that are presented to respondents (Smith *et al.*, 2015). This is considered one of the critical

elements of SC survey design. Methods for undertaking statistical design was researched to gain knowledge in the choice set generation process, as well as to determine what the best methods to be used in this study. The statistical design was then carried out, factoring in the relevant design choice set generation methods required, to produce an initial survey design.

Included in survey design process was the design of the survey layout as well as revealed preference and socio - demographic questions that were posed to respondents. SC surveys should include additional questions over and above the SC survey experiment. These questions are generally required to enhance the validity of the SC experiment being carried out and as well as to assist in evaluating the validity of responses to questions (Johnston *et al.*, 2017). Hess and Rose (2009) also suggest the inclusion of socio – demographic data, attitudinal data as well as data regarding how respondents process their choices. This information was required to further evaluate users travel perceptions via the DCM's. The survey instrument presentation, as well as the way in which the hypothetical scenario was explained to respondents was not a trivial task, and the survey instrument should be piloted before the final implementation (Smith *et al.*, 2015). With these results, the survey was amended and followed to the final survey implementation. The data collected was then converted into excel form, with columns representing the information acquired, and rows representing the individual observations. Some categorical variables were dummy coded. The data was then ready for use in the DCE.

4.3 Definition of Contextual Setting and Basic Survey Requirements

The contextual setting for this study was investigated in Chapter 3, which entailed an analysis of the traffic related aspects of Florida Road, such as land uses, types of traffic generation experienced, parking demand and supply as well as illegal parking manoeuvres being performed. The environment the study finds itself in plays an important role in formulating the SC experiment. The introduction of a P&R system to Florida Road is the basis of the contextual setting for this survey. The P&R system (as will be described in Section 4.4.2.1) formed part of the hypothetical scenario that was posed to respondents. Current modes of transport available to respondents were also included in the fixed choice set.

4.3.1 Survey Basics

The survey design used was one of a choice labelled experiment. Labelled choice experiments add realism to the study, and allow for respondents perceived biases towards an alternative (Kruijshaar *et al.*, 2009). In this study, it was critical that the alternatives be labelled as preferences for modes in choice behaviour was investigated. With alternatives being labelled, respondents are assumed to already have an inherent bias towards a mode, and preferences can be incited from this. Model parameters can be estimated for each alternative independently. As we are introducing a new transport mode as part of the alternatives, modes were required to be labelled.

The type of models used in discrete choice analysis have been described in the literature review. The model chosen for this study was the Multinomial Logit Model (MNL) . The characteristics of this model will be described in more detail in Section 5.2.1.

Hensher (1994) gives three types of questionnaires that can be posed to respondents in stated choice studies. These are ranking, choice or rating. Rating refers to the situation whereby respondents are asked to order their responses according to preference, but also to state how much an alternative is preferred, against the other alternatives. With this method, every alternative is utilised, and given a preference rating. In choice questions, the respondent chooses one combination of attributes in a choice set, over the other proposed alternatives. And lastly, ranking requires respondents to rank alternatives in order of preference showing which alternatives are least preferred and which are most preferred. Choice has been used in this study. Respondents are asked to choose one alternative that they prefer, over the rest. This is the commonly used response form for Discrete Choice Models (DCM's) , and MNL models in particular.

4.3.1.1 Survey (Study) Area

The study area was taken as Florida Road, and shown below. The boundaries for the study area include the intersection of Sandile Thusi Road and Florida Road and Florida Road and Musgrave Road. The location of the respective restaurants and bars were the primary consideration in the determination of the study area boundaries, as it is within these areas that user's park and encountered the most activity.



Figure 9 : Florida Road Study Area Boundaries (Google Earth, 2017)

It should be noted that even though we are only taking a sample of the population that uses Florida Road currently, given that the P&R parking facility that will be located at Greyville Racecourse, there will also be people that live within the vicinity of the P&R parking facility that would also use the system. The choosing of an appropriate P&R facility, and Greyville Racecourse is discussed further in Section 4.4.2.1. Some who live close by may even walk to the parking facility (and not use their vehicle). The true demand for the service would need to be calculated considering all these subsets of users. In the context of this study however, only those that visit Florida Road were considered, and used in the survey sample.

4.3.1.2 Target Population and Decision Maker Characteristics

An important consideration in this study was that the decision maker needed to be defined. Understanding respondent characteristics and more importantly, the value respondents place on attributes, plays a big role in the determination of attributes for inclusion in the study. The current trip characteristics of respondents are also very relevant, as they give an indication of actual travel behaviour.

The target population were those who visit Florida Road for recreational/ social purposes. It is this subset of users who generate the most traffic on Florida Road, and contribute to the build-up of traffic (when illegal parking manoeuvres are performed). Removing this traffic off Florida Road would assist in making the road safer for all users.

People who use Florida Road for this purpose are generally above 18 years old, and generally frequent Florida Road on weekends (Friday and Saturday evenings) except for those with families. There are families that visit Florida Road, groups of friends as well as work related social groups, each with their own set of transport needs. It is interesting to note that upon site observations, many people travelled to Florida Road by themselves, even when meeting with a bigger group.

Prospective Florida Road users targeted in this study are primarily those that travel by car to Florida Road. As discussed, these users contribute to the various traffic issues regarding Florida Road, and are considered most likely to use the P&R system. Those who experience frustration in finding a parking bay on Florida Road may also be prospective P&R users. The target population characteristics also assists in determining when the best time to carry out the survey. The time spent on Florida Road ranges from 10 mins to around 4 hours, depending on the trip purpose being undertaken.

As discussed in the literature review, P&R users are users with choices. They can either use their vehicle for a portion of the trip, or use it for the entire trip. For users to want to use the P&R, the utility of using the P&R needs to be greater than the utility of using their vehicle for the whole trip. Therefore, in this study, attributes used for P&R were those that highlighted the advantages of the service.

4.3.1.3 Sampling Strategy

In general, samples should be drawn in such a way that they are representative of population characteristics. There are various methods regarding choice of sampling strategy. Probability sampling methods were used in this study, which refer to sampling methods whereby every individual in the population has an equal chance of being chosen. Probability sampling methods include simple random sampling, stratified random sampling, cluster sampling, systematic sampling as well as multi – stage sampling.

The sampling frame included users of Florida Road that used Florida Road on weekends, as this was the busiest time. Simple random sampling was used. The main advantages of using simple random sampling lies in its ease of use and accurate representation of the larger population characteristics. This means that during this time, random individuals on Florida Road were surveyed, adding no bias towards individuals surveyed. Simple random sampling is a popular sampling method used

as it is easy to understand, communicate and implement, making it less prone to errors (Koppelman and Bhat, 2006).

4.3.1.3.1 Sample Size

There are a variety of methods that can be used to determine the sample size required, using different formula derivations as well as different inputs.

The formula used to calculate the minimum sample size required is shown below.

$$\begin{aligned} & \textit{Minimum sample size required} \\ & = \frac{(Z - score)^2 * (Std Dev) * (1 - Std Dev)}{\textit{margin of error}^2} \end{aligned} \tag{13}$$

Where $z - score = 1.65$ (for a confidence interval of 90%)

Standard deviation = 0.5

Margin of error = 10%

Using these values, a sample size of 69 respondents was calculated to be sufficient for this design. In the final survey however, 87 surveys were completed.

4.4 Formulation of Alternatives, Attributes and Levels

The first step in defining alternatives, attributes and levels to be considered was to identify all alternatives for evaluation, as well as identify the relevant characteristics of these alternatives that were presented to respondents. These alternatives, attributes and levels will then be combined and set by means of an experimental design, generating a number of choice sets for each alternative, which are then bundled and mixed into scenarios, to form the final choice sets posed. The focus of the following chapter is on the former aspects – the identification of relevant alternatives, attributes and levels to be included in this study.

In previous studies, this step has been carried out by the use of focus groups, interviews, general knowledge/ experience of the researcher, and well as information drawn from studies of a similar nature (Hensher, 1994; Sanko, 2001; Wittink, 2011; Johnston *et al.*, 2017). This study used a combination of focus group discussions, empirical studies as well the researchers experience on Florida Road to formulate the alternatives, levels and attributes that were included.

Adamowicz, Louviere and Swait, 1998 stated that the objectives of this phase of SC design should be:

- ◆ To identify how prospective users think about the decision process (what they include as well as the correlation between different attributes)
- ◆ To identify what aspects are either systematic variables or part of the error term

The focus group discussion and findings will be discussed, as well as previous SC research on choosing alternatives, attributes and levels.

4.4.1 Focus Group Discussions

A focus group discussion was carried out to assist in the identification of alternatives, attributes and levels to be used for the various alternatives explored in the choice set (to be detailed in the sections to follow). This focus group discussion was intended to help gain a greater understanding of the traffic issues present at Florida Road, the context of the decision to be made, current modes of transport used as well as service attributes users valued the most, in terms of choosing a transport mode when visiting Florida Road. The discussion also investigated how sensitive people were to the traffic issues present, as well as their awareness of how P&R systems operate. Another point of interest, was the ranges (in terms of service attributes) that were found to be reasonable in the minds of decision makers, such that realism could be preserved in the survey. Focus group discussions used under the transportation context are used as a way to gather public opinion on new (or current) transport services in order to either improve or formulate new services.

A diverse demographic group will be chosen from fellow co – workers, with their common thread being their patronage to Florida Road i.e. those who have visited destinations on Florida recently, particularly on weekends, and do so occasionally. A drawback of this sample population however, is that those surveyed were high income professionals, and did not display a range of employment status'. For this discussion, it was important that individuals within the focus group had experience in using Florida Road, so that the questions posed could be more specific to the study area. The focus group discussion was held at the RoyalHaskoning DHV offices in Umhlanga on 25 February 2018.

4.4.1.1 Key points from the focus group discussions

General Trip Characteristics

Participants were found to frequent Florida Road for many reasons, the most common being for recreational purposes such as socialising with friends at bars/ clubs and supper at various the restaurants. Other less common reasons include shopping at grocery stores, visiting the banking facilities, ordering take away and visiting the general shopping stores located there.

Trip origins for trips to Florida Road were mostly from the participant's home. Participants originated from various areas such as Morningside, Durban North as well as Glenwood and the Berea.

Trips to Florida Road were made generally on weekends (Friday to Sunday) during the evening, and on occasion, on weekday evenings. These trips were usually made after 6pm. Most of these trips were between 6 pm and 10 pm; however, there were those who spent time on Florida Road till 2am the next morning. On average, participants stated that they spent between 10 – 15 minutes in search of Parking on Florida Road, during the peak periods.

Florida Road Traffic Issues

Participants were in general agreement when it came to having frustrations on the traffic issues (and parking in particular) on Florida Road. The following issues were mentioned at the discussion:

- ◆ Double parking in the vicinity of restaurants (when waiting for parking)
- ◆ People circling/ driving around to look for parking
- ◆ Pedestrian not crossing at designated points
- ◆ Illegal parking at intersections
- ◆ Parking on driveways
- ◆ Cars driving recklessly above the speed limit up and down the road

All these factors were seen to contribute to unsafe situations and manoeuvres for drivers.

Park and Ride Attributes

Most participants have had an experience with a P&R service, most of which was during the Soccer World Cup held in South Africa in 2010. P&R services were set up (at Suncoast Casinos) for Fan Parks held near the stadiums.

The proposed P&R system was explained to the participants. The following were the P&R characteristics proposed.

- ◆ P&R service from Greyville Racecourse to Florida Road
- ◆ 20 min frequency for morning peak (9am to 6pm)
- ◆ 10 min frequency for evening peak (6pm to 12pm)
- ◆ Around 1.1km per one way trip
- ◆ 2 busses in circulation

Participants did prefer the 10-minute shuttle frequency in the evenings, however they felt that the service time should be extended, till around 2am.

Frequency was a big contributing factor to whether participants would use this service or not. Participants did not want long waiting times, and were less likely to use the service if the waiting time for a shuttle was more than 20 minutes. Security of their vehicle at the P&R facility was also a major concern. Sheltered facilities or a waiting area for users of the P&R was considered, due to weather conditions. Participants were less likely to use the P&R if there was no form of security at the facility. The catchment area was also considered. Some of those who lived within the catchment area would prefer to walk to the facility and use services on Florida Road. It was also mentioned that this could be a hotspot for criminal activity, if unpoliced. Personal security was also a concern. Another concern for participants was that their vehicle had to be used for a leg of the trip, whereas with Uber, there is no need for your own vehicle, which was seen to be more convenient. Trip purposes also played a role in whether the P&R would be used. Those who had short trips (trips to the grocery store, to get take away etc.) were more inclined to use their vehicle, than take the P&R, as this felt like a longer, more laborious trip. Of all the factors considered, security was found to be the most important, followed by cost of the shuttle trip, and the frequency of the service. Participants thought that fining illegal parkers on Florida Road, the service being free as well as longer operational hours would make the service more attractive.

Uber Attributes

Uber trips were generally used for recreational trip purposes, especially to places where participants knew they would have trouble to park, such as concerts, matches at the stadium etc.

In general, the cost of using Uber was found to be the most attractive factor considered. It was found to be cheaper to use an Uber for the recreational trips described above. The convenience of not driving at any point in your trip was also a major influence, as well as the waiting time for an Uber, which is normally less than

10 minutes. Participants said that they quite frequently use Uber to Florida Road. They also mentioned that many people on Florida Road use Uber to get there.

Private Car

Participants stated that sometimes, a car is more convenient as you can leave whenever you want to. Respondents felt a loss of independence without their vehicle. Short trips were almost always taken by private vehicle. Weather also played an important role. In general, when using their vehicle, participants parked in the nearest parking bay found, or on some of the side roads. Parking bays are more easily found in the morning rather than the evening. Some participants stated that they use private parking lots of restaurants to park in while they make short trips to various stores. On average, participants stated they spent 10-15 minutes looking for a parking bay in the peak hour. This involved them travelling up and down Florida Road, as well as the side roads, in search of a parking bay.

4.4.2 Formulation of Alternatives

Mode choice is influenced by a range of different aspects that encompass social, economic, cultural and environmental factors such as travel time, travel cost, waiting time, comfort etc. Mode choice models in particular, deal with the trade-offs individuals are willing to make for these factors (Minal, 2014).

The transport alternatives posed to respondents in the survey were a subset of the universal choice set that is available. The universal choice set represents all possible transport alternatives that are available to the respondent, for their trip to Florida Road. However, it is impossible (from a computational as well as logical point of view) to include all these alternatives, as not all are available or known to every respondent. Some of the transport alternatives from the universal choice set relevant to this study include travel by their private vehicle, bus or taxi (public transport), by bicycle or walking (non – motorised transport) or by metered taxi service such as Uber.

Instead of evaluating the appropriateness of every alternative, a few were selected based on current knowledge of the area, and the focus group discussions, for inclusion in the survey. Generally, the choice of alternatives to be included is context dependant (Louviere *et al.*, 2000). The most important aspect that assisted in choosing alternatives to be represented in the survey was general site assessments

as well as the focus group discussions. Alternatives chosen to be featured in this survey were private vehicle (car), the P&R system and Uber. The reason behind the inclusion of each alternative is explored in more detail. Some of the reasons why other alternatives were not included are also discussed.

According to Kenneth E Train (2009) the choice set should have the following three properties; 1) the alternatives need to be mutually exclusive, 2) the choice set needs to be exhaustive and 3) the number of alternatives need to be finite.

4.4.2.1 Park and Ride

The P&R system was a critical inclusion to the study, as it forms the motivation for this research. P&R schemes are an important component of parking management strategies. Exploring the attributes that influence the use of such services can provide greater understanding into users preferences towards these services (Abdul Hamid, Mohamad and Karim, 2008).

The following section elaborates on the development of the P&R system that will be posed to respondents in this experiment.

The Proposed Park and Ride Site

According to Pratt (2013), potential P&R sites should be chosen primarily based on the location, as this effects the supply of parking available, as well as the distance users have to travel. The location should be able to accommodate most of the demand (i.e., having enough parking spaces for the car users, bicycle users, etc). It should also be placed near the trip origins (residential areas) and far from the trips destinations.

Primarily, vacant land or existing underutilised parking areas within the study area were investigated as potential P&R sites. Some of the sites considered as a prospective P&R facility location include the Greyville Racecourse parking area, Suncoast Casino Parking lot, as well as the Moses Mabhida Stadium parking facilities. Given that each site comes with their own pros and cons, Greyville Racecourse was chosen as the location of the P&R parking facility. During most of the week the parking facility is underutilised, as this space is only used for race days or major events (such as the Durban July). It is also in close proximity to Florida Road, and would suffice as a start- up P&R facility. The main consideration for this parking facility was that it assists in shifting the parking demand for Florida Road, to another location. There are around some 180-200 parking bays available in one

of the parking lots, which was ideal for the envisioned P&R service. It is also just over 1 km away from Florida Road, within the Greyville residential area. Permission to use this site would be required. The availability of the parking area for use as a P&R facility would also need to be verified before implementation.

Park and Ride Context - Operational Characteristics

The characteristics of this system and thus the hypothetical scenario was not designed in too much detail, and only the main operational characteristics were included, as some of the attributes considered were varied in the SC experiment. The basis of the P&R service that was presented to respondents will be discussed here, and is shown in the schematic below.

Greyville Racecourse is located approximately 1km away, making it ideal for the service. Given the specified distance from Florida Road, and an average shuttle bus speed of say 50km/hr, it will take 1 bus approximately 2 minutes to complete a single trip. However, if the average speed increased/ decreased by 15km/hr, the trip time would decrease/ increase by 1 minute respectively. This trip time does not consider pick - up/ drop - off time, which would vary, according to demand. For the purposes of this study however, the pick - up/ drop - off time was kept to between 1 - 2 minutes. Each bus will pick up/ drop-off at a designated stopping area on Florida Road. The fleet will consist of 2 shuttle busses at the start. Initially the P&R system was proposed to operate on weekends only. Once a sufficient demand for the service has been established, operational hours for the service can then increase, as well as the fleet size, to match the demand. The service will also operate throughout the day, from 9am to around 12am. The frequency of the P&R shuttle service will vary throughout the day, depending on the demand. It is expected that the demand will increase through the evening (around 8pm) and continue till late. The shuttle service will be a secure, quality bus service. The shuttle trips will be priced, per trip to Florida Road, and back to the parking facility. Use of the P&R parking facility was not priced. This P&R cost is an element that will be varied in the survey. The P&R characteristics described are shown schematically below.



Figure 10 : Park and Ride Service Characteristics

In the final survey, respondents were only presented with the most crucial aspects of the P&R system – the route, any charges, scheduling aspects and security aspects. This information was considered sufficient enough for respondents to be able to make informed mode choice decisions, and for the researcher to estimate the demand for the service, as well as gather meaningful conclusions during data estimation.

4.4.2.2 Private Vehicle

Respondents current mode - private vehicle (cars) was an obvious choice of alternative. In the research investigated, the primary objective of providing P&R services was the removal of private vehicles from the local road network (Parkhurst, 1995; Litman, 2013; Pratt, 2013). Also, one of the major findings upon site investigations and focus group discussions was that private vehicles were the most common vehicle type found on Florida Road and the primary causes of the traffic disturbances on Florida Road. A broader objective of this study was to encourage the removal of private vehicle traffic off Florida Road by people using the P&R system. The survey respondents will also only be those who travel by private vehicle, either as a driver or passenger to Florida Road. The private vehicle alternative that will be shown to respondents related to their current trip to Florida Road i.e. an existing travel pattern. The car alternative is usually considered more attractive than other modes of transportation (especially when compared to PT modes). Some find it more

relaxed, flexible and in some cases quicker than alternative modes. It is also considered as a status symbol to many (Seik, 1997).

4.4.2.3 Uber

In recent years in South Africa, Uber has gained in popularity and usage. Uber refers to an application on your phone, which allows you to book and pay for the use of a driver and vehicle, for a specific trip. Uber was an alternative that came to the forefront during focus group discussions. Many people indicated that they had used Uber previously to visit Florida Road, as well as seen a number of Uber vehicles parked on Florida Road. Uber was added to the list of alternatives to make the choice set appear more realistic as well as current to respondents.

Public transport options were not included in the list of alternatives. This mode was not seen to be a common mode of transport used to access Florida Road, by the target population. Public transport options are also existing TDM measures, which aid in the reduction of private vehicular traffic. Since it had been identified that private vehicles were the primary cause of traffic on Florida Road, non- motorised modes such as walking, cycling etc. were not considered in the survey. People using these modes were not considered primary users of the P&R system.

Prior to giving respondents the survey, a screening question was posed, asking respondents if they had travelled by car to Florida Road on the day the survey was implemented. This question assisted in filtering only the car drivers/ passengers for use in the survey. It also confirmed that the respondents had a private vehicle available to them, for their trip to Florida Road.

4.4.3 Derivation of Survey Attributes and Levels

Attributes can be defined as the main factors that influence the choice of mode a person uses (Ben-Akiva and Bierlaire, 2003). For example, travel time and travel cost is generally important attributes in situations involving mode choice, as these represent aspects most commonly considered (Hess and Rose, 2009). Attributes should be prioritised in order of importance and relevance to the study. Attributes that are unlikely to vary are generally excluded. Methods identified to assist in the formulation of attributes include gathering information from focus groups, previous research, and to an extent, the researcher's individual experience (Cherchi and

Hensher, 2015). In this study, attributes were kept as generic as possible, to simplify the analysis.

The first step was to identify the various attributes to be included in the survey. Then, a unit of measurement was specified for each attribute. The final step was to select “levels”, which are values of the attributes that will be varied in the experimental design. The number of choice situations increase considerably as the number of attributes, or attribute levels increases (Smith *et al.*, 2015). It is therefore good practice that only the most relevant aspects be included in the design.

Step One: Identification of Attributes

It is important to note that not all possible attributes can be included in the survey. Only the most important and relevant to this study were included.

Attributes Identified from Focus Group Discussions

From the focus group discussions, it was clear that travel time and travel cost were considered important to users of Florida Road, and in particular, prospective users of the P&R system. Security was a major consideration, as many did not feel comfortable leaving their vehicles parked with no security guards at a parking facility. Time spent waiting/ searching for a parking bay was also a consideration. During peak periods, some stated that they spent around 10-15 minutes looking for a parking bay on Florida road. Those that spent longer waiting for a parking bay were interested in alternative’s access modes to Florida Road. Another contributor to this was illegal driving movements, performed by people waiting for a parking bay.

Attributes Identified from Previous Research

A study carried out by Shiftan, Vary and Geyer (2006) examined the potential of shuttle bus services within a national park, with the objective of decreasing vehicle use on the park roads. This study used an SC and DCMs to quantify the effect of various service characteristics on visitor’s mode choice and on reducing car travel in the parks. Attributes included in this study were auto drive time, auto walk time (for private vehicle use) and fare and headway for P&R shuttle service use.

Hole (2004a) carried out a similar study to the research topic. The research used SC data to forecast the demand for an employee P&R service for a University. The experiment contained only two attributes; P&R door-to-door travel time and cost, which were varied over three levels relative to the individuals’ current commute.

Abdul Hamid, Mohamad and Karim (2008) carried out research on the factors that influence P&R usage. The study found that in terms of trip characteristics, trip purpose, total time taken from origin to destination, total cost incurred (from origin to destination) and number of transfer made were most important to current users. In terms of parking characteristics, P&R service charges, frequency of P&R use and the availability of parking at the P&R facility were also important considerations.

In (Sanko, 2001), it is suggested that more 2 and not less than 6-7 attributes be used in a SC survey. Fewer are suggested, if respondents are unfamiliar with alternatives presented.

Each attribute that was presented to respondents, and the reasoning behind their inclusion is expanded upon on the section to follow.

Travel Cost

This is one of the most important attributes considered in previous research as well as in the focus group discussions. Cost, and in the case of mode choice decisions, is an intuitive consideration. Travel cost was added to the survey to investigate trade-off behaviour in respondents with regards to cost and various transport service characteristics as well as forecast the impact of cost on the P&R service demand and lastly, to investigate how individuals value the cost of different mode alternatives.

Ben-Akiva and Bierlaire (2003) states that it is important to differentiate between the two types of travel costs; the “out – of – pocket” costs such as tolls, as well as general costs, such as car operating costs, for example. This study referred to travel cost as being the general operating cost, in the case of car, the cost of an Uber trip, in the case of Uber, and the cost of using the P&R service as well as car operating costs, for the case of the P&R service.

Travel Time Variation

An important aspect concerning the traffic related issues at Florida Road is the time spent looking for a parking bay. The insufficient number of parking bays provided makes it difficult for drivers to find a parking, causing an increase in illegal parking and driving manoeuvres, as well as driver frustration. The P&R system has the potential to address these concerns, and so, travel time variation was added to the survey to highlight to respondents the travel time differences experienced by usage of different modes.

Travel time variation for private car related to the time spent looking for a parking bay. It was hypothesised that those who spend a longer time looking for a parking bay on Florida Road, would be more inclined to use the P&R service, as these “time – savings” would be realised. Travel time variation by P&R and Uber, related to the time saved, by drivers not having to park their vehicle on Florida Road.

Security

Previous research cited that security at the P&R parking facility was an important consideration to prospective P&R users (Hole, 2004b; Abdul Hamid, Mohamad and Karim, 2008). Focus group discussions also revealed that the presence of a security guard at the P&R facility made respondents feel more at ease about using the service. With crime in South Africa being on the increase, safety and security has become a primary concern. Security provision at the P&R facility was therefore included in the study.

Park and Ride Service Headway

Long waiting times for P&R shuttle busses were considered a deterrent to service patronage. In general, long headways with any mode discourage the use of that mode. Service headway is an important characteristic to users who have time constraints or those who intend to spend a short time on Florida Road. A quick, efficient transport is an attractive characteristic to potential users. P&R service headway was also added to the survey to test respondent’s reactions to changes in service headways.

Step Two: Selection of Measurement Units for Attributes

The table below shows the measurement units that were used for each variable included in the survey.

Table 5 : Attributes and Their Respective Measurement Units Used in The Survey

Variable	Measurement Unit
Travel cost	Rands (R)
Travel time variation	Minutes (mins)
Security	Dummy coded variables

Park and ride service headway	Minutes (mins)
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The most logical measurement unit for travel cost was Rands, as travel cost represents the general operating costs to respondents. In the same breadth, travel time variation was represented in minutes, as this variable represented the time saved (or spent) by looking for parking. Security could not be represented by numerical variables, as this was a bit of an abstract concept. Dummy variables were used, which would later be coded in the data set required for the DCE. The P&R service headway was represented in minutes.

Step Three: Specification of Levels for Attributes

Attributes and their respective levels should be believable, and as a far as possible, represent the real-life situation. It is good design practice to construct levels that replicate real - life as far as possible, especially for existing alternatives. Levels for existing alternatives should have at least one level that is close to the real-life situation. With new alternatives, making attribute levels believable is also a primary consideration (Hensher, 1994).

The number of levels required for a design depends primarily on the study objectives and the complexity of the design to be undertaken. For each attribute variable considered, the levels used and their ranges will be discussed.

Total Travel Cost

Travel cost in this survey, was taken as the cost of a trip, from the place of origin, to Florida Road. This trip could be by private vehicle, or Uber. Regarding the P&R service, travel cost is denoted by the cost of a shuttle service trip, added to the cost of a car trip (to Greyville Racecourse).

The cost levels used for this alternative was R5 and R10 for the cost of a shuttle bus trip. It was chosen to rather make the cost of using a parking bay at the Greyville parking facility free, and place a cost on the shuttle bus trip. To obtain realistic travel costs, information from focus groups discussions was used, to gather where about people who visit Florida Road originate from.

The origins ranged from further areas such as Umhlanga, to closer areas such as Morningside. Using these relative distances and an average petrol price (at the time of calculation) along with average fuel consumption, one can obtain a generalised travel cost. This method, crude as it may seem, was considered the best way to formulate base values for levels. The same cost levels that were used for the car alternative, were used for the Uber alternative as well. For both these modes, the trip origins would be the same, and the cost considerations, especially in the minds of respondents, would be relatively the same. The focus group discussions also helped refined what was realistic and acceptable in the minds of potential survey respondents. The equation below shows how travel cost for the car and Uber alternative was developed.

$$\begin{aligned}
 \textit{Travel Cost}_{car} & \\
 &= \textit{distance from origin to Florida Road} * \textit{Petrol price} \quad (14) \\
 & * \textit{Average fuel consumption}
 \end{aligned}$$

The final levels for travel cost are shown below

Table 6 : Travel Cost Attribute Levels

ALTERNATIVES	LEVELS		
Car	R20 per trip	R40 per trip	R60 per trip
Park and Ride	cost of car trip only-Park and Ride service is free	car trip cost +R5 per shuttle trip	car trip cost +R10 per shuttle trip
Uber	R20 per trip	R40 per trip	R60 per trip

Total Travel Time Variation

The values for travel time variation are based on the time spent looking for a parking bay at Florida Road. For car users, this is considered a time loss, as this involves waiting for a parking bay, and for P&R and Uber users it is considered a time gain – the time respondents would have spent looking for a parking bay is now saved. Therefore, private vehicle travel time variation was considered differently to that of Uber and P&R.

For the car alternative, the values for travel time variation were taken to range between 0 – 15 minutes. Even though it is difficult to find parking, it is not uncommon for people to find a parking bay immediately – some may say it just depends on your timing and luck. In focus group discussions, 15 minutes was considered the upper limit for time taken to find a parking bay.

For Uber and P&R, the parking time savings ranged from 5 – 15 minutes for these modes. Again, these values are based on actual parking times specified in focus group discussions.

Table 7 : Travel Time Attribute Levels

ALTERNATIVES	LEVELS		
Car	find a parking bay immediately	lose 5 minutes in time spent looking for a parking bay	lose 15 minutes in time spent looking for a parking bay
Park and Ride	save 5 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
Uber	save 5 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay

Security

Security was an attribute only considered applicable to private vehicle and the P&R. In terms of Uber, people generally do not experience any personal safety issues, more so if they aren't travelling alone.

For the car alternative, security was defined in terms of Florida Road, and parking. The safety aspects of Florida road were explored, as well as how people value safety in this area. It was found that people preferred to park on the on- street parallel parking on Florida Road, rather than the side roads, as they felt that it was safer. The pedestrian traffic as well as lighting along the roadway aided in car users feeling their car was safer. This contrasted with the many adjacent side roads to Florida Road, which are generally quieter and not well lit. Therefore, these security aspects were the basis for security in terms of private vehicles.

Security in terms of P&R referred to whether there was a security guard at the P&R facility, or not. Focus group participants felt safer leaving their vehicle at a facility with a security guard present, than at one that is unmanned. Therefore, only two levels of security were used – no security guard, and the presence of a security guard. The levels for security are shown below.

Table 8 : Security Attribute Levels

ALTERNATIVES	LEVELS	
Car	Parking available on the main road (Florida Road)	Parking available on the side roads adjacent to Florida Road
Park and Ride	no security guards at parking facility	security guards at parking facility

Service Frequency

This attribute relates to the P&R mode only, and refers to the headway between successive vehicle pick –ups or drop – offs. The travel time for a shuttle bus (Greyville Racecourse to Florida road) was calculated previously, and aspects considering a

round trip (passenger loading/ offloading times etc.) were used to estimate headway. The minimum amount of time required for a round trip was 6 minutes; therefore, an initial headway of 10 minutes (rounded) was proposed. Headway of 20 minutes was then also considered, to elicit respondent reaction to the change in time.

The table below shows the final alternatives, attributes and levels that were used in the survey.

Table 9 : Alternatives, Attributes and Levels included in this Study

ALTERNATIVES	ATTRIBUTES	LEVELS		
Car	Total Travel cost	R20 per trip	R40 per trip	R60 per trip
	Total Travel time variation (loss)	find a parking bay immediately	lose 5 minutes in time spent looking for a parking bay	lose 15 minutes in time spent looking for a parking bay
	Security	Parking available on the main road (Florida Road)	Parking available on the side roads adjacent to Florida Road	
Park and Ride	Total Travel cost	cost of car trip only-Park and Ride service is free	car trip cost +R5 per shuttle trip	car trip cost +R10 per shuttle trip
	Total Travel time variation (savings)	save 5 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	Shuttle service available every 10 minutes	Shuttle service available every 20 minutes	
	Security	no security guards at parking facility	security guards at parking facility	
Uber	Total Travel cost	R20 per trip	R40 per trip	R60 per trip
	Total Travel time variation (savings)	save 5 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay

4.4.4 Experimental Design Requirements from DCE

It is also important to keep in mind certain design constraints regarding the DCE (that will follow once the survey has been designed and implemented) while still in the survey design phase. These steps in the process are interlinked, and there are some elements from DCE design that should be considered in the SC design phase. More importantly, a design needs to have adequate variation in attribute levels and present respondents with levels that elicit trade-off behaviour, for model estimation to infer meaningful results. The analysis of DCE data is undertaken within the constraints of the experimental design (Lancsar, Fiebig and Hole, 2017). Some of the initial considerations when generating an experimental design include:

The Model to be Estimated

The model chosen for this study was the MNL. Reasons behind choosing this model will be detailed in Section 5.2.1. There are some constraints regarding MNL models, which will be also be explored.

The main requirements for MNL discrete choice experiments in terms of choice set generation are:

- ◆ The set of alternatives presented should be exhaustive, including all alternatives.
- ◆ The alternatives should be mutually exclusive.
- ◆ Choice sets should contain a finite number of alternatives (Train, 2009).

In this study, only the main modes available to respondents were included. PT was not included in this study as this would not affect usage of the P&R system. In the same breath, non – motorised modes such as walking and cycling were not included. Alternatives and mutually exclusivity is an assumption that will be maintained in the model estimation process, and discussion of results. The number of alternatives in this study are three.

The Number of Parameters to be Estimated

The main SP parameters that were included in this study were the four attributes; travel cost, travel time variation, headway and security. Socio – demographic questions, as well as questions regarding respondent’s current travel patterns also added to the number of parameters that were estimated by the model.

Whether the Model Will Include Interactions Between Attributes

The main interaction element that was included in the survey was that between the travel cost of car, and that of the P&R service. This is mainly due to the P&R travel cost values using the travel cost for the car alternative as a base, and adding the P&R fare to that. Hence, there is a natural correlation between these two attributes.

4.5 Experimental Design

Once the alternatives, attributes and levels were formulated, the survey experiment was designed such that the choice sets posed to respondents could provide meaningful insights into the thought process of an individual, when faced with a choice (Wittink, 2011). One of the core aspects in SC survey design is the experimental design. Experimental design and choice set generation is a research topic on its own (Rose and Bliemer, 2009; Quan et al., 2011).

The basis of an experimental design involves the identification of relevant characteristics (attributes) that will be compared in the study. In the context of this study, this step involved the formulation of alternatives as well as attributes to be presented to respondents. Then, the number of levels and the ranges of these levels were set. From this step, different methods can be applied, which essentially combine the alternatives' attributes levels given certain constraints (dominance, implausible options etc.) into choice sets that can be presented to respondents. The methodology behind the construct of these choice sets is the focus of this chapter.

A fixed choice set design approach was taken in this study. This means that, for every choice set presented, the number of alternatives available remained the same. i.e. all choice sets presented to respondents gave the option of choosing their own vehicle, Uber or the P&R. These designs are found to be the most common applied in transportation research (Toner et al., 1999) via (Sanko, 2001).

In the sections to follow, the generation of the full and fractional factorial will be described. Then, the process of removing choice sets from the fractional factorial, to generate the final choice sets presented to respondents, is explained.

4.5.1.1 Full Factorial and Fractional Factorials

Full factorial design takes into account all possible choice sets that can be generated, by combining each level of each attribute, with every attribute level (Louviere *et al.*, 2000). Full factorials also consider all main and interaction effects as they are by default, orthogonal (Ngene Manual, 2012). These designs are only feasible when there are a small number of attributes and levels used, and the number of combinations is kept to a minimum. However, once the number of attributes and levels increase, the number of choice sets increases exponentially. This kind of design is not practical; therefore, fractional factorial designs are used, which reduces the number of combinations posed to respondents. Many research papers have cited this solution to the full factorial problem.

For the survey we had three alternatives, and four attributes, each with differing levels. There are two attributes with two levels each, and two attributes with three levels each. In full factorial designs, the number of combinations is determined by using the number of levels, raised to the power of the number of attributes used (Sanko, 2001). The full factorial represented by this design is $2^2 * 3^2 = 36$ scenarios.

The number of combinations is too many to pose to all respondents at one time. Even if choice sets are blocked (broken up into sections); there are still too many choice scenarios for respondents to be faced with at one time. Therefore, a fractional factorial design was used. A fractional factorial design only shows respondents a subset of the full factorial, thereby reducing the respondent (as well as researcher burden).

There are many methods to create a fractional factorial, and in this research, an orthogonal design was used. The main aim of orthogonal designs is to reduce the correlation between attribute levels used in experimental design, and is a more structured way of representing choice sets (Ngene Manual, 2012). Other possible options include randomly selecting choice situations from the full factorial, or assigning blocks of choice sets to different groups of respondents, or D – efficient designs (ChoiceMetrics, 2012).

4.5.1.2 Creating an Orthogonal Fractional Factorial Design

Orthogonality refers to the situation whereby each attribute level occurs an equal number of times as every other attribute level. All parameters are also independently estimable. Another property of orthogonality is that the attribute levels for each attribute need to be uncorrelated with every other attribute level (ChoiceMetrics, 2012). Orthogonality was previously considered important for many reasons, however, in recent times, principles of orthogonality have been replaced by designs such as efficient designs (Sanko, 2001).

The data analysis programme SPSS (Statistical Package for the Social Science) was used in the creation of the orthogonal fractional factorial. SPSS has an inbuilt function to create orthogonal designs. The inputs are your alternatives, attributes and levels. The following figure shows how the data was inputted into SPSS. The SPSS's ORTHOPLAN command produces the orthogonal design. As a default, it produces minimum sized orthogonal design (SPSS Manual, year unknown).

In SPSS, levels were categorised according to "low", "medium" and "high" and assigned values of 1, 2 and 3 respectively, to simplify the analysis. Once the design was carried out, the coding was replaced with actual attributes and levels. The representative coding that was used in SPSS is displayed below.

Table 10: Table showing Coding used in SPSS to Generate Orthogonal Fractional Factorial

ALTERNATIVES	ATTRIBUTES	LOW (1)	MEDUIM (2)	HIGH (3)
Park and Ride (1)	Total Travel cost	cost of car trip only- Park and Ride service is free	car trip cost +R5 per shuttle trip	car trip cost +R10 per shuttle trip
	Total Travel time variation (savings)	save 5 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	Shuttle service available every 10 minutes		Shuttle service available every 20 minutes
	Security	no security guards at parking facility		security guards at parking facility
Uber (2)	Total Travel cost	R20 per trip	R40 per trip	R60 per trip

ALTERNATIVES	ATTRIBUTES	LOW (1)	MEDUIM (2)	HIGH (3)
	Total Travel time variation (savings)	save 5 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
Private vehicle (3)	Total Travel cost	R20 per trip	R40 per trip	R60 per trip
	Total Travel time variation (loss)	find a parking bay immediately	lose 5 minutes in time spent looking for a parking bay	lose 15 minutes in time spent looking for a parking bay
	Security	Parking available on the main road (Florida Road)		Parking available on the side roads adjacent to Florida Road

Each attribute level was represented by low, medium or high, to simplify the SPSS input, and to avoid having to add each attribute level separately. Low medium and high were also given a number allocation; 1, 2 and 3 respectively. Using SPSS, an orthogonal design with 81 choice scenarios were created. The 81 choice cards were randomly organised into 27 choice sets, containing each alternative, with varying levels of the attributes travel cost, travel time savings, headway and security to generate the different scenarios. In this step, orthogonality was still maintained as all 81 choice cards were maintained. The 27 choice sets created can be found in Appendix 8.5.

4.5.1.3 Choice Set Generation

The number of choice sets in the orthogonal design was too high to pose to all respondents, and had to be minimised. In Sanko (2001), guidelines were given into the process of removing irrelevant choice sets. It should be noted that combinations and choice sets need to be realistic, but sometimes it is not possible to have all combinations within the individuals experience (Hensher, Rose and Greene, 2005). The following two principles were used to eliminate choice sets:

Contextual constraints – choice sets that create scenarios that are implausible in reality can be removed. With this, orthogonality is lost. Keeping implausible scenarios gathers no useful information in model estimation (Sanko, 2001).

Trivial games – trivial games refer to choice sets that have an obvious choice outcome. With this, orthogonality is also lost. Sometimes, it is good practice to include at least one trivial game in the choice sets, so as to assess the reliability of the response (Sanko, 2001).

Dominant alternatives – dominant scenarios refer to choice sets whereby one alternative scenario is always chosen (Smith et al., 2015). These scenarios give no indication of trade-off behaviour.

The choice sets that were removed are highlighted in red in Appendix 7.4.

This was done manually by simply removing choice sets that either did not make sense (i.e. they were implausible) and choice sets that had dominant alternatives. Dominant scenarios can also result in unrealistic situations, and do not give meaningful information on trade-off behaviour. Since one of the main aims of the survey design was to interpret reality as best as possible, choice sets which were implausible in reality were excluded. The following choice sets presented are examples of some of the choice sets that were excluded in the study.

Table 11 : Example Choice Sets that were Excluded in the Survey

		Private vehicle	Park and Ride	Uber
6	Total Travel cost	R60 per trip	car trip cost (R60) +R10 per shuttle trip	R20 per trip
	Total Travel time savings	lose 5 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 20 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	no security guards at parking facility	-

		Private vehicle	Park and Ride	Uber
9	Total Travel cost	R60 per trip	car trip cost (R60) +R10 per shuttle trip	R20 per trip
	Total Travel time savings	lose 15 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 20 minutes	-
	Security	Parking available on the main Road (Florida Road)	security guards at parking facility	-

		Private vehicle	Park and Ride	Uber
23	Total Travel cost	R60 per trip	car trip cost (R60) +R10 per shuttle trip	R20 per trip
	Total Travel time savings	lose 5 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 20 minutes	-

	Security	Parking available on the main Road (Florida Road)	security guards at parking facility	-
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In these three choice sets, Uber was an obvious choice. The travel cost is much lower than the other modes, and coupled with good travel time savings and Uber popularity, make this alternative highly competitive. The levels for Uber and private vehicle were also very similar, offering little variation in attributes.

From this exercise, 18 choice sets were left. It should be noted that orthogonality was lost in this step, as removing choice sets by default, removes any attribute balance. It was then decided that these choice sets be blocked into two blocks, and nine choice sets be posed to respondents per block. The final choice sets to be posed to respondents can be found in Appendix 8.6.

4.6 Survey Design Assumptions and Limitations

Up to this point, the method and development of choice sets has been discussed. In this section, the assumptions and limitations relating to the survey design method and process are explored.

The Reliability of Stated Preference: In SC surveys, respondents are usually asked to choose what they would prefer, rather than what they actually do. This sometimes may differ to what an individual eventually does do. There are many reasons that attribute to this behaviour, such as respondent bias, respondents trying to justify their own behaviour as well as respondents trying to control policies (Cherchi and Hensher, 2015). This uncertainty exists in all SC surveys undertaken.

Definition of Attributes and Levels: The alternatives chosen were not the only alternatives available to people for their trip to Florida Road. There are a range of alternatives possible, however, only the most common alternatives were used, for simplicity. The fractional factorial design used also takes into account only selected alternatives and attributes.

Inclusion of Status Quo (or opt – out): No status quo or “opt-out” option added, this is known as a forced choice problem.

Respondent Perception: One of the main limitations common to most SC experiments is the respondent’s ability to understand the hypothetical situations

posed, and provide reliable answers (Ahern and Tapley, 2008). Some research suggests that when hypothetical situations are far removed from the respondent's actual experience, results are less accurate. Sometimes respondents have constraints in their capacity to process information, or may not be willing to put in the required effort to evaluate alternatives, leading to respondent disengagement (Smith *et al.*, 2015).

Paper and Pen Survey Limitations: As the survey was administered by means of a paper and pen survey, current car attribute levels could not be collected, and therefore, P&R levels could not be pivoted on actual car levels. This would have assisted in adding realism to the survey, as well as made the DCE estimation more explanatory. Normally Computer Aided Personal Interview's are an efficient method to collect data this way. Using designs pivoted on actual attribute levels experienced by respondents reduce the risk of alternatives being confusing to respondents (Ben-Akiva *et al.*, 1994).

4.7 Construction of Survey Instrument

The construction of the actual questionnaire is the underlying backbone of the experimental design. A table of numbers is meaningless to the respondents at this stage, and needs to be transformed into something where the purpose of the study can be easily understood. Survey layout design was researched to gather good principles of survey design. The survey instrument design brings the survey together for the reader, in a form that clearly understood and comprehensible.

4.7.1.1 Survey Administration

The response form used for this survey was that of the traditional "paper and pen". This was considered the most direct and efficient method to collect data, as this study requires respondents that travel by private vehicle to Florida Road, who can easily be intercepted this way. Other types of surveys considered were computer aided personal interview (CAPI), or through the internet (online). Online surveys were found to be difficult in deciphering whether respondents used a vehicle for their trips to Florida Road; CAPI surveys were difficult to implement. It also ensures that respondents can be screened, prior to starting the survey, as to whether they travelled by private vehicle for their current trip.

4.7.2 Other Information Required

The SC sets were not the only variables included in the survey. Personal information as well as information on respondent's current travel patterns was also recorded.

The survey was split into three main modules:

Socio – demographic information – data on personal characteristics.

In order to explain the heterogeneity of preferences among respondents, Ben-Akiva and Bierlaire (2003) suggests that socio – economic variables should be included in the survey. Different respondents may value the various alternatives and attributes in different ways, and it is important to try and capture this source of preference heterogeneity. Aspects such as age, gender and employment status were included in the survey. Abdul Hamid, Mohamad and Karim (2008) suggests that socio – economic characteristics gender, ethnic group, age, marital status, employment category and monthly personal income are questions that should be added to SC surveys, to enrich the data collection, and build more explanatory DCM's.

Revealed data – data on current travel choices for trip to Florida Road.

It was important to understand respondents current travel patterns to Florida Road. The questions posed related to their last trip to Florida Road. Trip purpose, trip origin, time spent and trip frequency are just some of the questions that were asked. Trip purpose and time spent at Florida Road, for example, has a major impact on use of the P&R system. It is unlikely that those who are visiting Florida Road for a visit to the grocery store for around half an hour, would use the P&R. In general, it was hypothesised that those who spend less than around say 45 mins would be unlikely to use the P&R. The revealed data would also assist in understanding the major trip purpose on Florida Road (at that time) as well as how long people do spend there on weekends. The time taken to find a parking bay was also asked in the survey. This was considered another factor that would affect the P&R usage. It is assumed that those who spend longer on average to find a parking bay, are more likely to consider the P&R service. This is mainly as a result of driver frustration etc.

Stated Preference- choice cards to be presented with hypothetical P&R scenario.

In the DCE, some of these variables were used to understand the travel behaviour patterns of car users to Florida Road, as well as illicit preferences between different segmentations of groups i.e. male and female behavioural characteristics.

4.7.2.1 The SC Survey

Some of the final elements that tie the SC survey together will be discussed here. The survey was designed to target only those who came to Florida Road by car, thereby confirming that the respondents had a car available to them for their trip to Florida Road. To ascertain whether respondents had Uber available to them, the survey asked whether respondents had access to the Uber application.

Particular attention was paid to how the hypothetical situation was described to respondents. Respondents were shown a schematic of the hypothetical P&R scenario, and given the information as described in Section 4.4.2.1. The information provided was considered sufficient enough for respondents to make informed mode choice decisions.

Each choice set was presented to respondents in the format shown below. Column headings gave the names of alternatives, while the row headings presented the attributes of the alternatives. Reviewed literature showed that this is the most commonly found way to present choice sets. The current option (their own vehicle) was emphasised by the heading above alternative names; assisting respondents in accurately being able to identify with the alternatives. An example choice set is shown below.

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	PRIVATE VEHICLE	PARK AND RIDE	UBER
TOTAL TRAVEL COST (one way)	R20	Cost of car trip (R20) + R10 per shuttle trip	R20
TOTAL TRAVEL TIME VARIATION (one way)	Lose 5 minutes in parking time	Save 10 mins in parking time	Save 10 mins in parking time
SECURITY	Parking available on the side roads adjacent to Florida Road	No security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 10 mins	-
1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?	<input type="radio"/> HIGHLY LIKELY	<input type="radio"/> HIGHLY UNLIKELY	<input type="radio"/> I CANT BE SURE

Figure 11: Choice Set Layout and Design

For each choice set presented, two questions were posed to respondents. The first asked respondents to choose a mode of transport, under the circumstances presented. This included the hypothetical P&R scenario. The second question asked respondents how likely they were to actually choose this option, if the situation presented represented real life. Three levels were used for this question. It should be noted however, that upon analysis, data resulting from the second question was not used. The final questionnaire posed to respondents can be found in Appendix 8.6.

4.8 Pilot Survey

The questionnaire was initially tested for understanding, ease of task, time to complete as well as respondent engagement. Smith *et al* (2015) states that the primary goal of pre – testing (or pilot surveys) is to develop a questionnaire and choice sets that are understandable and credible to respondents, through effective presentation. There needs to be a balance between collecting reliable information, and avoiding respondent fatigue. Testing the survey provides insight into whether respondents understand the survey and its various components, and most importantly, whether the choice sets presented make sense to respondents. Hess and Rose (2009) suggests that significant pretesting of the survey instrument should be carried out.

For this survey, it was important that respondents understood the P&R service operations, as well as clearly understood what each attribute and level represented. The pilot survey was carried out in April 2018 at the RoyalHaskoning DHV offices in Umhlanga, Durban. Even though the survey was not carried out on Florida Road, respondents who had visited Florida Road on a regular basis were included. The focus group participants and pilot survey participants were not the same people. Twenty pilot surveys were carried out. The main objectives of this pilot survey were to:

- ◆ Determine the time taken for respondents to complete the survey;
- ◆ Determine whether respondents understood the attributes and levels that were used;
- ◆ Determine whether respondents understood the hypothetical P&R scenario (and whether the schematic presented assisted in this) and
- ◆ Ascertain feedback from respondents of their experience

The data was investigated further, along with comments given by the respondents. The main issues that were highlighted were that some respondents stated that they

felt the survey was too long. Some respondents also did not initially understand the travel time variation attribute used in the survey. However, this settled once the attribute was explained clearly.

It was also noted that from the respondents surveyed, not many had had experienced with SC surveys, so the choice sets posed did take some time to understand.

4.9 Final Survey Implementation

This section will cover the process of final implementation of the SC survey, as well as some high-level population demographics.

4.9.1.1.1 Resource Requirements

University students were used for the implementation of the survey. Prior to the main survey, meetings with the students occurred to:

- ◆ Explain the content of the survey and how stated preference surveys need to be approached
- ◆ Explain the hypothetical P&R scenario
- ◆ Brief the students on how to approach prospective respondents
- ◆ Answer any queries

Seven students were used on each survey day. Students were required to arrive at 6pm on both evenings, and complete 10 surveys each. A total of 140 surveys were handed out during the course of the weekend.

The diagram below shows the process by which each survey block was administered.

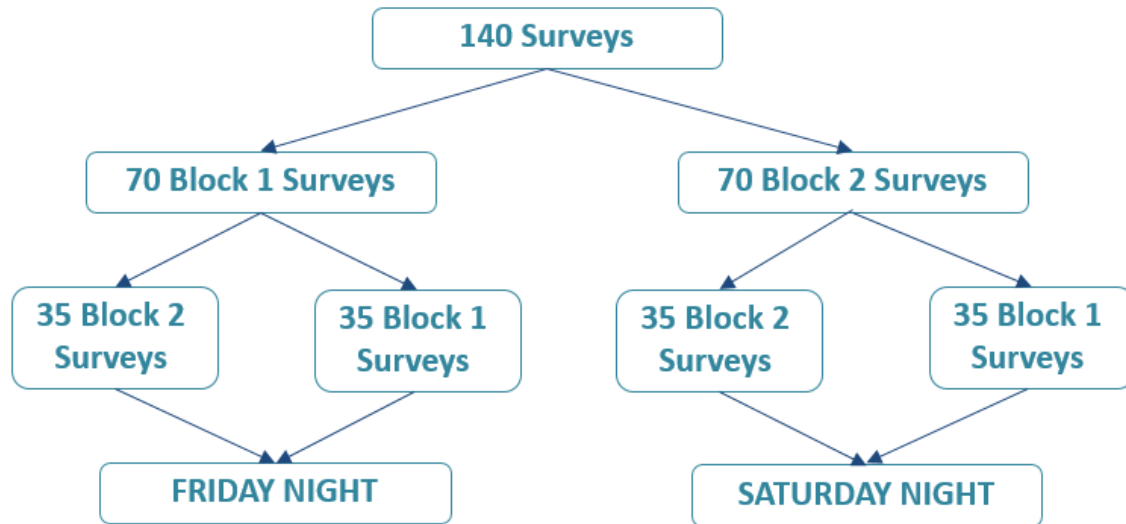


Figure 12 : Process of Survey Administration

4.9.2 Survey Findings

In this section, the response rate will be discussed, along with some findings from the survey.

4.9.2.1 Response Rate

The survey response results are shown in the table below.

Table 12 : Survey Response Rate

	Completed Surveys	Incomplete Surveys	Total
Block 1	43	27	70
Block 2	44	26	70
Total	87	53	140

The biggest contributor to the lowered response rate was incomplete surveys. As the survey was carried out on weekend evenings, some respondents were not too enthusiastic to fill out a survey. Some respondents answered only the socio – demographic and current trip questions, and not the SC portion of the survey. Some discontinued with the survey halfway through. In some instances, the students did not record whether the respondent was male or female, thereby disqualifying the survey.

4.9.2.2 At a Glance

A high level excel analysis was carried out on the data obtained from the SC survey, to provide insight into respondent’s choices and characteristics. The data received from 87 respondents, yielding 9 observations each, was used.

Socio – Demographic Characteristics

Firstly, the respondent’s personal information was closely investigated. Around 57% (50) of that survey were male, and 43% (37) were female, yielding a good gender mix of respondents.

In terms of employment, almost half of those surveyed 49% (43) were employed, 18% (16) were students, while 17% (15) of respondents stated that they were self – employed. Only 3% (3) stated that they were unable to work. The graphs below give a schematic look at the sample population characteristics.

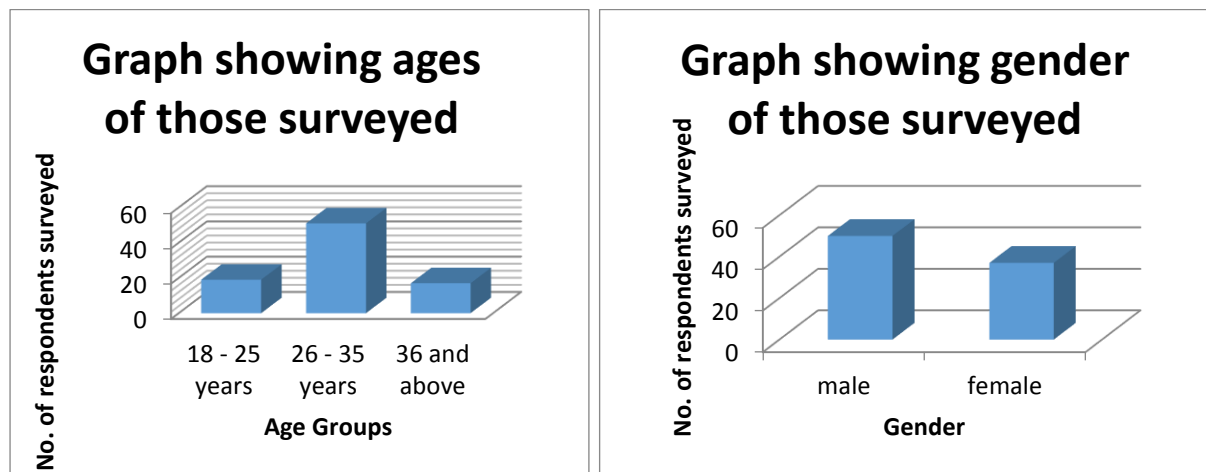


Figure 13: Demographic Characteristics of Respondents Surveyed

Trip Characteristics and Stated Preference Findings

There were 87 completed surveys, which yielded 783 observed choices in the dataset. In all 783 choices, the three modes were available for respondents to choose from. Almost half (384 – 49%) of those surveyed stated that they would choose their private vehicle (instead of Uber). Following this mode was the P&R service (208 – 27%) as well as Uber (190 – 24%). The availabilities of these modes also play a significant role in choice for respondents. In terms of Uber availability, 14 respondents did not have Uber available to them, thereby eliminating Uber from their choice set.

It was interesting to note that even though people did not “enjoy” waiting for a parking bay at Florida Road, most people would still prefer to take their own vehicles.

Respondents were asked how much time they had spent waiting for a parking bay on their previous trip to Florida Road. This time spent ranged between 0 minutes to 20 minutes, however, more people were found to spend around 10 minutes waiting for a parking bay.

Most trips to Florida road were made on weekends as opposed to weekdays. It was found that 89% (77) of surveyed trips were made on weekends and 11% (10) on both weekends and weekdays.

The time spent on Florida Road varied, generally according to trip purpose. Those who spent a shorter time on Florida Road generally visited the fast food restaurants situated throughout. Time spent ranged from 10 mins to 8 hours. There was found to be an even distribution of survey respondents with regards to the time spent at Florida Road.

Around 26 % (23) stated that they spent around an hour on Florida Road, 23% (19) spent between 1 – 2 hours, 23 (19) % spent between 2-3 hours and 28% (26) spent over 3 hours at Florida Road. Around 77 respondents stated that they were at Florida Road for social purposes. Work purposes contributed to 14% of all trips.

Places visited were also surveyed to give an indication as to the actual trip purposes, as well as to inform where the potential P&R pick up/ drop – off zone could be. It was found that most of those surveyed (43%) 37 visited the restaurants Cubana and Capello, with is located further south on Florida Road. Another popular location was further up North, near the bar and restaurant House of Curries. Around 23 %(20) visited this place, and 12 % (10) visited two bars near House of Curries.

The survey results were then coded in preparation for use in the DCM.

5 DATA ANALYSIS – DISCRETE CHOICE MODELLING

In everyday life, we are constantly faced with choices. Some of these are made consciously, while some are on a subconscious level by comparing alternatives, and choosing an action (Hensher, Rose and Greene, 2005). Travel behaviour analysis is usually carried out on the disaggregate level, implying that models represent the choice behaviour of individual travellers. Discrete choice analysis refers to the methodology used to analyse and predict travel decisions.

The data analysis included a Discrete Choice Experiment (DCE) framework whereby users of Florida Road were faced with 9 hypothetical choice scenarios involving the three modes concerned – their car, the new Park and Ride (P&R) service, or Uber. Using the data collected, Discrete Choice Models (DCM's) were estimated, thereby allowing for the prediction of mode choice by aggregating individual choice probabilities. Utility theory was used to analyse the results, and provide meaning to parameter estimates.

The programme used to carry out the data analysis was R and RStudio. R is a free statistical computing package, used for statistical analysis, and contains the command line language. RStudio is the interface for R, and contains the written code. R runs the code and programme files. The files required to run the models were:

- ◆ A data file – usually in excel (CSV) format, consisting of the coded survey results
- ◆ A model file – contains all model details and tells R what routines to run
- ◆ Libraries – these include built in functions for DCM's, and Multinomial Logit (MNL) models in particular

The objectives of the data analysis portion are intimately linked to the research aims and objectives, and brings the study together. In this section, the following study objectives will be met:

- ◆ Determination of the effect of each mode's respective service attributes on mode choice
- ◆ Determination of the effect of user's current travel characteristics on the demand for the P&R i.e. time spent and trip purpose
- ◆ Determination of the effect of user's socio - demographic characteristics on the demand for the P&R service i.e. age, gender, employment status

- ◆ Determination of the factors that influence trade-off behaviour between cost and P&R service characteristics

These objectives were met by the building of the relevant DCM's and analysis of their respective parameter estimates.

5.1 Discrete Choice Experiment Method

Lancsar, Fiebig and Hole (2017) argues that the research methods adopted for DCE's are dependent on the research questions, study design as well as contextual constraints present. In this section, the approach to building DCM's is described, and in particular, model estimation and subsequent analysis.

Many steps were involved in generating the discrete choice data, as has been discussed in Chapter 4. The SC survey results were coded for use in the statistical modelling package R. Numerical variables such as travel cost, travel time variation etc were retained with original numerical values. Categorical variables such as security were dummy coded using a binary form. Each row in the data set represented a single observation. There were 87 qualifying surveys with 9 observations per respondent, yielding a total of 783 observations.

To create a DCM, a model form was required. There are three general families of models that are used widely in the transportation field today, namely the Logit model, Probit Model and General Extreme Value (GEV) Model (Wittink, 2011). These models, along with their respective advantages and disadvantages were researched in the literature review so that the most relevant model for this research could be selected. The main differences between these models lies in the distribution and density function of the error term. Train (2009) suggests that researchers should choose a model whose distribution best meets the requirements of the research being conducted.

The Multinomial Logit Model (MNL) was chosen to be used in this research method. Louviere *et al* (2000) gives some good advantages of using MNL models. MNL models are easy to estimate, and provide unique parameter estimates. Logit models also have a closed - form specification of the integral for the choice probability, making it easier to estimate. There is also a vast array of software packages available to estimate logit models. There are however, some constraints that are required to be satisfied with use of MNL models, which will be discussed in the sections to follow. MNL models

are commonly used in transportation to predict and analyse travel behaviour (Wittink, 2011)

At this stage, it was important to understand the theory underlying DCM's, and their link to the concepts of choice theory and random utility models. The basis of DCM's is utility theory. Literature suggests that Thurstone (1927) originally developed the theory, following Marschak (1960) who formalised the approach (Hensher, Rose and Greene, 2005). The most simplistic definition of utility was found in a paper by Koppelman and Bhat (2006) who described utility as an indicator of value to an individual. For the case of MNLs, the basic utility function can be given by:

$$U_{int} = V_{int} + \varepsilon_{int} \quad (1)$$

Which can be expanded upon:

$$U_{int} = \beta_1 X_{int} + \beta_2 X_{int} + \beta_3 X_{int} + \dots + \beta_k X_{ink} + \varepsilon_{int} \quad (3)$$

Where U_{int} represents the utility of respondent n in choice situation t for the i alternative. V_{PNRnt} represents the deterministic part of the utility (variables that have been observed by the researcher) while ε_{PNRnt} represents the unobserved variables. The deterministic part of the utility function can be broken down further into the $\beta_1 X_{int}$ etc which captures respondent preferences for the observed variables.

Disaggregate DCM's were used in this study. The analysis disaggregates to the individual as the basic unit of observation. The individual choice data is then aggregated, yielding a single set of parameters describing mode choice behaviour in users of Florida Road, for the observed variables. Nine variables were added to the model, as shown in Table 13. These variables encompass three aspects; the SC data, the RP data and the finally, the socio – demographic data collected.

Models were estimated (i.e. the β parameters were estimated), using the survey data, MNL model framework and utility functional form required for the 3 respective models. Model estimation searches for β values that maximise the log likelihood function regarding the mode that was chosen (ChoiceMetrics, 2012). DCM's do this by a process called Maximum Likelihood Estimation (MLE).

Models were built up systematically, with a new model being constructed with the introduction of a new variable. To meet the intended aims and objectives of this study, the following variables were included in model estimation:

Table 13 : Variables Included in Model Estimation

	SC variables	RP Variables	Socio – economic variables
Variables included in DCM's	Travel cost	Trip Purpose	Age
	Travel time variation	Time spent at Florida Road	Employment Status
	Security		Gender
	Headway		

The variables were categorised according to type of data, to present a logical sequence of models, and results. There are traveller and trip related variables (that influence the travellers decision of mode choice) as well as mode related variables, which describe the alternatives that are presented to respondents. Models were specified in the following manner. The Stated Choice (SC) variables were initially included, followed by the RP variables, and finally, the socio – demographic variables.

Once the models were developed and parameters estimated, statistical tests were carried out to determine the statistical efficiency of the models built. The tests used in this study were the Log – likelihood (LL) ratio test and well as t – ratio significance tests. These were explained in Section 2.4.4.

Finally, parameter estimates were used to make general assumptions about the sample population behaviour. The parameter estimates were then used in further analysis predict choice probabilities as well as to analyse trade-off behaviour in survey respondents. Choice probabilities were calculated using the formula shown below;

$$P_{int} = \frac{\exp(V_{int})}{\sum_{j=1}^j \exp(V_{jnt})} \quad (15)$$

Where V_{int} refers to the deterministic portion of the utility function. Scenarios were developed to predict the changes in choice probabilities brought upon by the change in specified attributes (and in particular, attributes regarding the P&R service).

Attributes such as P&R travel cost and headway were varied. The results of these scenarios as well as model estimation are also discussed.

The above method of discrete choice analysis was used to analyse and predict the travel behaviour response of individuals who visit Florida Road, to the introduction of a P&R system for the area.

5.2 Model Specification

Mode choice decisions play an important role in transportation planning processes, and has a direct impact on policy making decisions. Mode choice models are intimately linked with human decision - making, and it is important to consider this when choosing a model (Minal, 2014). DCE's try to simulate choices respondents would make, in everyday life.

There are three major aspects that will be discussed under model specification. Firstly, a model must be chosen for estimation. Then, the approach to model building, and the process of including variables to the models will be described. Lastly, statistical tests to improve model specification will be discussed.

There are various DCM's used in transportation for the estimation and prediction of proposed demand. Models included are Logit models, Probit models etc. Different choice models are derived under different specifications of the density and unobserved factors, and these have been discussed in the literature review (Kenneth E. Train, 2009). The selected analytical method for choice data is primarily only one of the logit models, namely the multinomial logit model (MNL). The relevance of the MNL model to this study, as well as its properties will be discussed further.

5.2.1 The Multinomial Logit Model

The MNL model was developed from the binary logit model, and considers cases in which there are more than two alternatives. The properties and assumptions underlying the MNL model have been discussed in the literature review. MNL models are simple to use, and due to their closed - form probabilities, do not require simulation estimation.

It is important that the 3 major assumptions underlying MNL's are maintained. The first assumption is that the error (or random) components of the utilities are identically and independently distributed, with a Type I extreme value (Gumbel)

distribution. This implies that there are no common unobserved factors that affect the utilities of alternatives. The second assumption is that error components are independently distributed across alternatives. This means that there is no correlation across alternatives, and homogeneity is maintained. The last assumption is that the error components are identically distributed across observations/ alternatives i.e. the amount of “ noise” is the same across alternatives (Koppelman and Bhat, 2006). These assumptions need to be maintained in model estimation, as well as the resulting discussion of results. In the development of the MNL models, these assumptions were maintained. The general utility function required has been specified previously.

$$U_{int} = \beta_1 X_{int} + \beta_2 X_{int} + \beta_3 X_{int} + \dots + \beta_k X_{ink} + \varepsilon_{int} \quad (3)$$

For each alternative, the utility function was specified. As stated, the utility functions were built up systematically, with a sequential introduction of variables to the model. All β parameters were created mode specific, meaning that taste preferences were allowed to vary per mode. β parameters are used as weights, that establish the relative contribution of each attribute to the observed sources of utility.(Hensher, Rose and Greene, 2005). An example of the case specific utility function (using P&R and SC attributes only as an example):

$$V_{P\&R} = ASC_{P\&R} + \beta_{P\&R(TC)} \text{Travel cost}_{P\&R} + \beta_{P\&R(TTV)} \text{Travel time variation}_{P\&R} + \beta_{P\&R(SEC)} \text{Security}_{P\&R} + \beta_{P\&R(HW)} \text{Headway}_{P\&R} + \varepsilon_{int} \quad (16)$$

Some of the potential sources of error relevant to this study include socio – demographic aspects not included in this research such as income, education level, number of cars per household, number of persons per household etc. Other potential aspects include in vehicle travel time, shuttle bus levels of comfort and service characteristics etc. The probabilities of choosing each mode is then calculated by using the deterministic portion of the utility function, in the equation shown below (again using P&R as an example):

$$P_{P\&R nt} = \frac{\exp(V_{P\&R nt})}{\sum_{j=1}^j \exp(V_{P\&R nt})} \quad (17)$$

The MNL model uses Equation 3, the sample data collected, to calculate the utilities of each mode under the given choice scenarios, using the process of MLE to estimate β parameters. Then, using Equation 17, the choice probabilities were calculated.

5.2.2 Model Development

Manski (2008) cited via (Johnston et al., 2017) proposed a bottom up approach to model development, where the simplest models are estimated first, followed by the more complicated models. This was the approach followed in this research. The models were estimated in the sequence shown below:

Table 14: Model Development

	SC VARIABLES					RP VARIABLES		SOCIO - DEMOGRAPHIC VARIABLES		
	ASC	Travel cost	Travel time variation	Headway	Security	Time spent at Florida road	Trip purpose	Gender	Employment	Age
MODEL 1	X									
MODEL 2	X	X								
MODEL 3	X	X	X							
MODEL 4	X	X	X	X						
MODEL 5	X	X	X	X	X					
MODEL 6	X	X	X	X	X	X				
MODEL 7	X	X	X	X	X	X	X			
MODEL 8	X	X	X	X	X	X	X	X		
MODEL 9	X	X	X	X	X	X	X	X	X	
MODEL 10	X	X	X	X	X	X	X	X	X	X

Each variable was added sequentially to each model, to produce a total of 10 models. Similar variables were then grouped together. The SC variables were initially included, followed by the RP variables, and finally, the socio – demographic variables.

5.2.3 Base Model Utility Specification

The base model only considered the Alternative Specific Constant (ASC). This is considered the simplest specification of the MNL model. Generally, the ASC is added to utility equations to represent the average effect of all factors that influence choice, but have not been included in the utility function (Koppelman and Bhat, 2006). In the base model, it was assumed that the mode specific ASC's represent the average effects off all factors affecting the mode choice decision, as no variables have been specified in the utility function yet. The base model utility specification is shown below.

$$V_{\text{car}} = \text{ASC}_{\text{car}} \quad (18)$$

$$V_{\text{P\&R}} = \text{ASC}_{\text{P\&R}} \quad (19)$$

$$V_{\text{uber}} = \text{ASC}_{\text{uber}} \quad (20)$$

As only differences in utilities matter, the same applies to the ASC's. It is generally common practice to set one of the mode ASC to 0, in order to normalise the scale parameter (Ben-Akiva and Bierlaire, 2003).

5.2.4 SC Model Utility Specification

The utility function for the SC model was specified, and is shown below. In this model, the four SC attributes travel cost, travel time variation, security and P&R service headway were added to the model. This was carried out to test the effect of using only SC attributes in model estimation. Travel cost and travel time variation were added as mode specific linear variables. Mode specific variables allow for there to be taste differences with respondents, depending on mode. P&R service headway was also added as a linear variable, and dummy coded. The security variables were mode specific, and were dummy coded linear variables. The ASC's constants added to the base model were retained. The utility functions for each alternative are shown below:

$$V_{\text{car}} = ASC_{\text{car}} + \beta_{\text{car}(TC)} \text{Travel cost}_{\text{car}} + \beta_{\text{car}(TTV)} \text{Travel time variation}_{\text{car}} + \beta_{\text{car}(SEC)} \text{Security}_{\text{car}} \quad (21)$$

$$V_{\text{P\&R}} = ASC_{\text{P\&R}} + \beta_{\text{P\&R}(TC)} \text{Travel cost}_{\text{P\&R}} + \beta_{\text{P\&R}(TTV)} \text{Travel time variation}_{\text{P\&R}} + \beta_{\text{P\&R}(SEC)} \text{Security}_{\text{P\&R}} + \beta_{\text{P\&R}(HW)} \text{Headway}_{\text{P\&R}} \quad (22)$$

$$V_{\text{uber}} = ASC_{\text{uber}} + \beta_{\text{uber}(TC)} \text{Travel cost}_{\text{uber}} + \beta_{\text{uber}(TTV)} \text{Travel time variation}_{\text{uber}} \quad (23)$$

The β parameters were then estimated by the process of MLE.

The availabilities of travel modes are important for the estimation of DCM's. In each model, the car option was considered available to all respondents, as one of the qualifying questions in the survey was whether respondents had used their private vehicle (driver or passenger) for their trip to Florida Road. In the same sense, the P&R service was considered available to all respondents surveyed, as respondents had travelled by car. In terms of Uber availability, this issue was addressed by asking respondents in the survey whether they possessed the Uber application or not. This was considered a good indication of Uber availability, and included in model estimation.

5.2.5 RP Model

This model built upon the utility equations formulated in the previously developed SP model. In this model, the previous variables and utility functions were used and trip purpose and time spent at Florida Road were used as explanatory variables of the travel time variation and ASC mode specific variables respectively. Time spent on Florida Road as well as trip purpose (regarding their current trip) was added to the initial SC model. The trip purposes added were work and social. Time spent on Florida Road was added as an explanatory variable to the ASC for each mode, while trip purpose was used as an explanatory variable for travel time variation. It was hypothesised that respondents who spent a shorter time at Florida Road were less likely to use the P&R service, compared to those who spend a longer time there. Time spent on Florida Road referred to how much time respondents spent at their

destination/s on Florida road. Trip purpose may significantly affect mode choice behaviour as for example, a work trip may have a penalty for late arrival, while social trips have no such penalty. The equations for the shift in travel time variation for trip purpose and shift in ASC for time spent on Florida Road are shown below. These equations substituted the original travel time variation and ASC equations, to add more explanatory variables to the model.

Shift in Travel Time Variation for Trip Purpose:

$$\begin{aligned} & \beta_{car(TTV)} \text{Travel time variation}_{car} \\ &= \beta_{car(TTV)} \text{Travel time variation}_{car} + \beta_{car(TTV)work} \text{Shift for work trips}_{car} \quad (24) \\ &+ \beta_{car(TTV)social} \text{Shift for social trips}_{car} \end{aligned}$$

$$\begin{aligned} & \beta_{P\&R(TTV)} \text{Travel time variation}_{P\&R} \\ &= \beta_{P\&R(TTV)} \text{Travel time variation}_{P\&R} \\ &+ \beta_{P\&R(TTV)work} \text{Shift for work trips}_{P\&R} \quad (25) \\ &+ \beta_{P\&R(TTV)social} \text{Shift for social trips}_{P\&R} \end{aligned}$$

$$\begin{aligned} & \beta_{uber(TTV)} \text{Travel time variation}_{uber} \\ &= \beta_{uber(TTV)} \text{Travel time variation}_{car} \\ &+ \beta_{uber(TTV)work} \text{Shift for work trips}_{uber} \quad (26) \\ &+ \beta_{uber(TTV)social} \text{Shift for social trips}_{uber} \end{aligned}$$

Shift in ASC for Time Spent on Florida Road:

$$ASC_{car} = ASC_{car} + \beta_{car(ASC)time\ spent} \text{Shift for time spent}_{car} \quad (27)$$

$$ASC_{P\&R} = ASC_{P\&R} + \beta_{P\&R(ASC)time\ spent} \text{Shift for time spent}_{P\&R} \quad (28)$$

The ASC for Uber was not included as this variable was normalised to 0. Therefore, the final utility equations for this model are:

$$\begin{aligned}
 V_{\text{car}} = & ASC_{\text{car}} + \beta_{\text{car}(ASC)time\ spent} \text{ Shift for time spent}_{\text{car}} + \beta_{\text{car}(TC)} \text{ Travel cost}_{\text{car}} & (29) \\
 & + \beta_{\text{car}(TTV)} \text{ Travel time variation}_{\text{car}} + \beta_{\text{car}(TTV)work} \text{ Shift for work trips}_{\text{car}} \\
 & + \beta_{\text{car}(TTV)social} \text{ Shift for social trips}_{\text{car}} + \beta_{\text{car}(SEC)} \text{ Security}_{\text{car}}
 \end{aligned}$$

$$\begin{aligned}
 V_{\text{P\&R}} = & ASC_{\text{P\&R}} + \beta_{\text{P\&R}(ASC)time\ spent} \text{ Shift for time spent}_{\text{P\&R}} + \beta_{\text{P\&R}(TC)} \text{ Travel cost}_{\text{P\&R}} & (30) \\
 & + \beta_{\text{P\&R}(TTV)} \text{ Travel time variation}_{\text{P\&R}} + \beta_{\text{P\&R}(TTV)work} \text{ Shift for work trips}_{\text{P\&R}} \\
 & + \beta_{\text{P\&R}(TTV)social} \text{ Shift for social trips}_{\text{P\&R}} + \beta_{\text{P\&R}(SEC)} \text{ Security}_{\text{P\&R}} \\
 & + \beta_{\text{P\&R}(HW)} \text{ Headway}_{\text{P\&R}}
 \end{aligned}$$

$$\begin{aligned}
 V_{\text{uber}} = & ASC_{\text{uber}} + \beta_{\text{uber}(TC)} \text{ Travel cost}_{\text{uber}} + \beta_{\text{uber}(TTV)} \text{ Travel time variation}_{\text{car}} & (31) \\
 & + \beta_{\text{uber}(TTV)work} \text{ Shift for work trips}_{\text{uber}} \\
 & + \beta_{\text{uber}(TTV)social} \text{ Shift for social trips}_{\text{uber}}
 \end{aligned}$$

5.2.6 Final Model

This model encompassed the previous utility functions, and included the socio – demographic variables gender, employment status and age. In R, these variables were not added as part of the utility function, but rather as influencing certain existing attributes.

Socio – demographic variables added to DCM’s help in capturing heterogeneity in models. Johnston et al (2017) suggests that SC data should allow for observed and unobserved preference heterogeneity, and the extent to which heterogeneity is used, should inform and support decision - making. Heterogeneity is a consideration both in the experimental design and model estimation stages, as it plays a critical role in the estimation of parameter estimates, as well as the interpretation of results.

Gender was added to the model as a “shift” to the ASC for each mode. It was thought that gender would influence the overall preference a respondent has towards a mode. It was hypothesised that females were less inclined to use the P&R service than their

male counterparts. This could be due to many reasons, the most important being safety and security. Females could feel less safe travelling by P&R, especially if travelling alone or travelling at night. A similar concept can be applied to Uber as well.

Employment was added to the model as a “shift” to the travel cost variable for each mode. Cost and employment status in general have been linked. It was hypothesised that in general, those that are unemployed or students are more likely to prefer Uber use, than modes that involve use of their vehicle. Those who are employed would have a general preference for vehicle use.

Lastly, age was added to the model. It was hypothesised that those younger respondents are more likely to prefer Uber or P&R use, while older respondents are more likely to prefer car use. The ages of those surveyed ranged from 18 – 49 years old. The equations for the shift in ASC for gender, the shift in travel cost for employment as well as the addition to utility function for age is shown below.

Shift in ASC for Gender:

$$\begin{aligned}
 ASC_{car} = & ASC_{car} + \beta_{car(ASC)time\ spent} \text{Shift for time spent}_{car} \\
 & + \beta_{car(ASC)female} \text{Shift for female}_{car}
 \end{aligned}
 \tag{32}$$

$$\begin{aligned}
 ASC_{P\&R} = & ASC_{P\&R} + \beta_{P\&R(ASC)time\ spent} \text{Shift for time spent}_{P\&R} \\
 & + \beta_{P\&R(ASC)female} \text{Shift for female}_{P\&R}
 \end{aligned}
 \tag{33}$$

Shift in Travel Cost for Employment:

$$\begin{aligned}
 & \beta_{car(TC)} \text{Travel cost}_{car} \\
 = & \beta_{car(TC)} \text{Travel cost}_{car} + \beta_{car(TC)employed} \text{Travel cost}_{car} \\
 & + \beta_{car(TC)unemployed} \text{Travel cost}_{car} + \beta_{car(TC)student} \text{Travel cost}_{car} \\
 & + \beta_{car(TC)self-employed} \text{Travel cost}_{car}
 \end{aligned}
 \tag{34}$$

$$\begin{aligned}
& \beta_{P\&R(TC)} \text{Travel cost}_{P\&R} & (35) \\
& = \beta_{P\&R(TC)} \text{Travel cost}_{P\&R} + \beta_{P\&R(TC)employed} \text{Travel cost}_{P\&R} \\
& + \beta_{P\&R(TC)unemployed} \text{Travel cost}_{P\&R} \\
& + \beta_{P\&R(TC)student} \text{Travel cost}_{P\&R} \\
& + \beta_{P\&R(TC)self-employed} \text{Travel cost}_{P\&R}
\end{aligned}$$

$$\begin{aligned}
& \beta_{uber(TC)} \text{Travel cost}_{uber} \\
& = \beta_{uber(TC)} \text{Travel cost}_{uber} + \beta_{Uber(TC)employed} \text{Travel cost}_{uber} & (36) \\
& + \beta_{uber(TC)unemployed} \text{Travel cost}_{uber} \\
& + \beta_{uber(TC)student} \text{Travel cost}_{uber} \\
& + \beta_{uber(TC)self-employed} \text{Travel cost}_{uber}
\end{aligned}$$

Addition to Utility Function for Age:

$$\begin{aligned}
V_{car} = & ASC_{car} + \beta_{car(TC)} \text{Travel cost}_{car} + \beta_{car(TTV)} \text{Travel time variation}_{car} \\
& + \beta_{car(SEC)} \text{Security}_{car} + \beta_{car(age)} \text{Age}_{car} & (37)
\end{aligned}$$

$$\begin{aligned}
V_{P\&R} = & ASC_{P\&R} + \beta_{PNR(TC)} \text{Travel cost}_{P\&R} + \beta_{PNR(TTV)} \text{Travel time variation}_{P\&R} \\
& + \beta_{PNR(SEC)} \text{Security}_{P\&R} + \beta_{PNR(HW)} \text{Headway}_{P\&R} + \beta_{P\&R(age)} \text{Age}_{P\&R} & (38)
\end{aligned}$$

$$\begin{aligned}
V_{uber} = & ASC_{uber} + \beta_{uber(TC)} \text{Travel cost}_{uber} + \beta_{uber(TTV)} \text{Travel time variation}_{uber} \\
& + \beta_{uber(age)} \text{Age}_{uber} & (39)
\end{aligned}$$

Therefore, the final utility equations for this model were:

$$\begin{aligned}
V_{\text{car}} = & ASC_{\text{car}} + \beta_{\text{car}(ASC)\text{time spent}} \text{ Shift for time spent}_{\text{car}} \\
& + \beta_{\text{car}(ASC)\text{female}} \text{ Shift for female}_{\text{car}} + \beta_{\text{car}(TC)} \text{ Travel cost}_{\text{car}} \\
& + \beta_{\text{car}(TC)\text{employed}} \text{ Travel cost}_{\text{car}} + \beta_{\text{car}(TC)\text{unemployed}} \text{ Travel cost}_{\text{car}} \\
& + \beta_{\text{car}(TC)\text{student}} \text{ Travel cost}_{\text{car}} + \beta_{\text{car}(TC)\text{self-employed}} \text{ Travel cost}_{\text{car}} \quad (40) \\
& + \beta_{\text{car}(TTV)} \text{ Travel time variation}_{\text{car}} + \beta_{\text{car}(TTV)\text{work}} \text{ Shift for work trips}_{\text{car}} \\
& + \beta_{\text{car}(TTV)\text{social}} \text{ Shift for social trips}_{\text{car}} + \beta_{\text{car}(SEC)} \text{ Security}_{\text{car}} \\
& + \beta_{\text{car}(age)} \text{ Age}_{\text{car}}
\end{aligned}$$

$$\begin{aligned}
V_{\text{P\&R}} = & ASC_{\text{P\&R}} + \beta_{\text{P\&R}(ASC)\text{time spent}} \text{ Shift for time spent}_{\text{P\&R}} \\
& + \beta_{\text{P\&R}(ASC)\text{female}} \text{ Shift for female}_{\text{P\&R}} + \beta_{\text{P\&R}(TC)} \text{ Travel cost}_{\text{P\&R}} \\
& + \beta_{\text{P\&R}(TC)\text{employed}} \text{ Travel cost}_{\text{P\&R}} \\
& + \beta_{\text{P\&R}(TC)\text{unemployed}} \text{ Travel cost}_{\text{P\&R}} + \beta_{\text{P\&R}(TC)\text{student}} \text{ Travel cost}_{\text{P\&R}} \\
& + \beta_{\text{P\&R}(TC)\text{self-employed}} \text{ Travel cost}_{\text{P\&R}} \\
& + \beta_{\text{P\&R}(TTV)} \text{ Travel time variation}_{\text{P\&R}} + \beta_{\text{P\&R}(TTV)} \text{ Travel time variation}_{\text{P\&R}} \quad (41) \\
& + \beta_{\text{P\&R}(TTV)\text{work}} \text{ Shift for work trips}_{\text{P\&R}} \\
& + \beta_{\text{P\&R}(TTV)\text{social}} \text{ Shift for social trips}_{\text{P\&R}} + \beta_{\text{P\&R}(SEC)} \text{ Security}_{\text{P\&R}} \\
& + \beta_{\text{P\&R}(HW)} \text{ Headway}_{\text{P\&R}} + \beta_{\text{P\&R}(age)} \text{ Age}_{\text{P\&R}}
\end{aligned}$$

$$\begin{aligned}
V_{\text{uber}} = & ASC_{\text{uber}} + \beta_{\text{uber}(TC)} \text{ Travel cost}_{\text{uber}} + \beta_{\text{uber}(TC)\text{employed}} \text{ Travel cost}_{\text{uber}} \\
& + \beta_{\text{uber}(TC)\text{unemployed}} \text{ Travel cost}_{\text{uber}} \\
& + \beta_{\text{uber}(TC)\text{student}} \text{ Travel cost}_{\text{uber}} \\
& + \beta_{\text{uber}(TC)\text{self-employed}} \text{ Travel cost}_{\text{uber}} \\
& + \beta_{\text{uber}(TTV)} \text{ Travel time variation}_{\text{car}} \\
& + \beta_{\text{uber}(TTV)\text{work}} \text{ Shift for work trips}_{\text{uber}} \quad (42) \\
& + \beta_{\text{uber}(TTV)\text{social}} \text{ Shift for social trips}_{\text{uber}} + \beta_{\text{uber}(age)} \text{ Age}_{\text{uber}}
\end{aligned}$$

5.3 Model Estimation and Results

Maximum likelihood estimation is the process whereby parameters are estimated in MNL models. This process involves the maximisation of Log Likelihood in relation to the β values, to find the maximum Log Likelihood estimate of β . The maximisation process requires the user to provide initial estimates of the parameter values. At MLE, we have:

$$\frac{\partial LL(\beta)}{\partial \beta} = 0 \quad (10)$$

The software package R then searches for improvements in the log-likelihood iteratively by changing the values of the parameters using this optimisation algorithm. In the case of the MNL model, the choice of starting values typically does not matter in practice, as the MNL log-likelihood function has a single maximum.

The model estimation results developed will be presented hereafter.

5.3.1 Base Case Model

To estimate the effect of including the P&R service as a potential alternative mode of transport to Florida Road, it was useful to create a base case scenario for comparison. The base case usually represents the status quo, or the “business as usual” scenario. However, the SC survey created presented respondents with only the hypothetical P&R scenario. The closest model that could represent a base case scenario was a model with the ASC only, and P&R excluded. The parameter estimates for the base model are shown.

Table 15 : Base Case Model Results

	BASE CASE MODEL	
	ESTIMATE	ROB T RATIO
ASC - car	0.4037	3.04
ASC - Uber	0	N/A

This model unfortunately cannot provide enough information about the status quo. It does not consider any variables, nor can it explain current behaviour accurately. This model will however, be used as a basis to measure change.

5.3.2 The Effect of SC Attributes

As discussed, in this model travel cost, travel time variation, security and headway were considered. A MNL model with 11 parameters was estimated. The Uber ASC was normalised to 0. In the results discussion to follow, all significant parameter estimates with their t - ratio values will be shown. Insignificant parameters are not shown in this section, but the full table of estimated parameters, can be found in the Appendix 8.7.

Table 15 : SC Model Results

Variables	SC MODEL	
	Estimate	Rob t ratio
ASC - car	0.9177	2.74
ASC - Uber	0	N/A
Travel cost - car	-0.0392	-6.25
Travel cost - P&R	-0.0378	-5.98
Travel cost - Uber	-0.0389	-5.98
Travel time variation - car	-0.0406	-3.09
Service Headway - P&R	-0.3153	-1.94
Security - P&R	0.3951	2.3

The ASC represents the impact of all variables that influence mode choice, that are not observed, or have not been included in the model. The car ASC was found to be positive and significant, indicating that respondents have an inherent preference for using their vehicle, as predicted. This preference is also higher for the car alternative than Uber. The ASC for P&R was found to be insignificant and therefore excluded from the model.

All coefficients have the expected sign. Travel cost for all modes had a negative utility, as predicted, as this represents a characteristic respondent prefer less off. These three variables are also significant for the 5% interval (i.e. the t – ratio is greater than 1.96). It appears that cost is perceived with a similar dislike for all modes. The values

of the coefficients display no inherent preference (or rather dislike) for the cost of one mode over another, as the β values are generally similar.

Travel time variation by car was the only significant travel time variation variable in this model. Travel time variation by car had a negative utility, implying that respondents considered this variable a disutility. This was as expected as this variable represented the time respondents would spend, looking for a parking bay on Florida Road. This variable was also found to be significant, for the 5% interval. Travel time variation by P&R and Uber had a positive utility, implying that respondents derived some sort of level of satisfaction from these variables. This makes sense, as these variables represented the time savings respondents experienced, by not having to park their car on Florida Road. Both variables were found to be insignificant, however. A reason for this could be that respondents placed a greater emphasis or importance on a loss, as opposed to a gain, in terms of utility.

The negative signs of the travel time and travel cost coefficients imply that the utility of car and the probability that it will be chosen decreases as the travel time or travel cost of car increases.

The P&R service headway was found to be a disutility, and significant. This implies that respondents prefer smaller headways than larger ones, i.e. a shuttle bus pick up every 10 minutes (as opposed to every 20 minutes, for example) and have a disutility towards headway which is intuitively correct. This variable is not significant within the 5% interval (it just slightly lower than 1.96) but it is significant with the 10% interval (where the t – ratio is greater than 1.65).

Security for both P&R and car was found to be positive, implying that respondents place value on these variables and these variables add to the explanatory power of the model. However, only the security of the P&R facility coefficient was significant. A possible reason for this is that respondents who frequent Florida Road perhaps feel safe regardless of where they park, and security is not an issue for them. Another potential reason is that respondents could not differentiate clearly between the two levels proposed in the survey for car security (i.e. parking on Florida Main Road, or on the side roads).

Cost is clearly an important attribute in this model, as all 3 variables were found to be significant. It appears also that respondents perceive costs with a similar dislike, regardless of mode considered. Travel time variation by car was found to be

significant, indicating that respondents have an inherent dislike when it comes to waiting for a parking bay on Florida Road.

5.3.3 The Effect of RP Attributes

This model estimated the effect of adding the RP attributes, time spent and trip purpose, to the previously estimated SC model. A MNL model with 19 parameters was estimated. The Uber ASC was normalised to 0. The significant parameter results are shown below.

Table 16 : RP Model Results

	RP MODEL	
Variables	Estimate	Rob t ratio
ASC - car	0.8852	1.87
ASC - Uber	0	N/A
Travel cost - car	-0.0398	-6.3
Travel cost - P&R	-0.0382	-6.02
Travel cost - Uber	-0.0391	-5.9
Service Headway - P&R	-0.3122	-1.86
Security - P&R	0.4115	2.38
Shift in travel time variation for work trip purpose - P&R	0.1148	1.96

The ASC for car was found to be positive and significant, as in the previous model. This would imply that the time respondents spend on Florida Road has no bearing on their mode choice.

As with the previous model, travel cost remains negative and significant. P&R security and headway were also again found to be significant. It should be noted however, that the travel time variation for car variable that was previously significant, was found to not be significant in this mode, and was therefore excluded.

The β parameters for those who visited Florida Road for work purposes was not found to be significant. However, the shift in travel time variation for trip purpose for P&R was found to be positive and significant. This would imply that respondents preferred

the P&R system for work trips. This make sense, as the travel time savings by P&R for work trips could be fully realised. Time spent was found to not be significant in this model.

5.3.4 The Effect of Socio - Demographic Attributes

This model estimated the effect of adding employment status, gender and age to the previously estimated RP model. A MNL model with 36 parameters was estimated. The Uber ASC was normalised to 0.

Table 17 : Final Model Results

	FINAL MODEL	
	ESTIMATE	ROB T RATIO
Travel cost - car	-0.0409	-6.24
Travel cost - P&R	-0.039	-6.02
Travel cost - Uber	-0.0399	-5.87
Travel time variation - P&R	-0.1197	-1.7
Service Headway - P&R	-0.2927	-1.73
Security - P&R	0.4199	2.39
Shift in travel time variation for work trip purpose - P&R	0.1368	2.32
Shift in travel time variation for social trip purpose - P&R	0.0928	1.66
Shift in travel cost for those who are students - car	-0.0893	-3.98
Shift in travel cost for those who are unemployed - car	-0.1086	-3.03

Respondents appear to still have a general dislike for the travel cost (by all modes), and this dislike is of a similar magnitude for all modes.

Travel time variation for the P&R service was found to be negative and significant. This was a bit counter – intuitive as it was expected that respondents would have a positive utility towards travel time savings gained, from not spending time finding a parking bay on Florida Road. One possible reason for this is that perhaps respondents do not actually see the time savings being relevant, as this time saved may be offset by the time taken to park at the P&R facility, wait for a shuttle bus to arrive etc. Another possible reason could be that respondents did not properly

understand the meaning of the travel time variation attribute, to give accurate results.

It is interesting to note that RP variables that were previously insignificant are now significant, with the introduction of socio – demographic variables.

P&R headway was again found to be negative and significant, suggesting that respondents have a general preference for shorter headways.

Gender and age were found to be insignificant in this model. A potential reason for this could be that there was not sufficient data/ observations for the model to make accurate inferences on mode choice regarding these variables or that these variables are indeed insignificant to this study.

In terms of employment, employment status regarding car usage was found to be significant, particularly for those who were students and those who were unemployed. Students and those who were unemployed had more of a dislike towards the travel cost by car, than those who were employed and those who were self-employed. This dislike, was slighter stronger for students, than those who were unemployed.

With the insignificant variables removed, the final utility equations for the three modes are shown below:

$$V_{\text{car}} = ASC_{\text{car}} + \beta_{\text{car}(TC)} \text{Travel cost}_{\text{car}} + \beta_{\text{car}(TC)unemployed} \text{Travel cost}_{\text{car}} + \beta_{\text{car}(TC)student} \text{Travel cost}_{\text{car}} \quad (43)$$

$$\begin{aligned}
V_{P\&R} = & ASC_{P\&R} + \beta_{P\&R(ASC)time\ spent} \text{ Shift for time spent}_{P\&R} \\
& + \beta_{P\&R(ASC)female} \text{ Shift for female}_{P\&R} + \beta_{P\&R(TC)} \text{ Travel cost}_{P\&R} \\
& + \beta_{P\&R(TC)employed} \text{ Travel cost}_{P\&R} \\
& + \beta_{P\&R(TC)unemployed} \text{ Travel cost}_{P\&R} + \beta_{P\&R(TC)student} \text{ Travel cost}_{P\&R} \\
& + \beta_{P\&R(TC)self-employed} \text{ Travel cost}_{P\&R} \\
& + \beta_{PNR(TTV)} \text{ Travel time variation}_{P\&R} \beta_{P\&R(TTV)} \text{ Travel time variation}_{P\&R} \quad (44) \\
& + \beta_{P\&R(TTV)work} \text{ Shift for work trips}_{P\&R} \\
& + \beta_{P\&R(TTV)social} \text{ Shift for social trips}_{P\&R} + \beta_{PNR(SEC)} \text{ Security}_{P\&R} \\
& + \beta_{PNR(HW)} \text{ Headway}_{P\&R}
\end{aligned}$$

$$\begin{aligned}
V_{uber} = & ASC_{uber} + \beta_{uber(TC)} \text{ Travel cost}_{uber} + \beta_{Uber(TC)employed} \text{ Travel cost}_{uber} \quad (45) \\
& + \beta_{uber(TC)unemployed} \text{ Travel cost}_{uber} \\
& + \beta_{uber(TC)student} \text{ Travel cost}_{uber} \\
& + \beta_{uber(TC)self-employed} \text{ Travel cost}_{uber}
\end{aligned}$$

These final equations will be used in further analysis.

5.3.5 Log Likelihood

The LL values for the three models were compared. A total of 36 parameters were estimated in the final model. There appeared to be a substantial jump in LL of slightly over 100 units, from the starting LL value (-808.7194), to the LL value for the final model (-705.1338). This would imply that the models estimated, consecutively got better in explaining mode choice behaviour of respondents, upon the introduction of more explanatory variables. The table below shows the LL progression of the three models estimated.

Table 18 : Log- Likelihood Estimates for Models

	Log likelihood	No of parameters	P value	LL ratio test ρ^2 value	Accept/ reject
Starting LL value	-808.7194				
SP Model	-731.0593	11			
RP Model	-722.3527	19	0.0261	17.41	Reject Previous Model (0.0261 < 0.05)
Final Model	-705.1338	36	0.0074	34.44	Reject Previous Model (0.0074 < 0.05)

P – values are used to determine the relative significance of the test. The p – value can be described as the probability of getting the observed value of the test statistic, or a value with even greater evidence against H_0 , if the null hypothesis is actually true. The smaller the p – value, the greater the evidence against the null hypothesis. With a given significance level α , then:

$$\text{Reject } H_0 \text{ if the } p \text{ – value } \leq \alpha$$

For the test, you need a p-value less than 0.05 to accept the model when using a confidence level of 95 %.

The p – value in both models were less than 0.05 (which relates to a confidence interval of 95%), rejecting the null hypothesis, and accepting the former model. Ideally, p – values should be 0, or very close to 0. In each case, the new model estimated was superior to the previous.

5.4 Scenarios

For the analysis presented below, only variables found to be significant in the final MNL model were used. Particular attention was given to the significant SC variables. This section explores the impact of cost on the choice probabilities of the alternatives considered, as well as delves into the cost implications on users, for improved P&R service quality.

5.4.1 The Impact of P&R Cost, Security and Headway on Choice Probabilities

This section explores the impact of mode choice probabilities on the P&R service quality aspects – security and headway. Five scenarios are presented, in which security and headway times are varied, and the choice probabilities were recorded. In this first set of scenarios, the cost of all modes is kept constant, and the P&R service is assumed to be free. The following scenario includes a cost (R10) on the P&R shuttle trip.

Table 19 : Choice Probabilities for Scenarios when P&R Service is Free

SCENARIO: P&R service is free and ...	No security guard at parking facility	Presence of security guard at parking facility	Presence of security guard at parking facility and a headway of 5 minutes	Presence of security guard at parking facility and a headway of 10 minutes	Presence of security guard at parking facility and a headway of 20 minutes
CAR	0.32	0.27	0.29	0.30	0.34
P&R	0.35	0.45	0.41	0.38	0.31
UBER	0.33	0.28	0.30	0.32	0.35

In terms of security, there was an increase in probability of choosing P&R by 0.110 when there is a security guard at the P&R facility, when the P&R service is free, and car and Uber costs are equal. With increasing headway however, the probability of choosing P&R decreases by a factor of 0.006 for every minute increase in headway times. It is interesting to note that with a service headway of 20 minutes and a

security guard at the P&R parking facility, the probability of choosing each mode is almost equal. Of course, it also should be noted at this time, that only certain variables were taken into account in this analysis, but the choice probabilities may vary, depending on the introduction of say, significant variables that were not measured in this study. The P&R has the highest probability of being chosen when there is a security guard at the P&R facility, and the headway is 5 minutes. The probability of choosing car or Uber throughout the analysis remained relatively equal. This is potentially since these variables were kept equal and constant, in this analysis.

Table 21 shows the same scenarios that were presented previously, however, the cost of a P&R shuttle trip was set to R10. With a cost associated to the P&R service, the initial choice probability for P&R is lower (0.27) than the previous probability (0.35), showing that cost adds to the disutility of P&R. It is an obvious assumption, that respondents prefer the service to be free, than associated with a cost. With shuttle trip charges, headway has a similar impact on decreasing the probabilities of respondents using the P&R service, however, the actual probability is much lower (0.24 as compared to 0.31).

Table 21: Choice Probabilities for Scenarios where P&R Service is R10 per Shuttle Trip

SCENARIO: P&R service is R 10 per shuttle trip and ...	No security guard at parking facility	Presence of security guard at parking facility	Presence of security guard at parking facility and a headway of 5 minutes	Presence of security guard at parking facility and a headway of 10 minutes	Presence of security guard at parking facility and a headway of 20 minutes
CAR	0.36	0.31	0.330	0.35	0.37
P&R	0.27	0.36	0.32	0.29	0.24
UBER	0.38	0.33	0.34	0.36	0.39

P&R has the highest probability of usage again, when there is a security guard at the P&R facility, and the headway is 5 minutes, even though now there is an additional cost.

5.4.2 How Much Are People Willing to Pay Better P&R Service Quality?

Willingness to pay concepts have been documented in numerous publications (Ben-Akiva and Bierlaire, 2003; Hole, 2004a; Kenneth E. Train, 2009; Lancsar, Fiebig and Hole, 2017). Here, willingness to pay (WTP) for P&R service quality aspects such as P&R facility security and P&R headway are discussed. The WTP for headway and security can be considered the value of headway (and security respectively), which refers to the monetary value that respondents placed on these variables. This was calculated by using the β parameters estimated for P&R security and headway, and dividing these values by the β parameter estimated for P&R travel cost.

Table 20 : Calculation of Value for P&R Service Characteristics

P&R	Beta – parameters estimated			Value of Security (R)	Value of Headway (R)
	Travel cost	Security at parking facility	Service headway		
	-0.039	0.4199	-0.2927		

The value for security was calculated to be R10,77 (say R11,00). This would imply that, with all other factors staying the same, respondents were willing to pay R11,00 extra, for the presence of a security guard at the P&R facility, over not having any security at the P&R. Since security was coded as a dummy – variable, you cannot calculate the incremental value of security as you move from no security at the P&R facility, to a security guard at the P&R facility. It is evident that respondents place a high value on the security of their vehicle at the facility, while they are away. Security is a subjective concept, and is dependent on the respondent’s perceptions of the context. For example, respondents may consider some areas safer than others, in

which the willingness to pay for security would be lower. This cost, is over and above the cost of using the shuttle service.

The value of P&R headway was calculated to be R7,51 (say R8,00). This would imply that, with all other factors staying the same, respondents were willing to pay R8,00 extra, for a decrease in service headway, from 20 minutes to 10 minutes. This would equate to a willingness to pay of R0.80 per minute decrease in headway intervals. As the difference in headways get larger, so too does the willingness to pay, but at smaller headways, the willingness to pay value can almost be negligible. This means that, respondents do not value a difference of say, 5 minutes in headway intervals, as much as they value a difference of say 30 minutes, for example.

6 DISCUSSION

This chapter summarises the findings of model estimation, as well as results from the scenarios developed.

In terms of variables, travel cost has been a consistently significant variable throughout the analysis. Previous research also suggests that travel cost is a critical variable in mode choice decisions. Also, cost is perceived with the same importance to the sample population, for all modes considered.

Travel time variation by Park and Ride (P&R) was also considered a significant variable in model estimation. Some may for example, consider the time savings by P&R to be offset by the time taken to park (at the P&R facility) as well as wait for a shuttle bus to arrive. This could be a potential reason for the negative and significant value of this variable.

Characteristics of the P&R are also important to prospective users - P&R service characteristics were found to be more important than for example, car characteristics. Security of the P&R service was a major consideration for respondents. Respondents were found to be willing to pay around R11 extra for the presence of security guards at the P&R facility. P&R headway was also an important variable. In subsequent data analysis, the choice probabilities decreased by a factor of 0.006 for every minute increase in headway.

The current travel characteristics considered in mode choice modelling was trip purpose, as well as time spent at Florida Road. These characteristics were not found to be significant in the models built, except for the shift in travel time variation for trip purpose for P&R which was found to be positive and significant. This would imply that respondents had a preference to use the P&R system for work trips, over that of social or shopping trips, particularly due to the travel time savings realised.

The socio – demographic variables included in the model were age, employment status and gender. Some socio – demographic characteristics were found to be significant – the shift in travel cost for those that are unemployed, as well as the shift in travel cost for those who are students, both for the car alternative. These variables were negative, implying that those under those employment demographics “prefer” the cost of car less. Age and gender was not found to be a significant variable in the study.

The “ideal” conditions that create the highest choice probabilities for use of the P&R among respondents is one where the P&R service is free, where there are security guards at the P&R facility, as well as shorter shuttle service headways. Not having security guards at the P&R facility is a major deterrent to P&R use, as respondents were found to be willing to pay around R11 extra, for the presence of security guards. With the travel cost of the other modes (car and Uber) remaining constant, these modes displayed similar choice probabilities throughout.

7 CONCLUSIONS

This study aimed to predict the mode choice behaviour of car users of Florida Road, upon the introduction of a P&R system for the area, using the method of discrete choice analysis. In doing so, the demand for the service, should it exist, was quantified, in terms of choice probabilities. A Discrete Choice Experiment (DCE), encompassing a Stated Choice (SC) survey data was carried out to achieve this aim. Another aim of this study was to gain knowledge in the field of SC and DCE, to effectively implement these aspects, and produce significant results. Of interest in this study was also to examine the relative influence of mode attributes on the decision maker's choice, as well as analyse how personal characteristics affect individual decision making. Also of interest, was the identification of attributes that influence the choice of mode in users of Florida Road.

This was carried out by gathering all information available on Florida Road, relevant to this research, applying research methods in the fields of SC survey design and DCM as well as data analysis using Discrete Choice Models (DCM's) to make inferences on current and predicted user's preferences.

The SC survey was designed and implemented considering the three modes; Car, the P&R as well as Uber. Attributes that influence mode choice for users of Florida Road considered in the SC survey and developed from focus groups and previous research were travel cost, travel time savings, P&R security and P&R service headway. Additional questions regarding respondent's current travel patterns (pertaining to Florida Road) as well as personal characteristics were included in the questionnaire, to enrich the data collected, and was used in model estimation. Choice behaviour was modelled via the MNL model, to produce information on predicted respondent choice behaviour.

In this concluding section, all findings are compared and reviewed, and recommendations will be given for further research. It was found that cost was a major consideration for the sampled population. This variable was found to be significant for all three modes, and in all 3 models estimated. Respondents also viewed cost with a similar dislike, and there were no inherent preferences (or dislike) for travel cost of one mode over another. P&R cost in particular, made a significant impact on mode choice probabilities. Upon implementation of the P&R system, caution should be taken when considering costing of the P&R trip. There needs to be adequate travel cost savings for users, for them to switch from using their vehicle, to

the P&R system. The P&R needs to be competitive with other modes of travel, and be more attractive. Travel time savings should also be maximised, as this was also found to be a significant P&R variable. In terms of travel time, potential users need to “feel” like using the P&R is a quicker, more convenient option than using their private car, for example.

To ensure a sustainable demand for the P&R system, P&R service characteristics should be optimised, and the utility of using the P&R service should be higher than that of the other modes considered. From the data analysis, it was evident that for a higher patronage, the cost of using the P&R service should be low, or ideally, the service should be free. Shorter headways between pick – ups/ drop – offs should be maintained. Another important aspect is that, to promote the service, adequate advertising on social media is recommended. The more people who know about the service and its relative advantages, the more people are likely to use the service. Aspects such as parking facility location, bus schedules, costs etc should be highly publicised. A high - quality shuttle bus service should also be provided, to further attract prospective users to the service.

For the P&R system to be truly successful, P&R should be also introduced with measures to discourage use of parking bays on Florida, and encourage the use of the P&R service. An option considered is to start charging parking costs for the bays on Florida Road, thereby discouraging the use of this parking. This can be done for the sections of Florida Road that parking issues exist, such as between the intersections of Florida Road and 9th avenue and Currie Road.

To further enrich this study, more surveys should be carried out, to gather a broader field and range of results. Surveys should also be carried out on different weekends, to capture a more diverse range of Florida Road users. It would also be interesting to survey weekday users, to get an idea of the weekday demand for such a service.

8 APPENDIX

8.1 Bibliography

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8.2 Ethics Clearance

Application for Approval of Ethics in Research (EIR) Projects
Faculty of Engineering and the Built Environment, University of Cape Town

APPLICATION FORM


Please Note:




Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form before collecting or analysing data. The objective of submitting this application prior to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the EBE Ethics in Research Handbook (available from the UCT EBE, Research Ethics website) prior to completing this application form: <http://www.ebe.uct.ac.za/ebe/research/ethics1>

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant	Nikita Bilala	
Department	Department of Civil Engineering	
Preferred email address of applicant:	BLLNK002@myuct.co.za	
If Student	Your Degree: e.g., MSc, PhD, etc.	Meng in transportation
	Credit Value of Research: e.g., 60/120/180/360 etc.	180 credits
	Name of Supervisor (if supervised):	Roger Behrens/ Mark Zuidgeest
If this is a researchcontract, indicate the source of funding/sponsorship	Click here to enter text.	
Project Title	Using stated preference surveys to estimate the demand for park and Ride. A case study - Florida Road.	

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

SIGNED BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Nikita Bilala		22 Jan 2018

APPLICATION APPROVED BY	Full name	Signature	Date
Supervisor (where applicable)	Roger Behrens		22 Jan 2018 Click here to enter a date.
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section 1; and for all Undergraduate research (Including Honours).	f T. Bello-Ochende Click here to enter text.		16/03/2018 Click here to enter a date.
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.	f T. Bello-Ochende		16/03/2018

8.3 Focus Group Questions

To get an idea of whether people are aware of the traffic issues experienced on Florida Road as well as what the most common responses to these issues is.
What is your most common reason for using Florida Road? I.e. what is your main trip purpose? How long do you spend there? Where on Florida Road do you generally go to?
What is your general trip origin? I.e. where are you generally coming from?
Do you visit Florida Road on weekends or weekdays (mostly?)
Do you experience or notice parking issues when you go to Florida Road? If so, what are the types of problems you experience?
Have you ever decided to use another destination because of not being able to find a parking on Florida Road?
General Park and ride
What is your understanding of a Park and ride service? I.e. we want to find out whether people understand how a park and ride service works
Have you ever used a park and ride service? If so, where about?
Park and ride attributes
What are the biggest factors that would influence your decision to use this park and ride service?
Can we rate these factors, from most important to least important?
Do you think using this park and ride service would be quicker or slower than using your vehicle (as opposed to looking for parking) when visiting Florida Road? In relation to your current trip, what do you think these time frames are?
Would time of day, as well as the time (how long) you spend on Florida Road, affect whether you use a park and ride service?
What cost would you be willing to pay to use the park and ride, per trip? Would you prefer the service to be free?
Is the location and distance of the Park and ride service (away from Florida Road) a big deciding factor on usage?
Do you have any other suggestions for where the park and ride should be located?
How frequent would you like the service to be? In terms of scheduling
Would security at the park and ride make you more likely to use the service?
Do you have any suggestions on how Park and Ride can be made more attractive to potential users?
Uber Attributes
What are the reasons for you choosing to use Uber over your car?
Can we rate these factors, from most important to least important?
What trip purposes do you use Uber the most for? How often do you use it?
Do you find Uber to be a cheaper form of transport? (than using a car)
Do you feel that using an Uber is a more convenient way of getting around the city? Than using a car
Is the safety of using an Uber an important factor to you?
Have you used an Uber to Florida Road? How was the experience?
In your opinion, what is the best advantage of using Uber?
Private Car
Why do you use a car for your current trip to Florida Road?
Can we rate these factors, from most important to least important?

Where do you generally park on Florida Road?
Do the parking issues experienced on Florida Road deter you from using this destination?
On average, how long do you spend looking for parking? Do you generally have to walk a distance to your destination? From your parking
Will having less on street parking deter you from using Florida Road?
Of all the transport modes which is:
The most cost effective?
The most convenient?
Amounts to the greatest cost savings? In terms of travel cost
The most secure (personal safety AND road safety)?

8.3.1.1 Findings

General Trip Characteristics

Participants were found to frequent Florida Road for many reasons, the most common being for recreational purposes. These involve socialising with friends at bars/ clubs and supper at various the restaurants. Other less common reasons include shopping at grocery stores, visiting the banking facilities, ordering take away and visiting the general shopping stores located there. People who live closer to Florida Road (in the area of Morningside for example) were more inclined to use the business facilities on Florida Road as a result of it being so closely located to their homes.

Trip origins for trips to Florida Road were mostly from the participant's home. Participants originated from various areas such as Morningside, Durban North as well as Glenwood and the Berea.

Trips to Florida Road were made generally on weekends (Friday to Sunday) during the evening, and on occasion, on weekday evenings. These trips were usually made after 6pm. Most of these trips were between 6pm and 10pm, however there were those who spent time on Florida Road till 2am the next morning. Participants also mentioned that there were also those who frequent the restaurants in the mornings (on weekdays mostly), for breakfast or coffee runs. Trips were rarely made during the lunch period, the main reason for this being that all participants work in Umhlanga; located quite a distance away from Florida Road. It was also noted that evening trips were made more frequently than morning or lunch time trips. On average, participants stated that they spent between 10 – 15 minutes in search of Parking on Florida Road, during the peak periods.

Florida Road Traffic Issues

Participants were in general agreement when it came to having frustrations on the traffic issues (and parking in particular) on Florida Road. The following issues were mentioned at the discussion:

- Double parking in the vicinity of restaurants (when waiting for parking)
- People circling/ driving around to look for parking
- Pedestrian not crossing at designated points
- Illegal parking at intersections
- Parking on driveways
- Fast cars driving up and down the road

All these factors were seen to contribute to unsafe situations and manoeuvres for drivers.

Because of these issues, some participants did consider using an alternative destination, such as Suncoast Casino, and Durban North, both places that have ample parking.

General Park and ride

In general, participants did understand how a park and ride system works. Most participants have had an experience with a P&R service, most of which was during the Soccer World Cup held in South Africa in 2010. P&R services were set up (at Suncoast Casinos) for Fan Parks held near the stadiums. This shuttle service was free. Overall, participants had had a good experience with park and ride.

Park and ride attributes

The proposed P&R system was explained to the participants. The following were the P&R characteristics proposed.

- P&R service from Greyville Racecourse to Florida Road
- 20 min frequency for morning peak (9am to 6pm)
- 10 min frequency for evening peak (6pm to 12pm)
- Around 1.5km ways
- 2 busses in circulation

Participants did agree on the 10-minute shuttle frequency in the evenings, however they did feel that the service time should be extended, till around 2am. As Florida road is mostly used by the public for recreational type purposes, some restaurants are open till the morning hours.

Frequency was a big contributing factor to whether participants would use this service or not. Participants did not want long waiting times, and were less likely to use the service if the waiting time for a shuttle was more than 20 minutes. Suggestions were made to have a 10-minute frequency for most of the peak period, and then decrease it from say, after 12am, to half hour intervals. Participants did like the location of the P&R facility, in its close proximity to Florida Road. Security of their vehicle at the P&R facility was also a major concern. Sheltered facilities or a waiting area for users of the P&R was considered, due to weather conditions. Participants were less likely to use the P&R if there was no form of security at the facility. The catchment area of the P&R facility was also considered. Some of those who lived within the catchment area of the facility would prefer to walk to the facility and use services on Florida Road. It was also mentioned that this could be a hotspot for criminal activity, if unpoliced. Personal security was also a concern. Another concern for participants was that their vehicle had to be used for a leg of the trip, whereas with Uber, there is no need for your own vehicle, which was seen to be more convenient. Uber also is a good choice for those who intended to consume alcohol during their evening, for the reason above those who lived further north expressed concern in making a greater detour to the park and ride, as opposed to parking on site. Trip purposes also played a role in whether the P&R would be used. Those who had short trips (trips to the grocery store, to get take away etc.) were more inclined to use their vehicle, than take the park and ride, as this felt like a longer, more laborious trip. Participants were not willing to pay more than R10 per shuttle trip. Anything more than this and they were more likely to take their vehicle or get an Uber, as they were considered to be a cheaper option. Some felt that charging for the parking bay per hour was not a good idea. Those who were travelling in groups for their trip were more likely to consider using the park and ride. Of all the factors considered, security was found to be the most important, followed by cost of the shuttle trip, and the frequency of the service. Participants thought that fining illegal parkers on Florida Road, the service being free. Longer operational hours would make the service more attractive.

Uber Attributes

Uber trips were generally used for recreational trip purposes, especially to places where participants knew they would have trouble to park, such as concerts, matches at the stadium etc.

In general, the cost of using Uber was found to be the most attractive factor considered. It was found to be cheaper to use an Uber for the recreational trips described above. The convenience of not driving at any point in your trip was also a major influence, as well as the waiting time for an Uber, which is normally less than 10 minutes. Participants said that they quite frequently use Uber to Florida Road. They also mentioned that many people on Florida Road use Uber to get there. Shared cost was also considered an attractive factor. Safety of using an Uber was considered more when participants were alone late at night. Participants had used Uber to Florida Road on many occasions.

Private Car

Participants stated that sometimes, a car is more convenient as you can leave whenever you want to. Respondents felt a loss of independence without their vehicle. Short trips were almost always taken by private vehicle. Weather also played an important role. In general, when using their vehicle, participants parked in the nearest parking bay found, or on some of the side roads. Parking bays are more easily found in the morning rather than the evening. Some participants stated that they use private parking lots of restaurants to park in while they make short trips to various stores. On average, participants stated they spent 10-15 minutes looking for a parking bay in the peak hour. This involved them travelling up and down Florida Road, as well as the side roads, in search of a parking bay. Even though parking is more available above Florida road, participants were discouraged from using these as they were far and poorly lit. Less on street parking did deter participants from using Florida Road.

8.4 Orthogonal fractional factorial design in SPSS

Choice card	Alternatives	Total Travel cost	Total Travel time savings	Service Frequency	Security
1	1	1	1	2	1
2	3	3	1	1	1
3	2	1	3	2	2
4	3	3	1	2	1
5	1	1	1	1	1
6	2	3	2	2	1
7	2	2	1	1	2
8	2	2	1	1	1
9	3	3	1	1	2
10	2	2	1	1	1
11	1	3	3	1	1
12	1	1	1	1	1
13	1	2	2	1	1
14	1	3	3	2	2
15	1	1	1	1	2
16	1	1	1	1	1
17	2	3	2	1	1
18	2	1	3	1	1
19	3	3	1	1	2
20	3	2	3	1	2
21	1	3	3	2	1
22	2	3	2	1	1
23	2	3	2	1	2
24	2	1	3	2	1
25	2	1	3	1	2
26	3	1	2	2	1
27	1	3	3	1	2
28	2	1	3	1	1
29	2	2	1	1	1
30	2	1	3	1	1
31	1	2	2	1	2
32	3	3	1	1	1
33	2	2	1	1	2
34	3	1	2	1	1
35	1	2	2	2	2
36	1	2	2	1	1
37	1	3	3	1	1
38	1	3	3	1	1

Choice card	Alternatives	Total Travel cost	Total Travel time savings	Service Frequency	Security
1	1	1	1	2	1
2	3	3	1	1	1
3	2	1	3	2	2
4	3	3	1	2	1
5	1	1	1	1	1
6	2	3	2	2	1
7	2	2	1	1	2
8	2	2	1	1	1
9	3	3	1	1	2
10	2	2	1	1	1
11	1	3	3	1	1
12	1	1	1	1	1
39	3	1	2	1	1
40	1	2	2	1	2
41	2	3	2	2	1
42	1	1	1	1	2
43	1	3	3	1	2
44	3	1	2	1	1
45	3	2	3	1	2
46	2	2	1	2	2
47	2	1	3	1	2
48	3	2	3	1	1
49	3	1	2	2	1
50	2	3	2	1	1
51	3	1	2	1	2
52	3	3	1	1	1
53	3	1	2	1	1
54	3	2	3	2	2
55	3	3	1	2	1
56	3	2	3	2	1
57	1	2	2	1	1
58	2	3	2	1	1
59	1	1	1	1	1
60	3	2	3	1	1
61	2	1	3	1	1
62	2	2	1	2	1
63	1	1	1	2	1
64	1	2	2	1	1
65	3	3	1	1	1
66	3	2	3	1	1
67	2	3	2	2	2

Choice card	Alternatives	Total Travel cost	Total Travel time savings	Service Frequency	Security
1	1	1	1	2	1
2	3	3	1	1	1
3	2	1	3	2	2
4	3	3	1	2	1
5	1	1	1	1	1
6	2	3	2	2	1
7	2	2	1	1	2
8	2	2	1	1	1
9	3	3	1	1	2
10	2	2	1	1	1
11	1	3	3	1	1
12	1	1	1	1	1
68	3	1	2	2	2
69	1	3	3	2	1
70	3	2	3	2	1
71	3	3	1	2	2
72	2	3	2	1	2
73	1	3	3	1	1
74	1	1	1	2	2
75	2	2	1	2	1
76	2	2	1	1	1
77	3	2	3	1	1
78	1	2	2	2	1
79	1	2	2	2	1
80	2	1	3	2	1
81	3	1	2	1	2

8.5 Orthogonal choice sets

FINAL CHOICE SETS				
NUMBER		Private vehicle	Park and Ride	Uber
1	Total Travel cost	R20 per trip	cost of car trip only (R20) - Park and Ride service is free	R60 per trip
	Total Travel time savings	lose 15 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 20 minutes	-
	Security	Parking available on the main Road (Florida Road)	security guards at parking facility	-
2	Total Travel cost	R60 per trip	cost of car trip only (R60) - Park and Ride service is free	R60 per trip
	Total Travel time savings	lose 5 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	security guards at parking facility	-
3	Total Travel cost	R40 per trip	car trip cost (R40) +R10 per shuttle trip	R60 per trip
	Total Travel time savings	find a parking bay immediately	save 15 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the main Road (Florida Road)	security guards at parking facility	-
4	Total Travel cost	R40 per trip	cost of car trip only (R40) - Park and Ride service is free	R60 per trip
	Total Travel time savings	find a parking bay immediately	save 5 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	security guards at parking facility	-
5	Total Travel cost	R40 per trip	car trip cost (R40) +R5 per shuttle trip	R40 per trip
	Total Travel time savings	find a parking bay immediately	save 10 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-

	Security	Parking available on the side roads adjacent to Florida Road	security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
6	Total Travel cost	R60 per trip	car trip cost (R60) +R10 per shuttle trip	R20 per trip
	Total Travel time savings	lose 5 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 20 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	no security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
7	Total Travel cost	R20 per trip	cost of car trip only (R20) - Park and Ride service is free	R20 per trip
	Total Travel time savings	lose 15 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	no security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
8	Total Travel cost	R60 per trip	cost of car trip only (R60) - Park and Ride service is free	R20 per trip
	Total Travel time savings	lose 5 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
9	Total Travel cost	R60 per trip	car trip cost (R60) +R10 per shuttle trip	R20 per trip
	Total Travel time savings	lose 15 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 20 minutes	-
	Security	Parking available on the main Road (Florida Road)	security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
10	Total Travel cost	R20 per trip	car trip cost (R20) +R10 per shuttle trip	R20 per trip
	Total Travel time savings	lose 15 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	no security guards at parking facility	-

		Private vehicle	Park and Ride	Uber
11	Total Travel cost	R20 per trip	car trip cost (R20) +R5 per shuttle trip	R40 per trip
	Total Travel time savings	lose 15 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the main Road (Florida Road)	no security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
12	Total Travel cost	R20 per trip	car trip cost (R20) +R5 per shuttle trip	R40 per trip
	Total Travel time savings	lose 15 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 20 minutes	-
	Security	no car guards on Florida Road	no security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
13	Total Travel cost	R40 per trip	car trip cost (R40) +R5 per shuttle trip	R20 per trip
	Total Travel time savings	find a parking bay immediately	save 10 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
14	Total Travel cost	R20 per trip	car trip cost (R20) +R10 per shuttle trip	R20 per trip
	Total Travel time savings	lose 15 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
15	Total Travel cost	R40 per trip	car trip cost (R40) +R10 per shuttle trip	R60 per trip
	Total Travel time savings	find a parking bay immediately	save 15 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the main Road (Florida Road)	security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
16	Total Travel cost	R60 per trip	car trip cost (R60) +R5 per shuttle trip	R20 per trip

	Total Travel time savings	lose 5 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	no security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
17	Total Travel cost	R40 per trip	cost of car trip only (R40) - Park and Ride service is free	R40 per trip
	Total Travel time savings	find a parking bay immediately	save 5 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the main Road (Florida Road)	no security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
18	Total Travel cost	R60 per trip	car trip cost (R60) +R10 per shuttle trip	R60 per trip
	Total Travel time savings	lose 15 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the main Road (Florida Road)	no security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
19	Total Travel cost	R60 per trip	car trip cost (R60) +R5 per shuttle trip	R40 per trip
	Total Travel time savings	lose 5 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
20	Total Travel cost	R60 per trip	cost of car trip only (R60) - Park and Ride service is free	R40 per trip
	Total Travel time savings	lose 5 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
21	Total Travel cost	R20 per trip	cost of car trip only (R20) - Park and Ride service is free	R60 per trip
	Total Travel time savings	lose 15 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay

	Service Frequency	-	Shuttle service available every 20 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
22	Total Travel cost	R40 per trip	car trip cost (R40) +R5 per shuttle trip	R40 per trip
	Total Travel time savings	find a parking bay immediately	save 10 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
23	Total Travel cost	R60 per trip	car trip cost (R60) +R10 per shuttle trip	R20 per trip
	Total Travel time savings	lose 5 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 20 minutes	-
	Security	Parking available on the main Road (Florida Road)	security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
24	Total Travel cost	R60 per trip	car trip cost (R60) +R10 per shuttle trip	R40 per trip
	Total Travel time savings	lose 5 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 10 minutes	-
	Security	Parking available on the main Road (Florida Road)	security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
25	Total Travel cost	R40 per trip	cost of car trip only (R40) - Park and Ride service is free	R60 per trip
	Total Travel time savings	find a parking bay immediately	save 5 minutes in time spent looking for a parking bay	save 5 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 20 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	no security guards at parking facility	-
		Private vehicle	Park and Ride	Uber
26	Total Travel cost	R40 per trip	car trip cost (R40) +R5 per shuttle trip	R40 per trip
	Total Travel time savings	find a parking bay immediately	save 10 minutes in time spent looking for a parking bay	save 15 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 20 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	security guards at parking facility	-

		Private vehicle	Park and Ride	Uber
27	Total Travel cost	R20 per trip	car trip cost (R20) +R5 per shuttle trip	R20 per trip
	Total Travel time savings	lose 15 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay	save 10 minutes in time spent looking for a parking bay
	Service Frequency	-	Shuttle service available every 20 minutes	-
	Security	Parking available on the side roads adjacent to Florida Road	security guards at parking facility	-

8.6 Survey Questionnaire and Choice Cards

DEMOGRAPHIC QUESTIONS:				
What year were you born in?				

What is your current employment status?				
Unemployed	Employed	Student	Self - employed	Unable to work
QUESTIONS RELATED TO YOUR LAST TRIP TO FLORIDA ROAD:				
What was the origin of your trip today? E.g. Glenwood, Umhlanga etc.				

What was your trip purpose for today?				
Work	Social (dinner, drinks etc)	Shopping	Other	
When do you generally visit Florida Road?				
The Weekend (Friday/ Saturday/ Sunday)		Weekdays		
Where did you/ are you going to on Florida Road? e.g. Cubana, Taco Zulu etc.				

How long did you/ will you spend there? e.g. 10 mins, 1 hour etc.				
___ minutes or ____ hours				
On average, how often do you visit Florida Road?				
Every week	2-3 times a month	Once a month	Not a regular patron	
Where do you generally park on Florida road?				
Along the main Road (Florida Road)	Along side roads	Anywhere I can find parking	Other (specify) _____	
On average, how long does it take you to find parking?				
___ minutes				
Do you experience issues when looking for a parking? If so, what are they?				

GENERAL:				
Do you have the Uber application, or access to it?				
Yes		No		
Did you come alone, or travel with people? If so, how many?				
Yes	No	_____		

BLOCK ONE CHOICE SETS

CHOICE SET ONE:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	<u>PRIVATE VEHICLE</u>	<u>PARK AND RIDE</u>	<u>UBER</u>
TOTAL TRAVEL COST (one way)	R40	Cost of car trip only (R40) -Park and Ride service is free	R20
TOTAL TRAVEL TIME VARIATION (one way)	Lose 15 minutes in parking time	Save 5 mins in parking time	Save 5 mins in parking time
SECURITY	Parking available on the side roads adjacent to Florida Road	No security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 20 mins	-
1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?	<input type="checkbox"/> HIGHLY LIKELY	<input type="checkbox"/> HIGHLY UNLIKELY	<input type="checkbox"/> I CANT BE SURE

CHOICE SET TWO:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	<u>PRIVATE VEHICLE</u>	<u>PARK AND RIDE</u>	<u>UBER</u>
TOTAL TRAVEL COST (one way)	R60	Car trip cost (R60) + R10 per shuttle trip	R60
TOTAL TRAVEL TIME VARIATION (one way)	Find a parking bay immediately	Save 15 mins in parking time	Save 10 mins in parking time
SECURITY	Parking available on the main road (Florida Road)	No security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 20 mins	-
1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?	<input type="checkbox"/> HIGHLY LIKELY	<input type="checkbox"/> HIGHLY UNLIKELY	<input type="checkbox"/> I CANT BE SURE

CHOICE SET THREE:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	PRIVATE VEHICLE	PARK AND RIDE	UBER
TOTAL TRAVEL COST (one way)	R20	Cost of car trip only (R60) -Park and Ride service is free	R40
TOTAL TRAVEL TIME VARIATION (one way)	Lose 15 minutes in parking time	Save 5 mins in parking time	Save 15 mins in parking time
SECURITY	Parking available on the main road (Florida Road)	Security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 20 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

CHOICE SET FOUR:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	PRIVATE VEHICLE	PARK AND RIDE	UBER
TOTAL TRAVEL COST (one way)	R40	Cost of car trip (R40) + R5 per shuttle trip	R40
TOTAL TRAVEL TIME VARIATION (one way)	Find a parking bay immediately	Save 10 mins in parking time	Save 15 mins in parking time
SECURITY	Parking available on the side roads adjacent to Florida Road	Security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 10 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

CHOICE SET FIVE:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	<u>PRIVATE VEHICLE</u>	<u>PARK AND RIDE</u>	<u>UBER</u>
TOTAL TRAVEL COST (one way)	R40	Cost of car trip (R40) + R5 per shuttle trip	R60
TOTAL TRAVEL TIME VARIATION (one way)	Find a parking bay immediately	Save 15 mins in parking time	Save 10 mins in parking time
SECURITY	Parking available on the main road (Florida Road)	Security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 10 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

 HIGHLY LIKELY

 HIGHLY UNLIKELY

 I CANT BE SURE

CHOICE SET SIX:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	<u>PRIVATE VEHICLE</u>	<u>PARK AND RIDE</u>	<u>UBER</u>
TOTAL TRAVEL COST (one way)	R20	Cost of car trip (R20) + R10 per shuttle trip	R20
TOTAL TRAVEL TIME VARIATION (one way)	Lose 5 minutes in parking time	Save 10 mins in parking time	Save 10 mins in parking time
SECURITY	Parking available on the side roads adjacent to Florida Road	No security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 10 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

 HIGHLY LIKELY

 HIGHLY UNLIKELY

 I CANT BE SURE

CHOICE SET SEVEN:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	PRIVATE VEHICLE	PARK AND RIDE	UBER
TOTAL TRAVEL COST (one way)	R60	Cost of car trip (R60) + R5 per shuttle trip	R40
TOTAL TRAVEL TIME VARIATION (one way)	Lose 5 minutes in parking time	Save 10 mins in parking time	Save 15 mins in parking time
SECURITY	Parking available on the side roads adjacent to Florida Road	Security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 10 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

CHOICE SET EIGHT:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	PRIVATE VEHICLE	PARK AND RIDE	UBER
TOTAL TRAVEL COST (one way)	R60	Cost of car trip only (R60) -Park and Ride service is free	R20
TOTAL TRAVEL TIME VARIATION (one way)	Lose 5 minutes in parking time	Save 5 mins in parking time	Save 5 mins in parking time
SECURITY	Parking available on the side roads adjacent to Florida Road	Security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 10 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

CHOICE SET NINE:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	PRIVATE VEHICLE	PARK AND RIDE	UBER
TOTAL TRAVEL COST (one way)	R20	Cost of car trip only (R20) -Park and Ride service is free	R20
TOTAL TRAVEL TIME VARIATION (one way)	Lose 15 minutes in parking time	Save 10 mins in parking time	Save 15 mins in parking time
SECURITY	Parking available on the main road (Florida Road)	Security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 20 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

BLOCK TWO CHOICE SETS

CHOICE SET ONE:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	PRIVATE VEHICLE	PARK AND RIDE	UBER
TOTAL TRAVEL COST (one way)	R60	Cost of car trip only (R60) -Park and Ride service is free	R20
TOTAL TRAVEL TIME VARIATION (one way)	Lose 5 minutes in parking time	Save 15 mins in parking time	Save 10 mins in parking time
SECURITY	Parking available on the main road (Florida Road)	No security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 10 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

CHOICE SET TWO:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	<u>PRIVATE VEHICLE</u>	<u>PARK AND RIDE</u>	<u>UBER</u>
TOTAL TRAVEL COST (one way)	R60	Cost of car trip (R60) + R5 per shuttle trip	R60
TOTAL TRAVEL TIME VARIATION (one way)	Find a parking bay immediately	Save 10 mins in parking time	Save 15 mins in parking time
SECURITY	Parking available on the main road (Florida Road)	No security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 20 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

 HIGHLY LIKELY

 HIGHLY UNLIKELY

 I CANT BE SURE

CHOICE SET THREE

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	<u>PRIVATE VEHICLE</u>	<u>PARK AND RIDE</u>	<u>UBER</u>
TOTAL TRAVEL COST (one way)	R40	Cost of car trip only (R40) -Park and Ride service is free	R60
TOTAL TRAVEL TIME VARIATION (one way)	Find a parking bay immediately	Save 5 mins in parking time	Save 5 mins in parking time
SECURITY	Parking available on the side roads adjacent to Florida Road	No security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 20 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

 HIGHLY LIKELY

 HIGHLY UNLIKELY

 I CANT BE SURE

CHOICE SET FOUR:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	<u>PRIVATE VEHICLE</u>	<u>PARK AND RIDE</u>	<u>UBER</u>
TOTAL TRAVEL COST (one way)	R20	Cost of car trip only (R20) + R10 per shuttle trip	R20
TOTAL TRAVEL TIME VARIATION (one way)	Lose 5 minutes in parking time	Save 15 mins in parking time	Save 10 mins in parking time
SECURITY	Parking available on the main road (Florida Road)	No security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 10 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

 HIGHLY LIKELY

 HIGHLY UNLIKELY

 I CANT BE SURE

CHOICE SET FIVE:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	<u>PRIVATE VEHICLE</u>	<u>PARK AND RIDE</u>	<u>UBER</u>
TOTAL TRAVEL COST (one way)	R40	Cost of car trip (R40) + R10 per shuttle trip	R60
TOTAL TRAVEL TIME VARIATION (one way)	Find a parking bay immediately	Save 15 mins in parking time	Save 5 mins in parking time
SECURITY	Parking available on the main road (Florida Road)	Security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 20 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

 HIGHLY LIKELY

 HIGHLY UNLIKELY

 I CANT BE SURE

CHOICE SET SIX:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	<u>PRIVATE VEHICLE</u>	<u>PARK AND RIDE</u>	<u>UBER</u>
TOTAL TRAVEL COST (one way)	R20	Cost of car trip (R20) + R5 per shuttle trip	R20
TOTAL TRAVEL TIME VARIATION (one way)	Lose 15 minutes in parking time	Save 15 mins in parking time	Save 10 mins in parking time
SECURITY	Parking available on the side roads adjacent to Florida Road	Security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 20 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

 HIGHLY LIKELY

 HIGHLY UNLIKELY

 I CANT BE SURE

CHOICE SET SEVEN:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	<u>PRIVATE VEHICLE</u>	<u>PARK AND RIDE</u>	<u>UBER</u>
TOTAL TRAVEL COST (one way)	R20	Cost of car trip only (R20) -Park and Ride service is free	R40
TOTAL TRAVEL TIME VARIATION (one way)	Lose 5 minutes in parking time	Save 5 mins in parking time	Save 5 mins in parking time
SECURITY	Parking available on the main road (Florida Road)	Security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 10 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

 HIGHLY LIKELY

 HIGHLY UNLIKELY

 I CANT BE SURE

CHOICE SET EIGHT:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	PRIVATE VEHICLE	PARK AND RIDE	UBER
TOTAL TRAVEL COST (one way)	R60	Cost of car trip (R60) + R10 per shuttle trip	R60
TOTAL TRAVEL TIME VARIATION (one way)	Lose 15 minutes in parking time	Save 5 mins in parking time	Save 5 mins in parking time
SECURITY	Parking available on the side roads adjacent to Florida Road	No security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 20 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

 HIGHLY LIKELY

 HIGHLY UNLIKELY

 I CANT BE SURE

CHOICE SET EIGHT:

The following options are available to you, for your trip to Florida Road:

	YOUR CURRENT OPTION:	ALTERNATIVES:	
	PRIVATE VEHICLE	PARK AND RIDE	UBER
TOTAL TRAVEL COST (one way)	R40	Cost of car trip (R40) + R10 per shuttle trip	R40
TOTAL TRAVEL TIME VARIATION (one way)	Lose 15 minutes in parking time	Save 10 mins in parking time	Save 15 mins in parking time
SECURITY	Parking available on the side roads adjacent to Florida Road	Security guards at the Park and Ride parking facility	-
SERVICE FREQUENCY	-	A shuttle bus pick-up/drop-off every 20 mins	-

1. UNDER THESE CIRCUMSTANCES, WHICH TRAVEL MODE WOULD YOU CHOOSE?(Tick the most preferred option)

2. IF THIS SITUATION REPRESENTED REAL LIFE, HOW LIKELY WOULD YOU BE TO CHOOSE THE OPTION ABOVE?

 HIGHLY LIKELY

 HIGHLY UNLIKELY

 I CANT BE SURE

8.7 Final Model Estimation Results

8.7.1 SP Model

	SP MODEL	
Variables	Estimate	Rob t ratio
ASC - car	0.9177	2.74
ASC - P&R	0.1898	0.48
ASC - Uber	0	N/A
Travel cost - car	-0.0392	-6.25
Travel cost - P&R	-0.0378	-5.98
Travel cost - Uber	-0.0389	-5.98
Travel time variation - car	-0.0406	-3.09
Travel time variation - P&R	0.0005	0.03
Travel time variation - Uber	0.0094	0.52
Service Headway - P&R	-0.3153	-1.94
Security - car	0.0898	0.57
Security - P&R	0.3951	2.3

8.7.2 RP Model

	RP MODEL	
Variables	Estimate	Rob t ratio
ASC - car	0.8852	1.87
ASC - P&R	0.2388	0.46
ASC - Uber	0	N/A
Travel cost - car	-0.0398	-6.3
Travel cost - P&R	-0.0382	-6.02
Travel cost - Uber	-0.0391	-5.9
Travel time variation - car	-0.0389	-0.84
Travel time variation - P&R	-0.0797	-1.4
Travel time variation - Uber	-0.0003	-0.01
Service Headway - P&R	-0.3122	-1.86
Security - car	0.0844	0.53
Security - P&R	0.4115	2.38
Shift in ASC for time spent - P&R	-0.0158	-0.12
Shift in ASC for time spent - car	0.0017	0.1
Shift in Travel time variation for work trips - car	0.0133	0.26
Shift in Travel time variation for work trips - P&R	0.1148	1.96
Shift in Travel time variation for work trips - Uber	-0.0416	-0.75
Shift in Travel time variation for social trips - car	-0.0054	-0.11
Shift in Travel time variation for social trips - P&R	0.0773	1.41
Shift in Travel time variation for social trips - Uber	0.0155	0.42

8.7.3 Final Model

	FINAL MODEL	
	ESTIMATE	ROB T RATIO
ASC - car	-0.1902	-0.21
ASC - P&R	-0.6803	-0.68
ASC - Uber	0	N/A
Travel cost - car	-0.0409	-6.24
Travel cost - P&R	-0.039	-6.02
Travel cost - Uber	-0.0399	-5.87
Travel time variation - car	0.0236	0.44
Travel time variation - P&R	-0.1197	-1.7
Travel time variation - Uber	0.0357	0.38
Service Headway - P&R	-0.2927	-1.73
Security - car	0.0771	0.48
Security - P&R	0.4199	2.39
Shift in ASC for time spent - P&R	-0.0225	-0.16
Shift in ASC for time spent - car	0.0261	0.22
Shift in Travel time variation for work trips - car	0.0106	0.2
Shift in Travel time variation for work trips - P&R	0.1368	2.32
Shift in Travel time variation for work trips - Uber	-0.0309	-0.49
Shift in Travel time variation for social trips - car	0.0051	0.1
Shift in Travel time variation for social trips - P&R	0.0928	1.66
Shift in Travel time variation for social trips - Uber	0.0218	0.44
Shift in ASC for females - P&R	-0.3034	-0.81
Shift in ASC for females - car	-0.1479	-0.49
Shift in travel cost for those employed - car	-0.0477	-1.13
Shift in travel cost for those employed - P&R	0.0603	1.05
Shift in travel cost for those employed - Uber	-0.0544	-0.95
Shift in travel cost for those unemployed - car	-0.0893	-3.98
Shift in travel cost for those unemployed - P&R	0.0168	0.44
Shift in travel cost for those unemployed - Uber	-0.0298	-0.61
Shift in travel cost for students - car	-0.1086	-3.03
Shift in travel cost for students - P&R	0.0307	0.66
Shift in travel cost for students - Uber	-0.0642	-1.1
Shift in travel cost for those self -employed - car	-0.0117	-0.36
Shift in travel cost for those self - employed - P&R	0.0029	0.07
Shift in travel cost for those self - employed - Uber	-0.0501	-0.81
Age - car	0.0376	1.17
Age - P&R	0.0362	1.07
Age - Uber	-0.001	-0.04