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A study of behavioural changes in a road congestion reduction scheme, where monetary rewards are provided for avoiding the rush hour

by

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Abstract

Mobility is a condition for economic growth. As transport systems become more and more congested due to increased demand for mobility, the normal response of governments has been to increase capacity through investment in more infrastructure. The Netherlands have introduced mobility management schemes which financially reward road users to avoid the peak-time. These schemes are proving that congestion problems can be addressed in other ways.

This research analyses data from one of these schemes using exploratory data analysis to provide insights into behavioural changes. The research examines the extent to which the demographics of the scheme population, and whether changing the financial reward, influences travel behaviour.

The research found that a reduction in financial reward did not significantly alter the overall result. The research also found that those participants who completed a voluntary survey, achieved higher levels of peak avoidances. However, the research found that there were no noteworthy behavioural differences related to the demographics of the participants. Moreover, the number and type of avoidance options declared by the participants did not seem to be related to congestion avoidance levels. Though, those participants with an origin and destination within a short distance of a transport hub, performed better than others. The last two findings were inconclusive and additional research is suggested. Overall, the findings indicate that attitude of participants is more important than demographics. The availability of modal alternatives also seems to have explanatory value.

Acknowledgements

Sincere thanks go to BNV Mobility BV for the supply of the anonymised data upon which this research is based.

I also owe a huge gratitude to Professor Jason Dykes my supervisor from City University London, for the time and effort that he has put in to my guidance and on support this master thesis. The time taken by Professor Dykes to review and discuss progress and direction of this dissertation was very much appreciated.

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1 Introduction

1.1 General

According to Vickrey (1969), Ortúzar et al. (2011) and Enoch (2012), changing commuter behaviours to influence demand for transport can be effective in meeting existing and future mobility needs. Initiatives in the Netherlands that reward road users for not travelling during the peak-time, have been shown to be an effective tool in achieving behaviour change (MU Consult, 2013). This reward-induced change in behaviour is intended to reduce travel demand on the road network at certain times of the day (Tillema et al., 2013). In some cases, these schemes are showing that peaks of demand for road transport can be met without the need for large infrastructure investment. They do this by offering a financial instrument for the optimisation of the road transport system, and better matching road demand with existing road capacity.

Several of these schemes have been piloted in the Netherlands since 2006, and some are in commercial operation. Therefore, understanding the behavioural changes across the demographic of the participants is of interest to scheme operators and sponsors alike. Also of interest to these two groups are the effects of the levels of rewards on scheme compliance and avoidance rates. These schemes are also known be of interest to other European nations as a potential instrument to include in future transport policies (Urban ITS Expert Group, 2013). Therefore, this research may be relevant for other governments, transport planners, and transport economists.

This research is intended to provide some insights into the behavioural aspects of a recent rewards-based peak-avoidance scheme in the Netherlands.

1.2 Background

Car ownership in the Netherlands has reached a level of 420 passenger cars per 1000 inhabitants (World Bank, 2014a). This car ownership ratio is somewhat lower than the EU27 average of 563 cars per 1000 inhabitants.

However, congestion in this small and densely populated country, results in typical daily traffic jams of between 200km and 500km in length. This level of congestion occurs almost daily on just 3000kms of motorways (Trafficnet, 2014).

Despite the relatively low motorisation rate, the Netherlands ranks as the second most congested country in the world (INRIX, 2014). The average Dutch motorist spending an additional 44 hours in traffic every year due to congestion. Pressure on the road network has been increasing due to the fact that car ownership has been rising steadily since 2001 (CBS, 2014a). Population growth and job migration to the densely populated urban areas has also added to this congestion (CBS, 2014b). This rise in motorisation and population movement has been met so far through investment in road transport infrastructure. However, the Dutch Government has long-since recognised that the traditional "predict and provide" approach to the provision of road infrastructure, is neither sustainable, nor affordable in the long term (Rijkswaterstaat, 2014). Even if car ownership levels have peaked, as is the suggestion for some OECD countries (The Economist 2012a & 2012b), the current congestion problem is recognised by Dutch planners and politicians, as one that needs to be resolved. This is currently being addressed in the Netherlands through radical and pioneering changes in transport policy that facilitate behavioural change (Rijkswaterstaat, 2014).

In order to tackle the demand management problem, the Dutch Government initially considered the instrument of kilometre charging and tolling (Bliemer et al., 2009). However, a proposed move to nationwide road pricing was unpopular with the public due to privacy, cost, and discrimination concerns[1].

Essentially the Dutch behavioural change schemes encourage commuters not to travel on certain routes during the peak-time, by the distribution of monetary

[1] Road pricing is often considered as a regressive approach; a tax on the poor and one that favours the rich as they have the higher ability to pay and a higher value of time (See (Rouwendal and Verhoef, 2006)

and non-monetary rewards. These programmes are often described as reverse congestion charging schemes and reverse tolling schemes. (Ben-Elia, & Ettema, 2009). They are also a form of road pricing (Ubbels, 2006).

There have been positive and sustained results with these targeted policies and projects in the Netherlands (Bliemer et al., 2009, Palm et al., 2010 & Palm et al., 2012). So much so, that they are now considered to be a good travel demand management substitute to the instrument of kilometre charging and tolling (Rijkswaterstaat, 2014).

There are a number of these schemes in operation in the Netherlands. Each one of them targeting different areas and corridors with chronic congestion.
This research reviews and analyses the travel behaviour changes emerging from one of these schemes. This recent scheme is focussed on a highly congested region: where road traffic is currently being reduced by up to 6000 peak-time avoidances every day.

2 Research aims, objectives and questions

2.1 Research overview and aims

This research involves a detailed analysis of a large data-set of 10,000 participants of this peak avoidance scheme. The research takes a hypotheses-based approach and uses exploratory data analysis techniques, to examine if congestion avoidance is influenced by the demographics of the participant population. It also examines the influence of changes in financial incentives on participant attrition and congestion avoidance rates.

Any significant relationships between behaviour changes and the demographics or reward structure identified by this research might help in the design of future travel demand management schemes. Such indications may support future initiatives in terms of the design of a more optimised reward structure and targeted marketing. The rationale being that if the right number and type of participants are recruited with appropriately targeted incentives, this can serve to optimally balance demand for road transport and capacity with the costs of the scheme.

2.2 Research objectives

There were three objectives set to support delivery of the aims of this research. These were to:

1. Review, analyse and explore the data and identify any patterns, trends and relationships between the reward level, the demographics and the behavioural change realised by the scheme.

2. Examine how understanding the behavioural changes could influence reward structure required and the size of the population that future schemes need to recruit in order to achieve the target number of peak hour avoidances.

3. Increase understanding in the field of travel demand management and behaviour change by surfacing the facts, interpreting the data and reaching conclusions through reasoned arguments about their relative significance.

2.3 Research questions

The following five research questions have been derived to support the aim and objectives of the research. These questions are supported by expert views and empirical evidence from the literature review.

RQ 1: Are congestion avoidance rates affected by a reduction in rewards?

RQ 2: Do the demographics of the population have any bearing on the participants' behaviour change, attrition rates and propensity to avoid the congestion?

RQ 3: Is there is a relationship between congestion avoidance and those who responded to a voluntary questionnaire?

RQ 4: Is there a relationship between congestion avoidance rates and the type or number of alternatives that the participants have available to them?

RQ 5: Does the origin and destination of participants influence avoidance behaviour?

3 The scheme under analysis

3.1 Overview

Participants are invited to join if they have been seen frequently at one or more congestion 'hotspots' during the peak-period prior to the start of the scheme[2]. Participants are provided with financial rewards for avoiding the peak-time in those 'hotspots'. Operation and enforcement of the scheme is achieved through automatic number plate recognition cameras, and if a participant's vehicle is not seen in the peak-time, then he or she will receive the reward. Participants can choose a reward that is either paid in money (cash) or a combination of cash and credit on the participant's public transport payment card. The combination of cash and credit has a slightly higher monetised value. However, the participants are at liberty to choose either option. The rewards are higher in the first 40 days in order to achieve high levels of avoidances from the outset. After this initial period, the reward levels for both options are reduced.

For completeness, an outline of the rewards system and structure is included in Appendix A.

3.2 Project Data

For the purpose of this research, the author had access to a single source of qualitative and quantitative data. This data included avoidance behaviour and limited demographic information about the participants. This data was originally gathered by the scheme operator for operational reasons.

To date, and to the knowledge of the author, there has been no analysis of the behavioural change seen on this project from the influence of demographics or the changes in reward levels.

[2] For 8 weeks prior to the start of the scheme the congestion hotspots are monitored with Automatic Number Plate Recognition (ANPR) cameras. Participants that are detected often are candidates for recruitment

3.3 Confidentiality, Data Privacy and Ethics

Permission to use the anonymised data for the purpose of this research was provided by the scheme operator. The data-set was provided on the understanding that the data will not be published into the public domain. Therefore, the original data has not be published with this dissertation. Only the descriptive statistics and data visualisations at an aggregate level that describe facts, detect patterns, develop explanations and test hypotheses are included.

Privacy or ethical issues have been dealt with by the supplier of the data. The information in the data-set has been completely anonymised by the scheme operator to their satisfaction. There is no traceability from the data or observations to the scheme participants themselves. Notwithstanding this, after the research study is completed, all of the data will be destroyed.

The City University Ethics Questionnaire has been completed and appended to this dissertation in Appendix B.

4 Review of Literature

4.1 Meeting the transport demand – traditional approach

4.1.1 Transport – A derived activity

Ortúzar et al., (2011, p.3) remind us that demand for transport is primarily derived. Meaning that transport is not an end in itself, rather, it is a means to an end. Kaparias (2013) illustrates this by showing that transport networks and systems either move people to participate in activities, such as work, education and leisure (mobility), or they move goods from one place to another for some economic purpose; such as manufacturing, use, or consumption (freight).

Since we all have similar needs and behaviour patterns that occur at similar times of the day, our transport facilities and systems are characterised by peaks of excess demand, interspersed by periods of excess capacity. Ortúzar et al., (2011, pp.3-8) explain that the induced nature of transport demand and the limits on transport supply, means that capacity and demand throughout a typical transport network is rarely in balance.

4.1.2 Peaks of demand lead to congestion and unsustainability

Peaks of excess demand typically lead to congestion in the transport system causing delays, excessive energy use, lost opportunity, and other unsustainable consequences such as noise and accidents. Many of us experience these every day in traffic jams during the morning and evening peak hours (Black, 2010).

Congestion and all of its associated externalities are a major part of the unsustainability of transport (Black, 2010 pp, 23-63), and this is of concern to politicians, economists, planners and the general public (Saleh & Sammer, 2012).

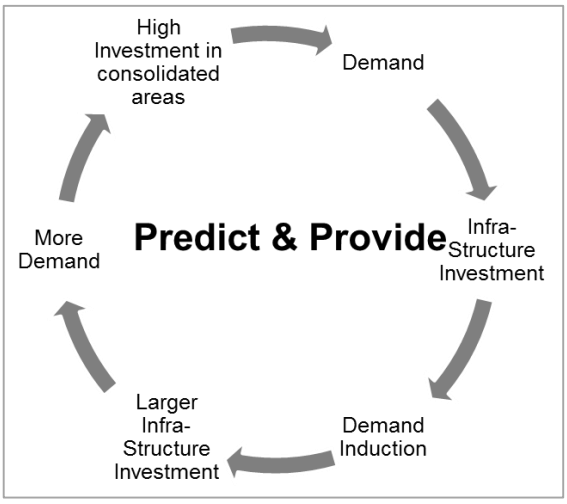
4.1.3 Traditional solutions to address congestion on roads

Congestion mitigation tools are many and varied. Black (2010) lists 12 congestion mitigation tools in his volume, which range from expanding the road system to dynamic road pricing. He also discusses a number of other travel demand management techniques aimed at changing user behaviours.

Saleh and Sammer (2012) explain that expanding the road system, rather than attempts to curb demand and influence behaviour, has been the traditional policy and approach of governments to solve the supply and demand problem. Transport planners have been matching road capacity against the demands of economic growth and car ownership for many decades. Now, further expansion in some geographies has become unaffordable, both economically and socially. It has become clear that uncontrolled demand for transport by road, first cautioned by Pigou (1920), cannot be sustained.

4.1.4 The predict and provide approach

Expanding the road network through a “predict and provide” approach has been shown in many developed nations to have become a vicious circle. The “predict and provide” approach is based upon the forecasting of traffic demand, that is then satisfied through the build of more infrastructure. This in-turn induces more demand and leads to the requirement for high investment and land use (Saleh and Sammer, 2012). This approach has been shown to be unsustainable and has typically resulted in many undesirable effects such as car dependency, land-take, and congestion (Black, 2010). The “predict and provide” model is illustrated in figure 4.1.1.



Source: Adapted from a study performed by the author on behalf of BNV Mobility BV

Figure 4.1.1 – The Vicious Circle of the Predict and Provide Model

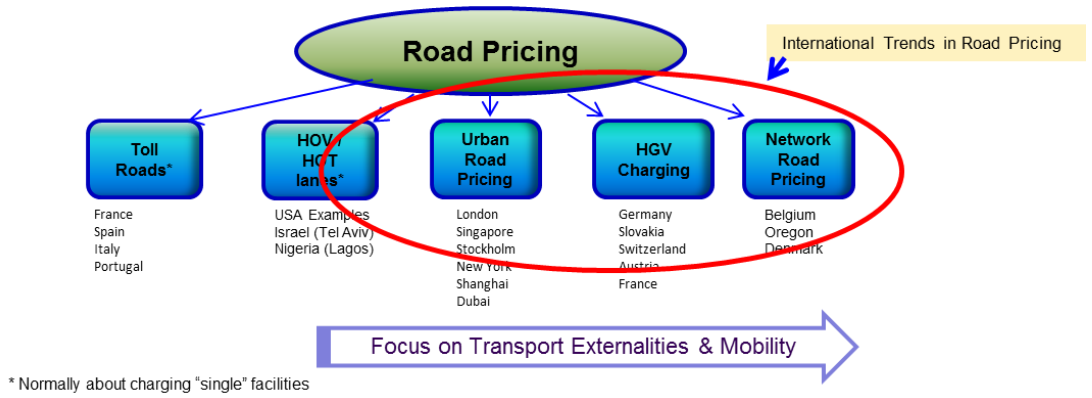
4.2 Road pricing – the economists "answer" to congestion

A solution for the road congestion problem popular to most transport economists, is the principle of road pricing. The theory being that pricing as an instrument can change road user behaviour, and if dynamically applied, it can suppress demand at the busiest times of the day.

Traditionally, road infrastructure has been seen as a 'public good', financed by governments and "free". However, most nations use course road pricing mechanisms such as taxes on fuel, car registration, parking fees and annual circulation tax. But as Ubbels, (2006) points out, the economic theory of a more efficient road-pricing scheme have only rarely been implemented in practice. There are specific schemes around the world that target particular areas of congestion such as the London, Stockholm and Singapore congestion charging schemes. However, at a global level, directly paying for using a road is still the exception rather than the rule (Walker, 2011).

There is an international trend to move from 'free roads' to a wider application of the "user pays" principle. This can then evolve to the use of road pricing as an economic instrument to address transport externalities and enhance mobility management (Verhoef et al., 2008).

The Diagram in Figure 4.2.1 shows how international trends in road pricing are evolving.



Source: Adapted from a study performed by the author on behalf of BNV Mobility BV

Figure 4.2.1 – International Trends in Road Pricing

4.3 Road pricing and behaviour change

Economists assert that pricing policies should be one of the main pillars of transport policy (Ubbels, 2006). This is predicated on the simple law of demand which states that when the cost of a good or service reduces, then consumption increases. Conversely, when costs increase, consumption reduces. However, as Ubbels (2006) points out, cost is not just related to monetary costs, but also includes the non-monetary costs of time, discomfort and risk. Ubbels also points out that price sensitivity is influenced by the quality and price of alternative modes.

Economic theory on road pricing was first promoted by Pigou (1920) and Knight (1924) as the only fair way to internalise the externalities of road transport such as congestion and pollution. Vickrey (1969) was a modern-day advocate of road pricing and congestion charging. His solution was to apply real-time differentiated tolls and parking fees to eliminate bottlenecks. Vickery theorised that this would result in a change in behaviour of road users in terms of route choice, mode of transport, and time of travel.

Vickrey (1969) promoted pricing for access to the road transport system as a model application of market forces. His hypothesis is the basis for many behaviour change road pricing systems today. Vickery posits that those who are able to change their schedules to the cheaper less congested periods would do so, and that this would result in reduced congestion for all. The whole basis being that one is spreading traffic over time and thereby enabling increased flow. Vickrey's hypothesis suggests that a financial incentive is required to sustain reduced congestion.

For policy makers to have an influence on congestion and particularly peak hour reduction, Ubbels (2006) recommends a time differentiated charge. This will most likely result in travelling outside the peak. People will react differently to different pricing regimes (Ubbels, 2006), and it is considered that business trips are less elastic than social trips, meaning that trips for business or commuting maybe less sensitive to road pricing (Cavalini et al., 1996 cited by (Ubbels, 2006 pp49). However, the success of the Dutch mobility schemes have shown that commuters do have some flexibility (MU Consult, 2013).

4.4 From "predict and provide" to mobility management through behavioural change

Pricing measures are considered as one of the major tools of policy makers to influence transport development and behavioural change. Whether it is mode choice, departure time or whether to travel at all. (Ubbels, 2006). However, large-scale nationwide road pricing schemes along the lines described above, have not received political and public support to date. This is not because they don't offer the promise of being able to address the supply and demand conundrum, but it is the author's view, that they just are too large and risky in nature to be implemented within one political term. Moreover, such initiatives often represent a change in the taxation regime for many countries which can be challenging (van Wee, 2010).

The opposite of road pricing, vis-à-vis rewarding is also a pricing instrument (Ubbels 2006 & Ben-Elia and Ettema 2009). The road pricing pilot schemes

such as those in the Netherlands, as well as the more traditional approaches to road user charging being trailed in the USA (The Economist, 2013), are now focusing more and more on combatting transport externalities and facilitating behavioural change: These being the economic and social utilities first posited almost a century ago by Pigou (1920), Knight (1924), and more recently, by Vickery (1969 & 1997).

In more recent years, mobility management has become the source of some study and limited trailed application. Verhoef et al., (1996) reviewed the feasibility of regulating road transport externalities through travel demand instruments that would change behaviour. In the UK, Sloman et al (2010) describe the "Smarter Choices Programme" which is a series of mobility management measures that have successfully changed travel behaviours in a number of UK towns.

According to Saleh & Sammer (2012) mobility management policies are targeted at influencing the travel behaviour of individuals through voluntary reduction of travel from temporal, spatial, and mode-choice dimensions. Saleh & Sammer (2012) also point out that such policies can even influence the decision to travel at all.

Mobility management is a departure from the "predict and provide" approach, in that it is based upon policies that provide a more efficient transport system through behavioural change. In effect, mobility management is about getting better use from the existing transport infrastructure, changing behaviour and raising awareness of commuting alternatives at the lowest cost to society (Rijkswaterstaat 2014).

Mobility management therefore, aims to change behaviours and match transport demand with transport capacity across the road network and other transport modes. It is about motivating transport users with incentives and information to change their travel behaviour. It is about encouraging and informing us such that we can travel at a time, or on a mode, when demand is

reduced, or even to not travel at all. Such behavioural change is facilitated by providing incentives, knowledge of alternatives and having the flexibility to choose time of travel. With all of this, we then have the motivation and the information to avoid congestion and delay.

4.5 Dutch mobility context

The Netherlands are rather pioneering in the area of addressing the sustainability of transport, and have done a lot of policy work in respect of the related areas of mobility, economy, environment and land use (van Wee, 2010).

Road pricing was proposed to address road congestion and its related externalities. This was proposed as an instrument for behavioural change and a solution to the mobility issue. Despite the well-intended policy, it has been the centre of political debate for many years. Six successive ministers have proposed road pricing schemes so far, without much public support (van Wee, 2010). In 2010 road pricing was removed from the political agenda in the Netherlands and was subsequently replaced by initiatives of paying differently for mobility and getting better use from the existing infrastructure. These policies still exist today and are based upon stakeholder participation and incentivising behavioural change (MU Consult, 2013).

The Dutch schemes that have replaced the road pricing policy are intended to contribute to the long-term modification of commuter's work patterns. These modifications in commuter behaviour are targeted at where and when they perform their work, and how and when they travel. An example is the "SpitsScoren" scheme (translated to "profit from the peak") that was operated in the Rotterdam port area from 2008 to 2012 (TfL, 2012 pp.189-192). The schemes are also aimed to improve regional and employer accountability, and to encourage and stimulate the longer term development of commercial mobility services (MU Consult 2013 & Rijkswaterstaat 2014).

4.6 Optimising existing transport infrastructure in the Netherlands

Black (2010, p.173) states that in the Netherlands the car has created unacceptable levels of congestion that can only be addressed through large investment in new facilities. However, politicians and planners in the Netherlands are embracing this congestion issue in creative ways. They have shaped a strategic agenda for better use of the transport infrastructure termed "Beter Benutten" (Rijkswaterstaat, 2014).

Rewarding road users for avoiding peak hour traffic can achieve a similar behavioural change to that of pricing (Tillema et al., 2013). The results seen from these schemes are changed travel behaviour and a significant reduction of the total rush hour traffic. The mobility related schemes signal a move away from transport infrastructure provision towards one of mobility provision. It is the Dutch experience in the area of facilitated behavioural change that forms the basis for this research.

4.7 Behavioural changes seen in the Dutch schemes

Traffic congestion is an issue which involves complex special and temporal dynamic forces (Ubbels, 2006). Assumptions are made in transport models regarding behavioural responses to pricing related to congestion (Lindsey & Verhoef 2000). However, a time dependant fee seems to have a considerable effect on the departure time of road users (Ubbels, 2006).

Ubbels, (2006 pp. 47-49) states that there are very few physiological studies or empirical research of behavioural change due to the effectiveness of road pricing policies. What does exist is rather inconclusive and Ubbels concludes that a change in behaviour is very much dependent upon individual characteristics. Ubbels cites Ajzen (1991) as concluding that people's intentions drive behaviour. Meaning that people exhibit more behavioural change if they have a positive rather than a negative attitude towards the new behaviour. Pricing, or rewards play a part in this, as individuals weigh costs

and benefits. However, Ubbels hypothesises that other aspects such as comfort, time savings, awareness of CO2 emissions and congestion avoidance might be important as well. This suggests that perceptions, motivations and habits are also important in addition to pricing or rewards.

According to Ben-Elia and Ettema (2009), participation in these mobility schemes is linked to flexibility particularly around working time and constraints that come from the employer. However, they assert that participation is especially linked to personal motivations.

Review of the literature shows that Reasons to participate vary from scheme to scheme. According to the MU Consult report (2013), the top three reasons provided by participants for their involvement are as follows:

- Compensation
- Social reasons
- Travel Time savings

4.8 From a transport infrastructure age to a mobility age

Mobility is a condition for economic growth, but at the same time, mobility needs to be affordable; financially, socially and environmentally (Black, 2010 & Ortúzar et al., 2011).

Gaps in funding for existing and new transport infrastructure, combined with the focus on decarbonisation of transport and behavioural change is promoting an agenda of efficiency and getting better use from the existing transport infrastructure (OECD 2014).

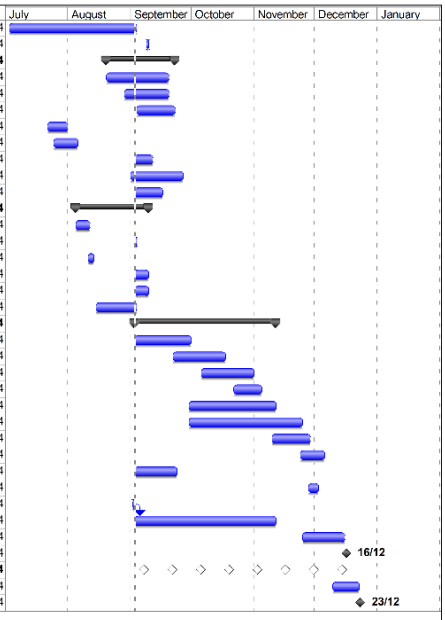
Trends in transport, particularly in behavioural change programmes such as the one under research, signal that we are moving from an infrastructure age to a mobility age.

5 Programme & methodology

5.1 Programme

The programme in figure 5.1.1 formed the basis for planning and progressing this research project. Progress was reviewed during regular supervisor meetings between June 2014 and December 2014.

ID	Task Name	Duration	Start	Finish
1	Develop Research Proposal	45 days?	Thu 03/07/14	Wed 03/09/14
2	Review marking criteria to focus structure, content and effort	1 day	Tue 09/09/14	Tue 09/09/14
3	**Perform Full Literature Review**	**24 days?**	**Wed 20/08/14**	**Mon 22/09/14**
4	Perform conceptual literature review	23 days?	Wed 20/08/14	Fri 19/09/14
5	Perform research literature review	16 days	Fri 29/08/14	Fri 19/09/14
6	Develop hypothesese based on Lit review	13 days	Thu 04/09/14	Mon 22/09/14
7	Establish what data is available and define the data required	8 days	Tue 22/07/14	Thu 31/07/14
8	Establish permission to mine and use the data	8 days	Fri 25/07/14	Tue 05/08/14
9	Research stats techniques that can be used to analyse data	7 days	Wed 03/09/14	Thu 11/09/14
10	Determine visualisation software to be used (e.g. Mondrian, Excel, Table	20 days	Mon 01/09/14	Fri 26/09/14
11	Finalise the research methods	10 days	Wed 03/09/14	Tue 16/09/14
12	**Collect clean and transform the data**	**26 days?**	**Tue 05/08/14**	**Tue 09/09/14**
13	Mine and collect data	5 days	Tue 05/08/14	Mon 11/08/14
14	Categorise the data	1 day?	Wed 03/09/14	Wed 03/09/14
15	Anonomyse the data (respecting ethics and privacy)	3 days	Mon 11/08/14	Wed 13/08/14
16	Clean the data	5 days	Wed 03/09/14	Tue 09/09/14
17	Transform the data into a form that is suitable for analysis	5 days	Wed 03/09/14	Tue 09/09/14
18	Vacation	14 days	Fri 15/08/14	Wed 03/09/14
19	**Analyse the data using descriptive stats and data viz techniques**	**50 days**	**Wed 03/09/14**	**Tue 11/11/14**
20	Describe facts	20 days	Wed 03/09/14	Tue 30/09/14
21	Detect patterns	20 days	Mon 22/09/14	Fri 17/10/14
22	Develop explanations	20 days	Mon 06/10/14	Fri 31/10/14
23	Test Hypotheses	10 days	Wed 22/10/14	Tue 04/11/14
24	Show patterns in the data using data visualisation techniques	31 days	Tue 30/09/14	Tue 11/11/14
25	Evaluate and interpret the results	40 days	Tue 30/09/14	Mon 24/11/14
26	Critically analyse the findings and draw conclusions	15 days	Mon 10/11/14	Fri 28/11/14
27	Develop conclusions	10 days	Mon 24/11/14	Fri 05/12/14
28	Synthesise the findings with the desk research	15 days	Wed 03/09/14	Tue 23/09/14
29	Identify and present study inaccuracies and limitations	3 days	Fri 28/11/14	Tue 02/12/14
30	Draft Contents listing	1 day	Tue 02/09/14	Tue 02/09/14
31	Draft Dissertation	50 days	Wed 03/09/14	Tue 11/11/14
32	Finalise Dissertation	15 days	Tue 25/11/14	Mon 15/12/14
33	Submit Dissertation	0 days	Tue 16/12/14	Tue 16/12/14
34	**Supervisor meetings (Nominal)**	**70 days**	**Mon 08/09/14**	**Mon 15/12/14**
43	Develop Presentation for Project Oral	9 days	Wed 10/12/14	Mon 22/12/14
44	Oral Examination	0 days	Tue 23/12/14	Tue 23/12/14



Project: Programme at 07 Sept
Date: Wed 03/09/14

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Page 1

Source: Author's own work

Figure 5.1.1 – Work Plan July – December 2014

5.2 Research methodology and approach

According to Zikmund et al (2012), the scientific method is an approach that allows us to synthesise knowledge and evidence, and it helps us to reach objective conclusions about the real world.

This research project uses the scientific method, and followed a seven-stage process as outlined in figure 5.2.1

Source: Own Work adopted from the scientific method in Zikmund et al, (2012)

Figure 5.2.1 – Seven-Stage Process Adopted for the Research - Adapting the Scientific Method

What follows in this chapter, is a description of each of the seven stages in figure 5.2.1

5.2.1 Review and synthesis of literature

A broad and detailed literature review was performed. This review identified the background and rationale for road pricing, and for using financial instruments for dealing with demand in road systems. It also examined the current paradigm shift away from the “predict and provide” approach for road demand, and concluded that we are moving from an infrastructure age to a mobility age. The literature review also identified and discussed authoritative sources on rewards-based peak hour avoidance schemes in the Netherlands, related to behavioural change.

5.2.2 Research question refinement

The literature review provided input to refine the research proposal and developed the research objectives, questions and methods. It also resulted in

the development of certain hypotheses about behavioural changes in congestion reduction schemes.

5.2.3 Data definition and collection

For this research, the author had access to a single source of qualitative and quantitative enterprise data. This data was gathered by the scheme operator for operational reasons. To that extent, the data should be considered as secondary data. The analysis of this secondary data provided a cost and time-effective way of conducting this research; since the collection of such data would have extended beyond the scope and time limitations of a normal MSc research project.

After receiving permission to use data from the scheme operators, the data-set to support the analysis was specified. The specification of the data-set was designed to match the research objectives and questions as closely as possible (see Appendix C).

The data request was constrained by the scope and availability of the secondary data, and some privacy and ethical considerations. The process of developing the data-set specification, was therefore an iterative process that was performed in close collaboration with the scheme operators.

The final data specification (Appendix C), was based upon a combination of travel behaviour observations for the scheme's population, and included the following:

1. The reference level of each participant. The reference level is based on a calculation linked to the number of times the participant was seen in the traffic prior to the start of the scheme.
2. The peak hour avoidance rates at the start of the scheme during an initial high reward period.
3. The peak hour avoidance rates after the first 40 days when the rewards were reduced.
4. Anonymised demographic data such as; gender, age, and vehicle ownership information for all participants.

5. High-level and generalised origin and destination information.
6. More detailed demographic data such as: distance travelled per year, education level and avoidance options available. This data was received for 65% of the participants who completed a voluntary questionnaire.

The data-set supplied was in tabular form, in comma separated values – where each row related to a participant in the scheme, and each column to a characteristic related to that participant's behaviour, or some demographic information. With information on 11,200 participants and multiple columns of categorical, nominal and ordinal data, this resulted in 357,840 items of raw data of different statistical types.

In its raw state, the data-set included many errors, omissions and missing information, and required a considerable amount of cleaning and further transformation for analysis.

5.2.4 Data preparation for analysis

This stage was about ensuring data quality, categorisation of the data and its transformation for analysis. Equally, it was about understanding the content of the data-set in detail.

According to Myatt, (2009) "The quality of the data is the single most influential factor in determining the quality of the analysis results". For this reason, the data was 'cleaned' for quality purposes. This included identifying and resolving errors, and removing or fixing entries with no data, or missing information. The scheme operators were consulted on how the data was collected and some of the specific meanings of the data and the reasons for the errors and omissions. The inconsistent or problematic data values were identified, and the values transformed or removed. As an example; for the variable 'Avoidance Rate after 40 Days', there were 1287 blank entries in the data. This was because those participants had not completed their second 40 day avoidance period at the time that the data was collected. These entries were deemed to be incomplete for the purpose of the analysis, and were removed from the data-set.

This data quality check and data cleaning resulted in a ‘clean’ data-set of 9787 participants.

Following the quality improvement process, the data was transformed into information that was suitable for analysis. Specifically, it was transformed into information that would match the research questions more closely.

Where data was insufficient, primary and secondary data from other sources was acquired or derived and carefully integrated with the existing data (Myatt, 2009). For example the generalised origin and destination postcodes were used to develop additional variables. This included identifying those participants having an origin and destination in a major town with access to good public transport.

5.2.5 Data analysis

Data analysis is a body of methods that help to describe facts, detect patterns, develop explanations, and test hypotheses (Kaparias, 2014).

Using a combination of basic descriptive statistical methods and exploratory data analysis techniques, the cleaned and transformed data-set was analysed in order to show patterns and describe facts about the data. This was done for the complete data-set and also for discreet sub-sets of the data.

The objective of the data analysis stage was to find facts which are non-trivial; that describe the data, and identify relationships which are novel. (Myatt, 2009).

In addition to basic statistical techniques, exploratory data analysis along the lines of those proposed by Tukey (1977) were employed using graphical techniques and Mondrian software (Theus & Urbanek 2011). This helped to detect patterns and provide insights into the data-set. Exploratory data analysis was also used to suggest and refine hypotheses to test.

From a descriptive statistics standpoint, the mean, median, mode, variance, standard deviation, and correlation values, were calculated for many of the numerical variables for the whole population.

Then a ‘filtering’ was performed which repeated the above analysis on a subset of the participants that had completed the optional questionnaire. This filtering was repeated for the remaining participants who had not completed the questionnaire. Any differences were identified and highlighted. Similarly, the filtering was repeated for each of the stated alternative options to traveling in the peak, and any differences and patterns identified.

A filtering was also carried out by clustering and analysing certain segments of the data with related observations. An example of this, is the analysis that was performed on the characteristics of the participants with higher than average performance.

This filtering and differences procedure was repeated for all of the variables in order to fully understand the data. Above all, it was performed to identify patterns and relationships in the data and to answer the research questions.

Following all of the filtering and identification of the main statistical values, some normality tests were performed to check whether certain variables were normally distributed. These normality tests were conducted by evaluating the degree of asymmetry of the distribution through the level of “skewness” and the degree of peakedness or flatness of the distribution through the level of ‘kurtoses

Regression analysis including some inferential statistics such as chi square tests were performed. This was done to identify the significance of the findings in the data and look at any relationships that might allow the development of a model that could help estimate values or predict future events. See Myatt, (2009).

5.2.6 Evaluation of results, findings development and critical analysis

Following the analysis, the results were evaluated, interpreted and further critically analysed to develop the findings and draw conclusions.

The data has been summarised in charts so that the reader can see the outcome of the analysis, the typical values of the data-set and how they vary.

Data visualisation techniques and design principles, such as those defined by Dykes, (2013), Meirelles, (2013), Tufte (2001) & Ware (2012) were adopted as far as possible to support and justify the work. These techniques were used to show the patterns in the data, and in some cases, identify patterns that were not obvious from the basic statistical analysis.

5.2.7 Synthesis of findings with the desk research

The findings derived from the data analysis and evaluation stages were further strengthened by synthesising the conclusions with the literature review. This supported the refinement of the conclusions. Moreover, it helped to develop the recommendations for future research and practice.

6 Work done and results obtained

6.1 Research Question 1

RQ1: Are congestion avoidance rates affected by a reduction in rewards?

The supporting hypothesis for this question is that the level of compensation influences participants' tendency to avoid congestion and change behaviour.

Null Hypothesis ($H1_0$): As the level of rewards are lowered, the avoidance rates reduce.

Alternative Hypothesis ($H1_A$): The level of rewards has limited effect on congestion avoidance rates.

Criterion (dependent) variables:

1. Avoidance rates for the first 40 days when the rewards are high,

2. Avoidance rates for the second 40 days when the rewards are lowered

Predictor (independent) variables:

1. Higher rewards for the first 40 days (€7.50 cash per day or €9 public transport reward)

2. Lower rewards for the second 40 days (€6 cash per day or €8 public transport reward)

Proposed Statistical Strategy:

Descriptive statistics, Normality test, chi squared test and correlation tests.

Proposed Exploratory Data Analysis Strategy:

Mondrian™ evaluation of the data-set

Sample size:

9787 participants

6.1.1 Summary statistics

The summary statistics of the data-set shown Table 6.1.1, indicate that the central values of mean and median avoidance rates[3] for the entire population. These values appear to be unaffected by the lowering of rewards. There was a small change in the standard deviation and a 1% improvement in the central measures[4] of the avoidance rates in the second 40 day period. This might suggest that the change in reward had a limited influence on the congestion avoidance rates; providing minor support for the alternative hypothesis.

General Statistics & Central Values	1st 40 days High Reward	2nd 40 days Low Reward
Mean Avoidance Rates	44%	45%
Median Avoidance rates	42%	43%
Standard Deviation	0.3	0.34
Total Population (Participants)	9787	9787

Source: Author's own work

Table 6.1.1 – Central value statistics for the congestion avoidance rates in both observed periods

6.1.2 Normality Tests

In social science, variable data rarely follows a normal distribution (Vaus, 2002). To check the avoidance rate data for normality, a simple test was performed by taking the mean and standard deviation of the two dependent variables in the data-set. Then an interval was constructed within which 95% of the values would be expected to lie (i.e., within the interval: Mean+/- 1.96 standard deviations). Applying this test created limits that were not feasible and confirmed that the distributions are non-normal. (See Appendix D). The

[3]Avoidance rates are measures compared pre-scheme behaviour of the participants

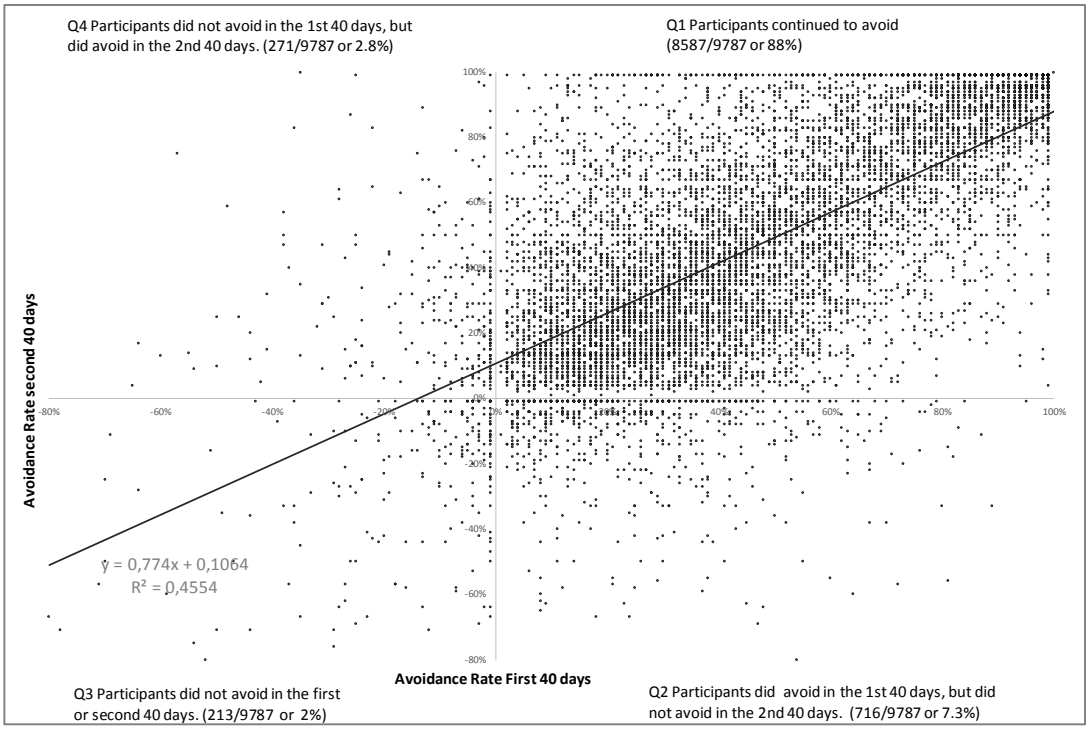
[4] Since the data does not appear to be normally distributed, the median avoidance rates rather than the mean are considered

non-normality can also be seen by observing the lack of symmetry in the distribution of avoidance patterns in figure 6.1.3.

Rather than transforming the variables to make them “normal”, or using non-parametric statistics, a linear correlation test, a chi square test and exploratory data analyses were performed in order to identify any relationships and patterns.

6.1.3 Linear Correlation Tests

The strength of the relationship between the participants’ behaviour in the first and second observation periods can be partially understood by a linear correlation test. The correlation test showed that there is a persistent and strong correlation coefficient of +0.69 between the numbers of avoidances in the two observation periods. This could indicate that a significant number of participants tend to strive to make sure the experiment will be a success, despite the rewards reduction. See Figure 6.1.1.

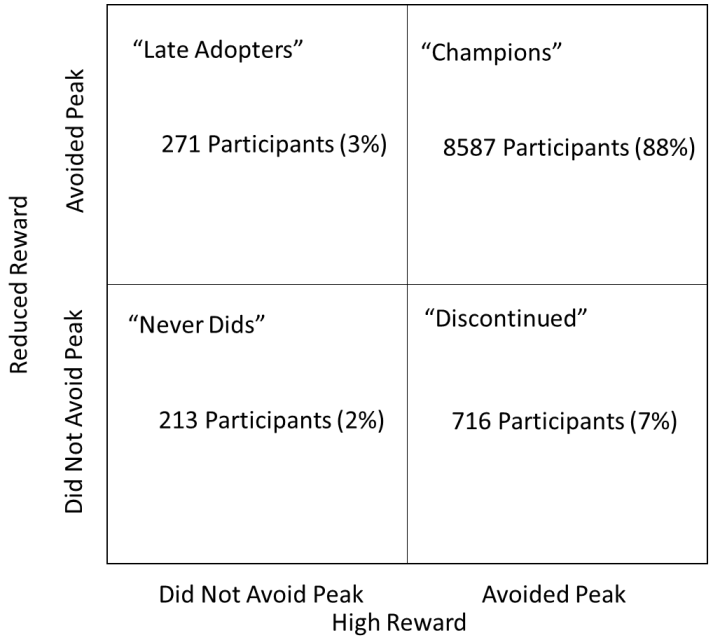


Source: Author’s own work

Figure 6.1.1: A Scatterplot and trend line showing the correlation between the avoidances in the first 40 days compared with that of the second 40 days

The data points in quadrant 1 of the scatterplot in figure 6.1.1 show those participants that were in continuous compliance. That is, that they were avoiding the congestion in the first period and continued to avoid in the second period when the rewards were lowered. The data points in quadrant 2 show those participants that stopped avoiding when the rewards were lowered. Quadrant 3 include those that were not avoiding in either period. And finally, quadrant 4 shows those participants that were not avoiding the congestion in the first period, but that started to avoid in the second period.

The information from the scatterplot is summarised in the compliance matrix in Figure 6.1.2. This shows the proportions of the participants and their degree of compliance in the high reward and low reward observation periods.



Source: Author's own work

Figure 6.1.2 –Avoidance Compliance Matrix

6.1.4 Changes in the distribution of avoidance rates

The changes in the distribution of avoidance rates in the high reward and low reward cases were analysed further; the distribution data is shown in table 6.1.2 and visualised in the histograms in figure 6.1.3

Congestion Avoidances	Change in avoidance: 1st 40 days High Reward	Change in avoidance: 2nd 40 days Low Reward	Trend	% Change
Participants not avoiding at all	484	929	↑	4,5%
0 - 20% Congestion Avoidances	1723	1789	↑	0,7%
20 - 40% Congestion Avoidances	2427	2010	↓	-4,3%
40 - 60% Congestion Avoidances	2072	1696	↓	-3,8%
60 - 80% Congestion Avoidances	1468	1447	↓	-0,2%
80- 100% Congestion Avoidances	1613	1916	↑	3,1%
Participants actively avoiding	9303	8858	↓	-4,5%
Total Population (Participants)	9787	9787	→	0,0%
Actual Avoidances per week	29519	29622	↑	0,3%

Source: Author's own work

Table 6.1.2 – Detailed statistics for the avoidance rates in both observed periods

Source: Author's own work

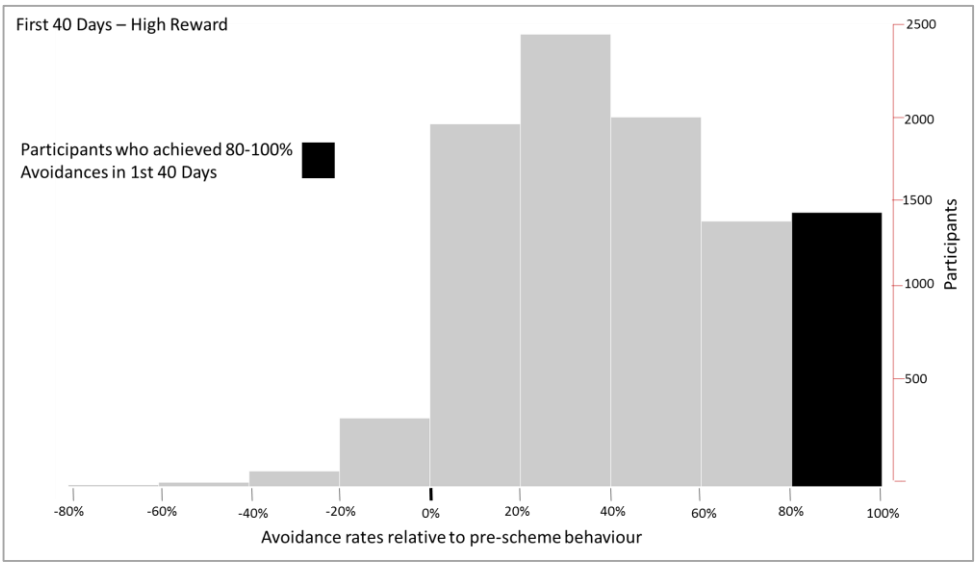
Figure 6.1.3 –Avoidance rates in both observed periods

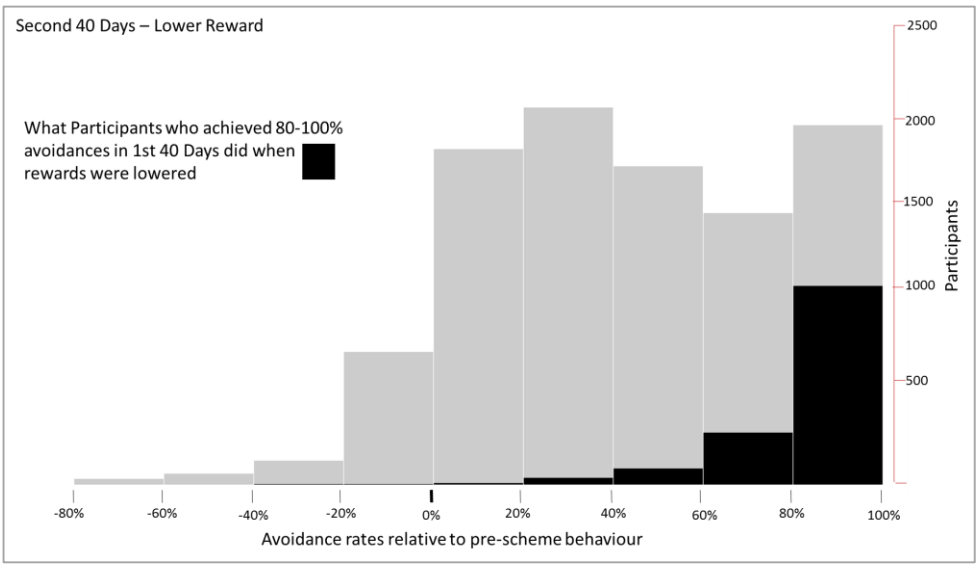
From the histograms and the table it can be seen that there was a general and sustained tendency to avoid the peak-time for the majority of the participant population. This was regardless of the reduction in rewards. However, there was a flattening of the distribution in the second observation period, resulting from an increase in those who stopped avoiding, combined with an increase in those who achieved higher avoidance rates. The non-avoiders, almost doubled when the rewards were lowered. Whereas those who achieved between 80-100% avoidances increased in the same period. Thus causing the flattening of the distribution.

6.1.5 An analysis of the increase in the higher avoidance rates

Sustained avoidances from 8858 (90.5%) participants and the progressive move to 80-100% avoidances from 3% of the participants was seen in the second observation period (See table 6.1.2). Also the actual number of weekly avoidances increased. This was despite the fact that the rewards were lowered. This could further support the alternative hypothesis that the level of reward has a limited effect on congestion avoidance rates for the majority of the population. This also holds for the scheme as a whole.

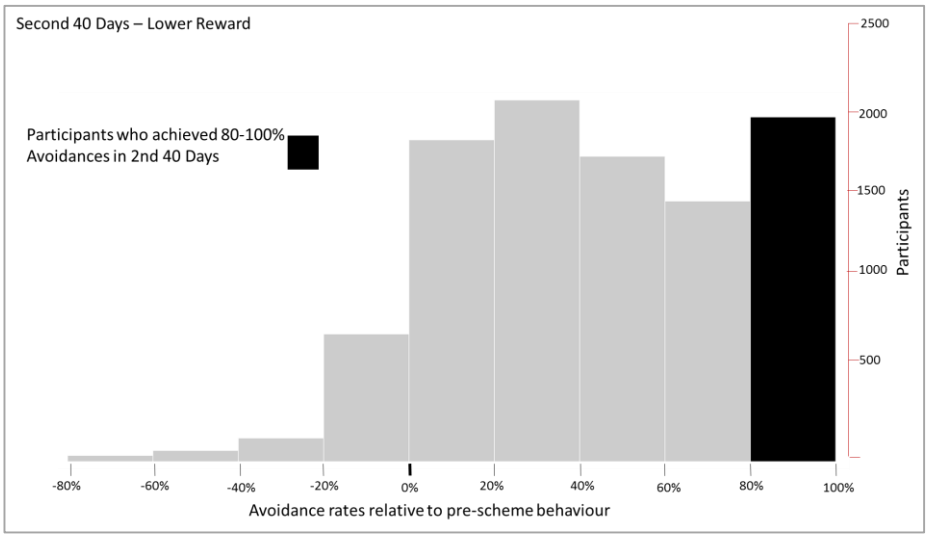
The histograms in figure 6.1.3 and the scatterplot in figure 6.1.1 show a progressive move to 100% avoidances in the second 40 day period from a number of participants. Equally, a number of those who had performed 80-100% in the first 40 day period, changed their behaviour in the second 40 day period. Figure 6.1.4 illustrates the change in behaviour of the higher avoiding participants in the first 40 day period when the rewards were lowered. Figure 6.1.5 shows the previous behaviour of the higher avoiding participants in the second 40 day period.

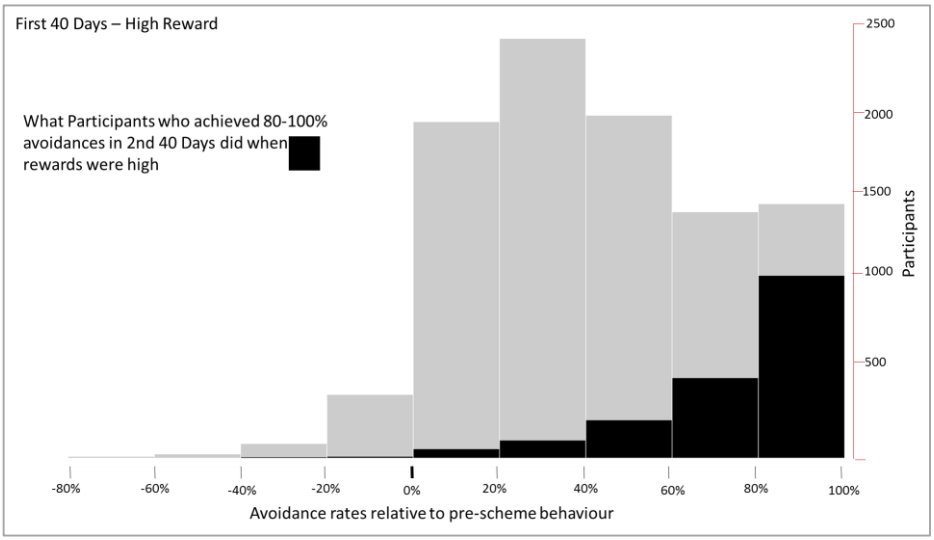




Source: Author's own work

Figure 6.1.4 – Change in behaviour of the participants who were achieving 80-100 avoidances in the first 40 day period when the rewards were lowered





Source: Author's own work

Figure 6.1.5 – Previous behaviour of the participants achieving 80-100 avoidances in the second 40 day period

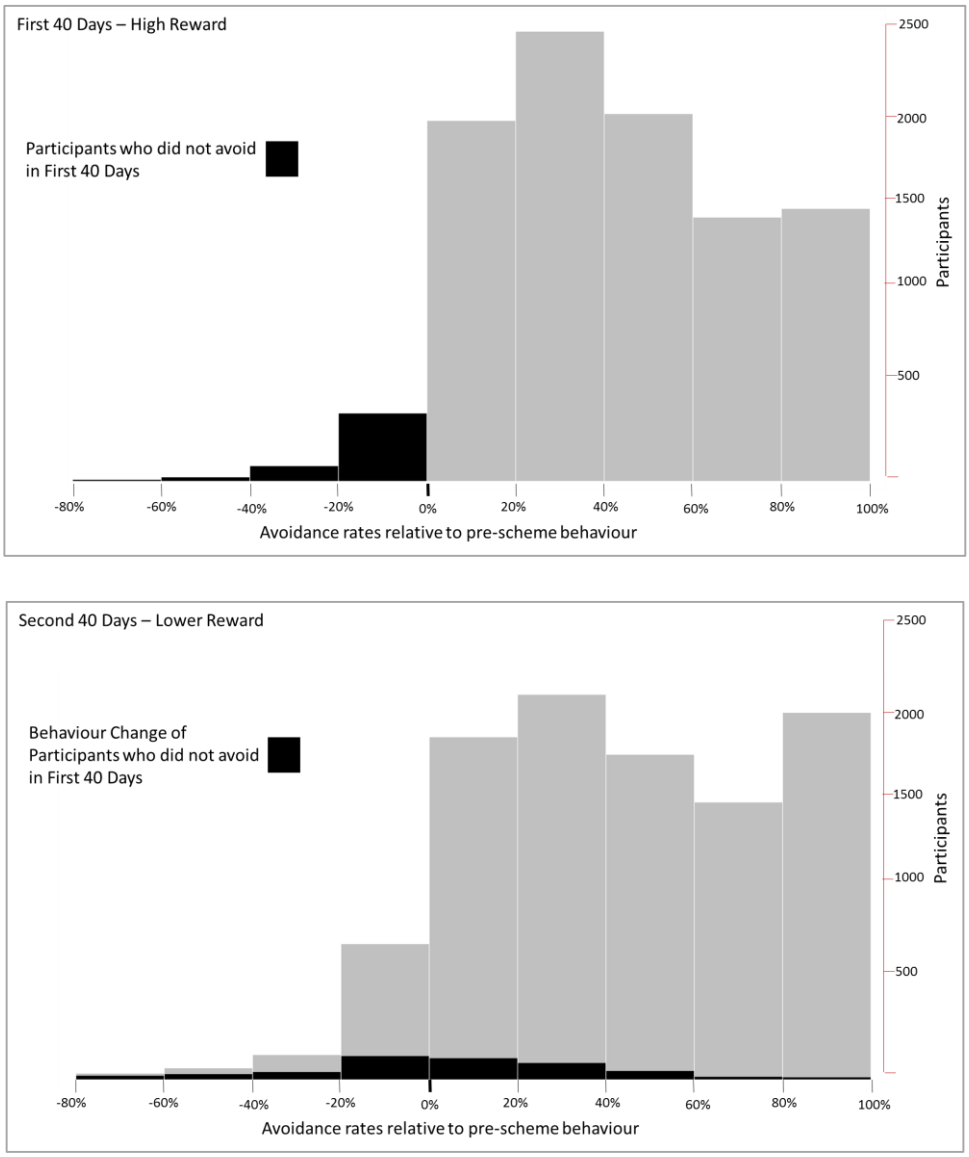
6.1.6 An analysis of the increase in non-avoidance rates

From the outset, 484 (4.8%) participants were not avoiding the peak and could be considered non-participants. When the rewards were lowered, an additional 445 (4.5%) participants also stopped avoiding the peak period. This increase in non-participation could indicate that the lowering of the reward was influential for some participants. A chi-square test indicated that the observed

frequency in avoidances from the first to the second observation period, differed significantly from what would be expected due to chance alone. See Appendix E.

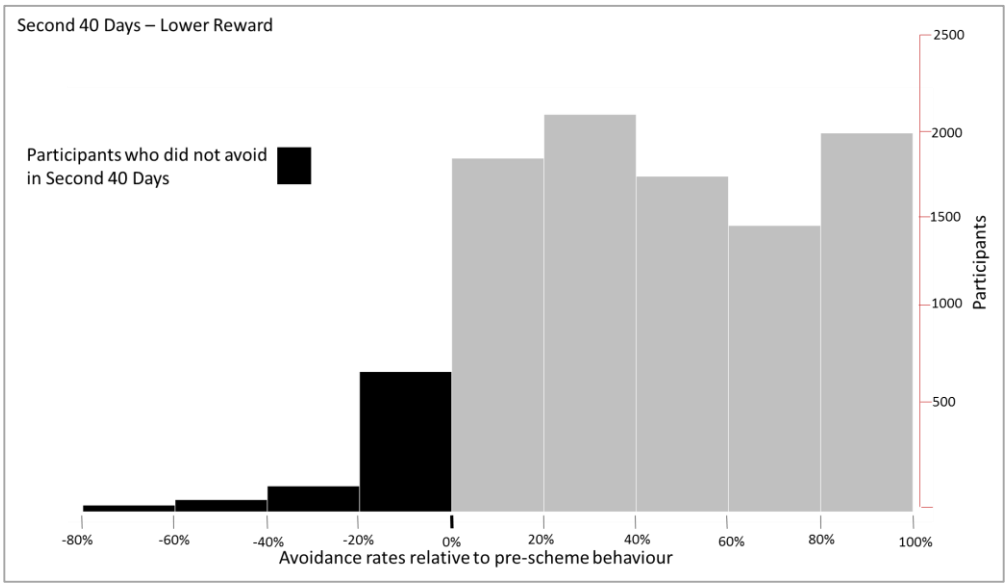
This provides support for the null hypothesis. However, what is more likely, is that this increase in attrition, represents some natural decay, and is independent of the reward reduction. This decay over time phenomenon has also been seen in schemes that did not have a change in the rewards level. For example, in a similar scheme performed in Rotterdam in 2008, more than 10% of the participants progressively stopped participating over an 80 day period (Palm et al., 2010). This indicates that that the 9.5% in 80 days attrition in our scheme, could be considered natural decay.

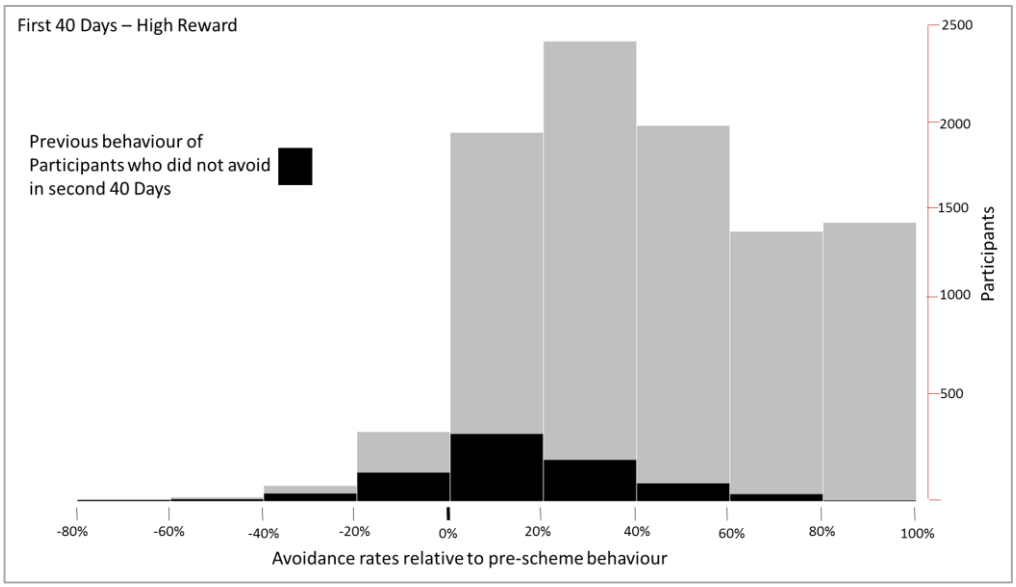
Moreover, more detailed analysis revealed a further insight. That is the participants who were not complying with the scheme in the first 40 day period were not completely the same individuals as those who were not complying in the second 40 day period. In fact, more than 50% of the non-compliant population in the first 40 days, became compliant in the second 40 days. This group achieved a low to moderate percentage of avoidances in the second period. This can be seen by comparing the two histograms in figure 6.1.6. What is also worthy of note is that more than 70% of the population who stopped avoiding in the second 40 day period, were previously making low to moderate levels of avoidance in the first 40 days; see figure 6.1.7.



Source: (Author's own work)

Figure 6.1.6 – More than 50% of the participants who did not avoid in the first 40 days became compliant in the second 40 days





Source: (Author's own work)

Figure 6.1.7 –70% of the population who stopped avoiding in the second 40 day period were previously making low to moderate levels of avoidance in the first 40 day period

These movements can also be seen by examining the scatterplot in figure 6.11. By examining quadrant 2 and quadrant 4, it can be seen that more participants who had been avoiding in the first 40 days stopped avoiding or did worse in the second period than in the first.

This complex combination of factors could indicate that for some, a lowering of the reward did not affect their motivation to avoid the congestion. Whereas

for others, particularly for those previously achieving low to moderate avoidance rates, the change in rewards could have meant that the overall benefit was marginal or negative. This may have had an influence in their motivation to continue to change their behaviour. To ascertain the absolute reasons would require further research and interviews which is outside the scope of this study. However it is recommended as future research.

From the scatterplot in figure 6.1.1 it can be seen that 213 (2%) individuals did not participate at all. For this group, it may be that there was a complete unwillingness or inability to change behaviour. However, this is inconclusive and would also require further research and targeted interviews.

6.1.7 Development of Success Rankings

To show the change in behaviour of the scheme participants after the rewards were reduced, success rankings were developed. These success rankings attempt to illustrate the move in avoidance rates from the first to the second 40 day period. They were designed by the author based upon avoidance rate levels, and improvement or deterioration in behaviour after the rewards were lowered. They were applied to the entire population using the logic outlined in table 6.1.3. The success rankings and frequency were then plotted in a histogram in figure 6.1.8.

Success Ranking	Criteria	Number of participants
0	Avoidance rates in both observation periods are less than 50% and the avoidance rate decreases	2604
1	Avoidance rates in both observation periods are less than 50% and the avoidance rate increases	1936
2	Avoidance rates in 1st observation period is greater than 50% and decreases below 50%	888
3	Avoidance rates in 1st observation periods is less than 50% and the avoidance rate increases to above 50%	1219
4	Avoidance rates in 1st and 2nd observation periods are greater than 50% and the avoidance rate decreases	1215
5	Avoidance rates in 1st and 2nd observation periods are greater than 50% and the avoidance rate increases	1925

Source: Author's own work

Table 6.1.3 – Success ranking criteria of avoidance rates in both observed periods

Source: (Author's own work)

Figure 6.1.8 – Success rankings showing the performance of the participants across both observation periods

The distribution of the success rankings in figure 6.1.8 show that the participant population either adhered to a good and improving behaviour when the rewards were lowered, or they adopted a poor and worsening behaviour. From the histogram, it is clear that there is a tendency to adopt a poor or worsening behaviour when rewards are lowered. However, the net number of avoidances actually increased due to the increase in 80-100% avoiders.

6.1.8 Preliminary conclusions

For the majority of the population (8587 participants) avoidances continued in the second period and a further 3% (271 participants) joined them who had previously not been avoiding. Only 7.3% of the population who were avoiding in the first period stopped avoiding when the rewards were reduced. This increase of non-avoiders is thought to be a natural decay in adherence to the scheme. What is important is that the net weekly avoidances increased when the rewards were lowered.

The analysis tends to support the premise that reduction in the reward has limited effect on congestion avoidance rates. See discussion and conclusions in section 7.1

6.2 Research Question 2

RQ2: Do the demographics of the population have any bearing on the participants' behaviour change, attrition rates and propensity to avoid the congestion?

The supporting hypothesis for this question is that a change in behaviour is likely to be dependent upon individual characteristics.

6.2.1 Information known about all participants

Avoidance behaviour and limited demographic information was known about all of the 9787 participants. This information is shown in terms of independent and dependent variables in table 6.2.1.

Independent Variables	Dependent Variables
• Number of times seen in the peak prior to the start of the scheme (reference level) • Gender • Age • Vehicle ownership • Reward option selected • Basic origin and destination information	• Avoidance Rate high reward • Avoidance rate lower reward

Source: Author's own work

Table 6.2.1 – information known about all of the participants expressed in terms of independent and dependent variables

In order to identify any relationships and behavioural differences across the participant population, the pre-scheme behaviour and demographics were

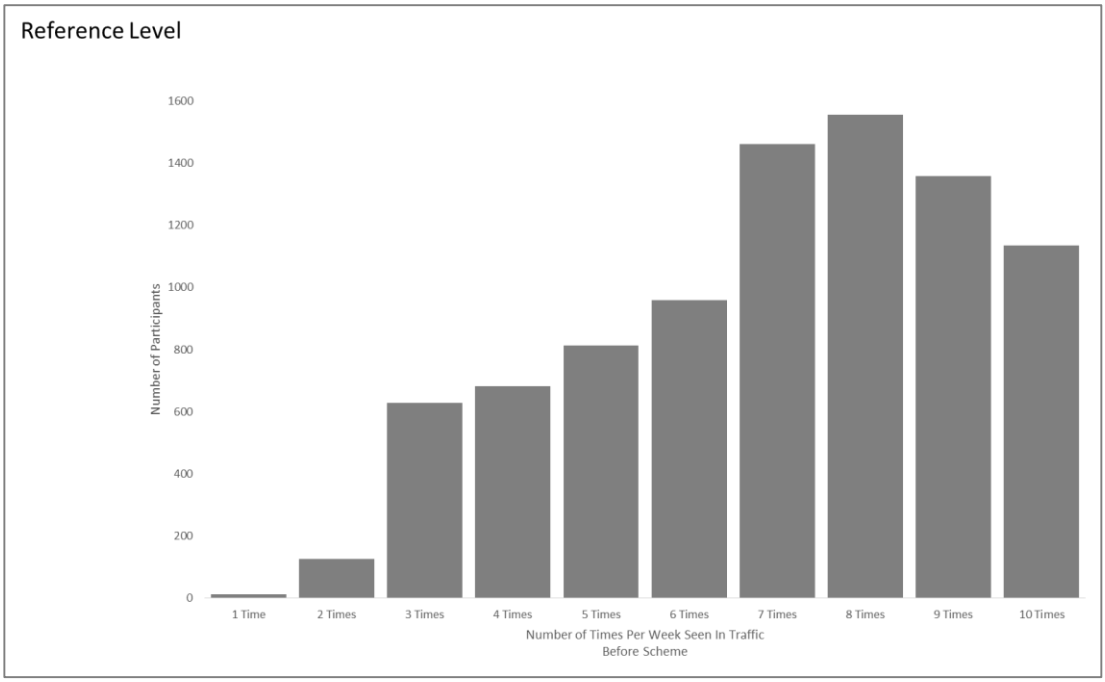
analysed in the context of the avoidance rates for both periods. The analysis was performed using a combination of exploratory data analysis, correlation tests, and chi square statistical tests.

6.2.2 Participants' reference level versus avoidance rates

A linear regression analysis indicated that the reference level variable is not correlated to the avoidance rate with a low $\boldsymbol{R^2}$ value of 15% goodness of fit to a regression line.

However, exploratory data analysis indicated that the number of times a participant was seen in the traffic before the scheme started, may be related to the avoidance rate that they achieved.

The reference level was converted to a weekly average number of the times that the participants were seen in the traffic prior to the scheme. This is shown in figure 6.2.1.

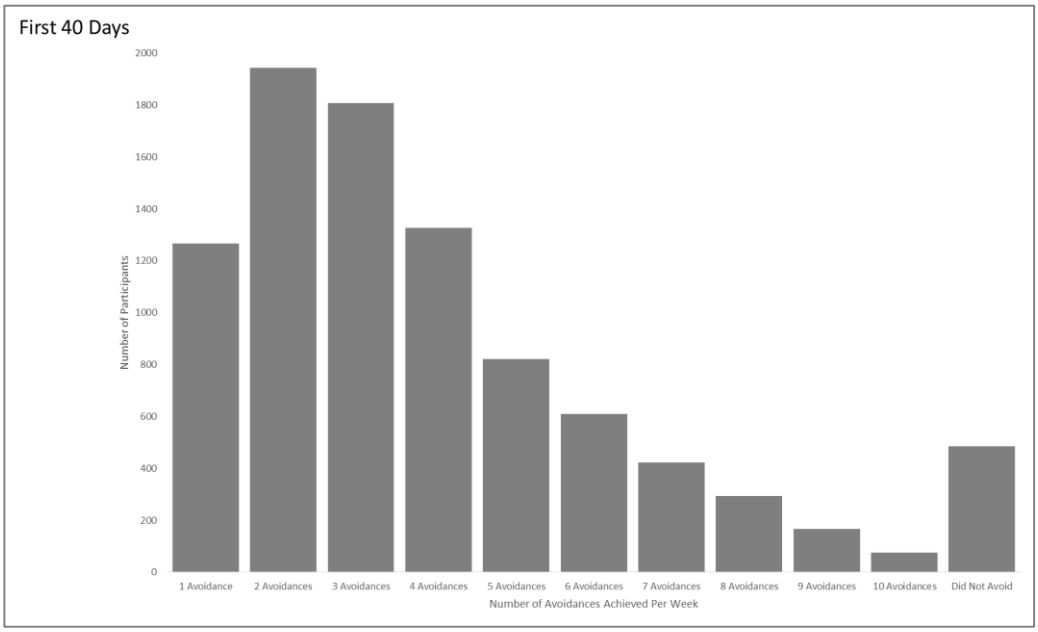


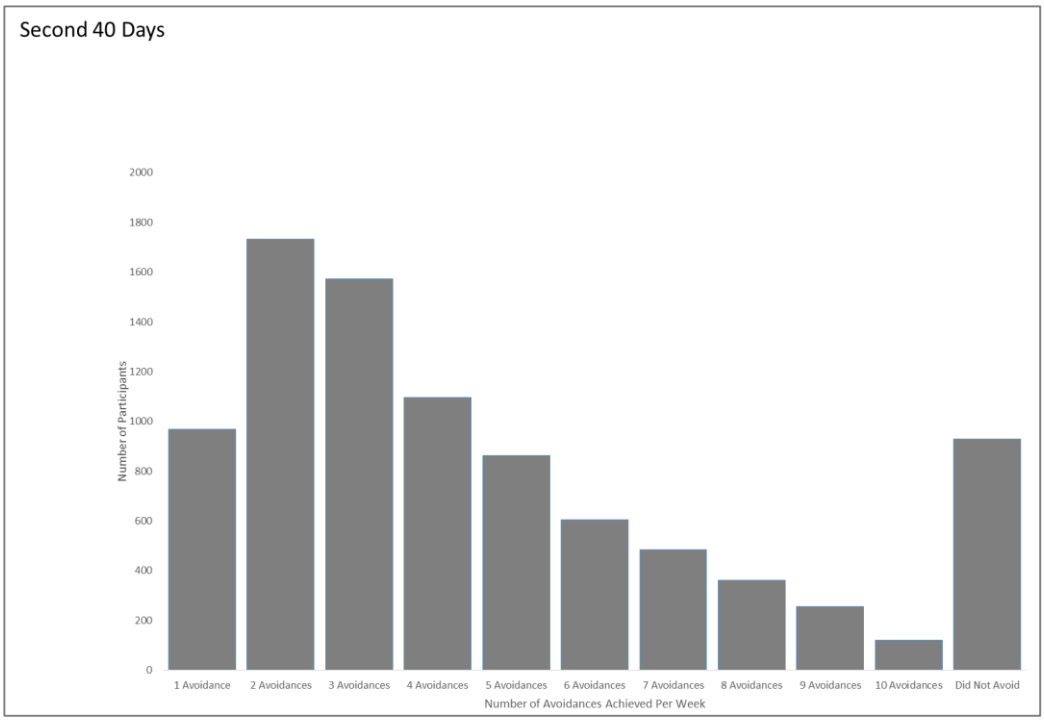
Source: Author's own work

Figure 6.2.1 – weekly average number the times that the participants were seen in the traffic prior to the scheme

The figure shows that a high percentage of the participants were seen in the traffic more than six times per week.

Further conversion of the data showed that the majority of the participants achieve one to four avoidances per week in both observation periods as shown in figure 6.2.2.





Source: Author's own work

Figure 6.2.2 – weekly average number of avoidances achieved by the participants (both periods)

Visualisation of the joint distribution of the reference level and avoidance rates reveals some clearer patterns in behaviour. See figure 6.2.3.

First 40 Days – High Reward

Actual Avoidances	Number of times seen per week in the peak-time (pre-scheme)									
	1 time	2 times	3 times	4 times	5 times	6 times	7 times	8 times	9 times	10 times
10 avoidance										76
9 avoidance									102	64
8 avoidance								111	109	73
7 avoidance							134	133	81	74
6 avoidance						99	173	129	124	85
5 avoidance					111	138	138	172	138	125
4 avoidance				134	168	153	226	267	229	149
3 avoidance			162	221	198	214	305	308	215	185
2 avoidance		56	280	200	204	209	300	275	219	200
1 avoidance	13	70	187	126	132	145	186	161	141	105

Second 40 Days – Lower Reward

Actual Avoidances	Number of times seen per week in the peak-time (pre-scheme)									
	1 time	2 times	3 times	4 times	5 times	6 times	7 times	8 times	9 times	10 times
l0 avoidance										121
9 avoidance									162	94
8 avoidance								176	117	68
7 avoidance							182	144	91	67
6 avoidance						136	161	152	90	67
5 avoidance					153	152	188	156	114	101
4 avoidance				162	151	120	193	189	178	104
3 avoidance			199	198	187	187	223	225	184	170
2 avoidance		61	231	183	157	196	236	282	216	172
1 avoidance	10	50	127	84	112	91	151	127	113	104

Source: Author's own work

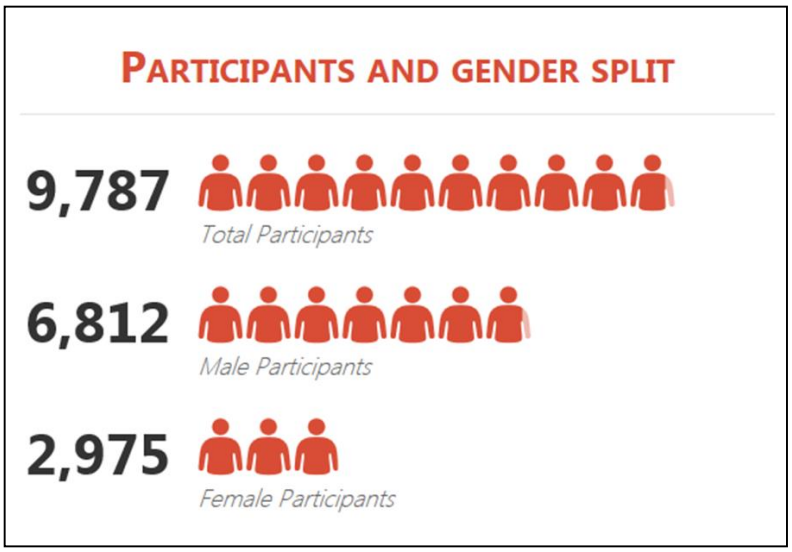
Figure 6.2.3 – weekly average number of avoidances achieved by the participants (both periods)

It can be seen that the actual avoidances compared to the times seen in the traffic before the start of the scheme, are more evenly distributed in the second observation period. There is also a tendency towards higher avoidance rates across the population in the second observation period. There was also a tendency for those with a higher pre-scheme reference to achieve higher levels

of avoidance. This might indicate a “learning” period and may further underline the lack of sensitivity to reward level analysed in research question one.

6.2.3 Gender

The number of participants and the gender split is illustrated in figure 6.2.4



Source: Author’s own work

Figure 6.2.4 – The number of participants and the gender split

Exploratory data analysis indicated that gender had a small influence on the participants’ avoidance behaviour. This was investigated further.

The chi square tests in Appendix E show that the avoidance behaviour differences between the sexes for those that stopped avoiding were not significant. However, the tests confirmed that in the 0-60% avoidance rate range, the frequency of females avoiding the congestion more than males was found to be significant. Thus suggesting, that gender does have a bearing on the avoidance rates achieved. The tests showed that there was a 7% difference between the observed frequencies of female avoidances in this range, when compared with the expected frequencies. Conversely, males tended to avoid congestion more than females in the 60-100% avoidance rate range. Once again, 7% more than expected.

6.2.4 Age

Age appears to be slightly significant for the avoidance rates, with a 3% superior performance for the older half of the population (those over 41). An average of 49% avoidances were achieved by the older half of the population, compared with an average of 46% avoidances by the younger half. Both of these observations were revealed from an analysis of subsets of the data and had a low variance.

6.2.5 Vehicle ownership

Exploratory data analysis indicated that those participants who had one car in the household avoided proportionately more at the higher avoidance rates than those who had two cars. This was subjected to a chi square test (see Appendix E). The test confirmed that the differences in vehicle ownership levels that having a small influence on avoidance rates was significant. Those with one car in the household tended to perform better in the 60-100%% avoidances range than those with two vehicles.

6.2.6 Reward Option selected

Participants were achieving avoidance rates in broadly the same proportions in both observation periods, regardless of the reward option selected. Exploratory data analysis indicated that origin, destination or reference level did not have any bearing on the choice of rewards. However, participants who took the cash plus public transport reward option, achieved slightly higher levels of avoidances in the 80-100% avoidance rate range.

Analysis also revealed that proportionately more participants who were older than 41 years chose the cash plus public transport option than those younger than 41. Females appearing to prefer the cash plus public transport option more than males. The indicated tendency was further analysed with chi

squared tests which confirmed that age was significant in the choice of reward but that gender was not – see Appendix E. 11 percent more participants that were older than 41 chose the cash plus public transport reward option than would be expected. This is considered significant and indicates a propensity for older participants to use public transport.

Car ownership levels also had an influence on the reward option selected; 14% of those with one car in the household preferred the cash and public transport option, compared with 9% of those with two or more cars. This difference was also confirmed to be significant by performing a chi square test (Appendix E). This is likely to be explained by the fact that many of the households that had two or more vehicles included a company car, thereby presenting less incentive for the use of public transport. This is confirmed by other studies which suggest that owners of a company car use alternative means of transport less often than others (MU Consult, 2013). Further research is recommended in section 7.1

6.2.7 Additional demographic information from the questionnaire

Basic information and performance data was known about all participants (see table 6.2.1). However, additional demographic information was known about others through a voluntary questionnaire. This information included the following:

- Marital Status
- Number in the Household
- Income range
- Education Level
- Payment of travel expense by company
- Avoidance options available:
    - Driving outside rush hours
    - Driving outside area (other route)

- Carpool/ as passenger
- Motorcycle
- Scooter/moped/bicycle
- Public Transport
- Working home
- Other

Of the 9787 participants, 6348 completed the questionnaire. This number represents 65% of the entire population and was completed proportionally and equally between the male (4414) and female (1934) participants.

6.2.8 Analysis of the detailed demographics

The number of people living in the household, based on two or more, does not appear as a crucial aspect in relation to the avoidance rates. However, exploratory data analysis revealed that those with one person in the household have a 3% higher avoidance rate than those with two or more in the household. They also tend to be younger with similar levels of variance across the sample.

The presence of children in a household, whilst boosting the number of vehicles (by 0,2 cars), does not appear to be an influencing factor for the avoidance levels. This suggests that, whilst there are more cars in family households, they do not use them in the peak hours in the scheme's hotspots. Those with a lower level of education did not avoid any more or any less than those with university level education. This was consistent across the avoidance rates. Also, whether trips were paid by the employer did not appear to have a bearing on the rate of avoidance.

Analysing the demographic differences of the participants reveal that differences of origin, destination, income, education, and marital status, did not make any significant difference to the avoidance rates.
Also none of the independent variables had any strong bearing on whether participants avoided or not.

6.2.9 Preliminary Conclusions

The pre/scheme behaviour of the population does not seem to have a large influence on congestion avoidance. The number of times a participant was seen in the traffic before the scheme started is not closely related to the avoidance rates achieved during the scheme, nor is it determinant on whether a participant avoids or not.

There were small differences identified in the higher and lower avoidance rates based on age and gender. The older half of the population tending to achieve higher levels of avoidances, and males tending to perform better than females. Vehicle ownership levels have been shown to have a small influence on avoidance levels. Those with one car in the household tended to perform slightly better in the higher avoidances range than those with two vehicles. Analysis revealed that age and car ownership levels was important in the choice of reward but that gender was not.

Overall it is concluded that were no substantial behavioural change differences based upon the demographics of the participants.

6.3 Research Question 3

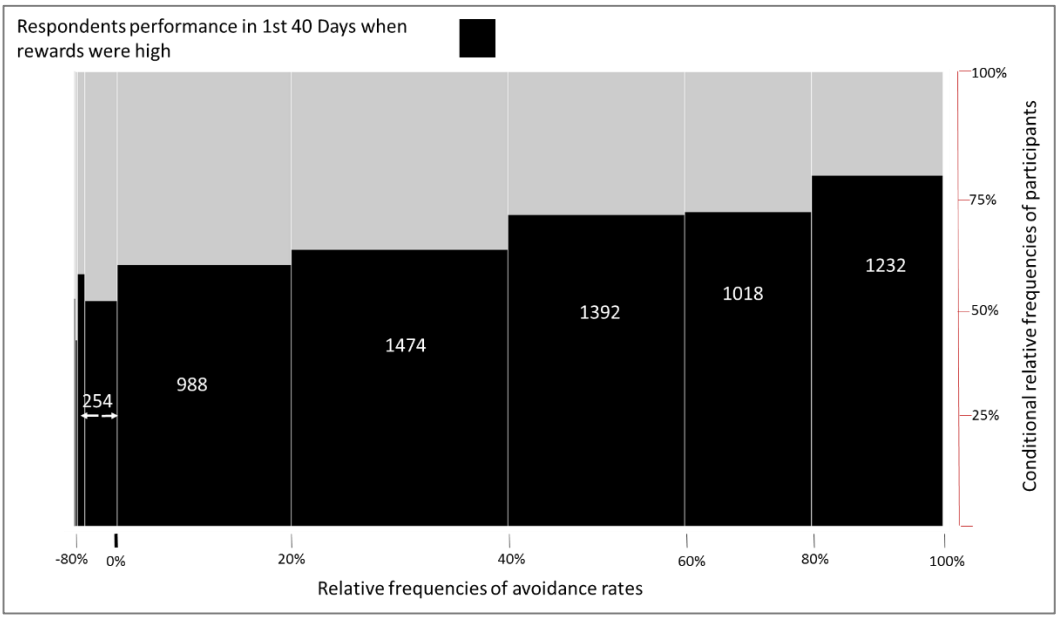
RQ3: Is there is a relationship between congestion avoidance and those who responded to the questionnaire?

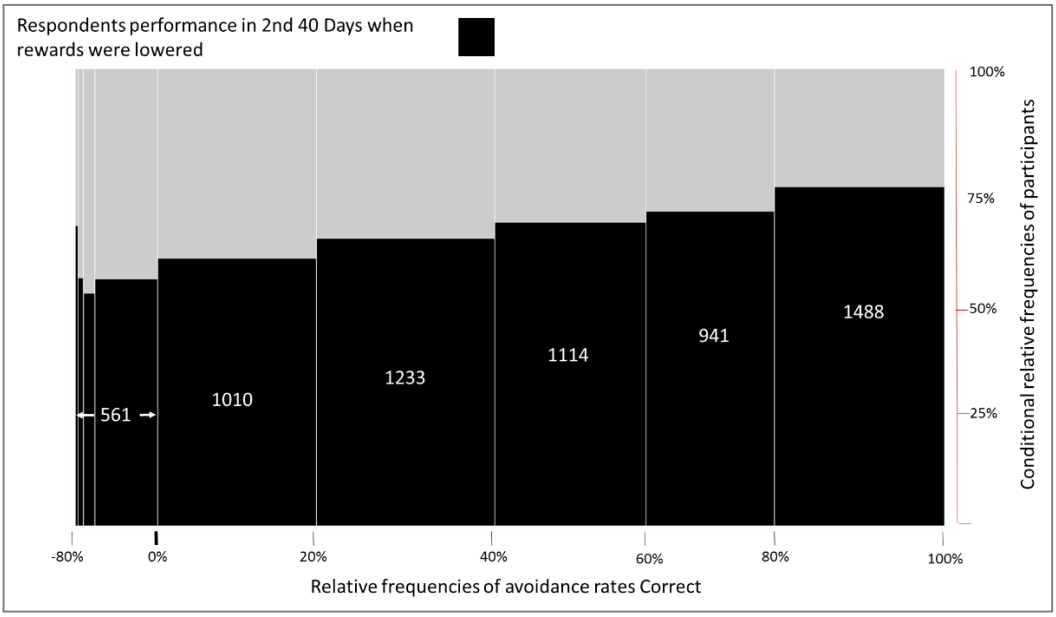
This research question examines whether those who responded to the questionnaire performed better in the scheme than those who did not. The supporting hypothesis for this question is that a change in behaviour could be partly dependent upon personal motivation and social reasons. Not just financial rewards.

6.3.1 Questionnaire respondents performed better

The basic statistics show that the avoidance rates from the participants who responded to the questionnaire are approximately 10 percentage points higher than those who did not respond. There is also a slightly closer correlation between the first 40 days avoidance rates and the avoidance rates after 40 days for respondents compared to the non-respondents. Correlation tests revealed a correlation coefficient of +0.71 for those who completed the questionnaire as compared to +0.65 for those who did not.

Analysing the avoidance rates using exploratory data analysis, showed that those who responded to the questionnaire, also generally performed better at the higher avoidance rates than the non-respondents. This is illustrated in figure 6.3.2.





Source: (Authors Own Work)

Figure 6.3.2 –Avoidance rate performance of questionnaire respondents vs non-respondents

6.3.2 The non-avoider rate

Non avoiders are those participants who were seen as much or more in the peak-time than their pre-scheme behaviour. Exploratory data analysis and a review of the statistics revealed that those participants who did not complete the questionnaire, had a much higher tendency to become “non-avoiders”.

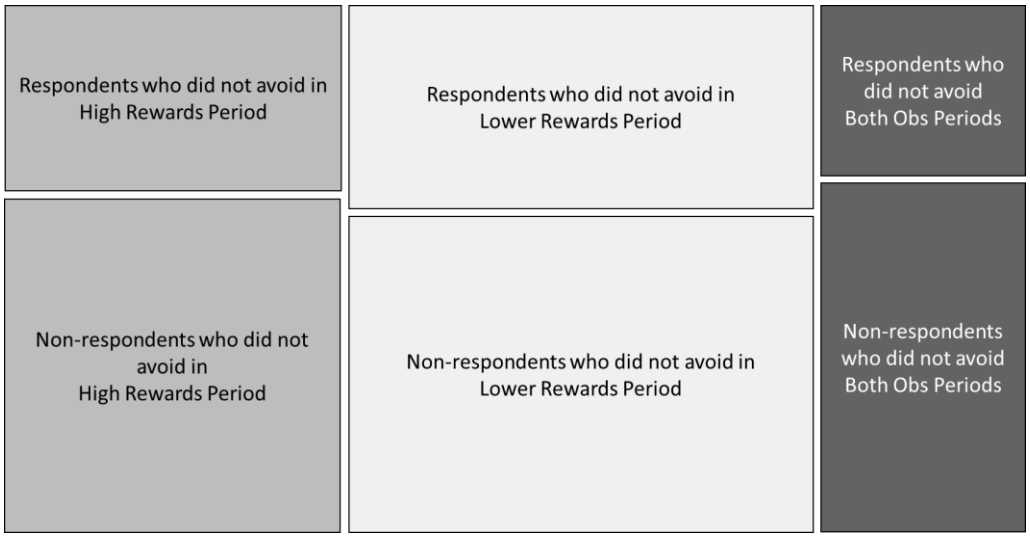
Thus indicating a higher commitment to the scheme from the questionnaire respondents. Table 6.3.1 shows the questionnaire response numbers, and the relative non-avoider rates in each observation period. It also shows those who never avoided.

Questionaire Response		1st 40 days - High Reward	2nd 40 days - Low Reward	Never Avoided
	Number	Non Avoiders	Non Avoiders	Non Avoiders
Non Respondents	3439	240 (7%)	428 (12%)	110 (3%)
Respondents	6348	244 (4%)	501 (8%)	103 (1.5%)

Source: (Author's Own Work)

Table 6.3.1 – Differences in non-avoidance between those who responded to the questionnaire and those who did not

The proportions of non-avoiders shown in figure 6.3.1, illustrate that there is more compliance with the scheme from those who completed the questionnaire than from those who did not.



Source: Author's own work

Figure 6.3.1 - Differences in non-avoidance of questionnaire respondents vs non-respondents

6.3.3 Non-respondents were more motivated by a cash reward

The non-respondents tended to prefer a cash reward 92% of the time. Whereas respondents took the cash reward 86% of the time. Since respondents have a higher bias to taking the cash plus public transport reward, this could indicate a higher intention to mode-shift.

6.3.4 Male respondents avoid more

Male respondents tended to avoid more. As a rule, males tended to avoid slightly more than females in the higher avoidance rate ranges. However, this is true for both the questionnaire respondents and the entire participant population as noted in the analysis performed for research question two.

6.3.5 Summary of other Findings

Detailed review of the data show that the questionnaire respondents who form the higher performing group, are on average one year older 41.8 vs. 40.5 years. They were also seen in the peak-time one more time per month before the start of the scheme, than the group that did not respond to the questionnaire.

6.3.6 Preliminary Conclusion

The analysis indicates that there is more commitment to avoiding from those who completed the questionnaire, than those who did not. Questionnaire respondents tended have higher levels of congestion avoidance rates and the attrition rate of respondents is markedly lower than non-respondents. The questionnaire respondents tended to opt for the cash plus public transport reward option more often than those who did not respond, suggesting more intention to shift mode.

6.4 Research Question 4

RQ4: Is there a relationship between congestion avoidance rates and the type or number of alternatives that participants have available to them?

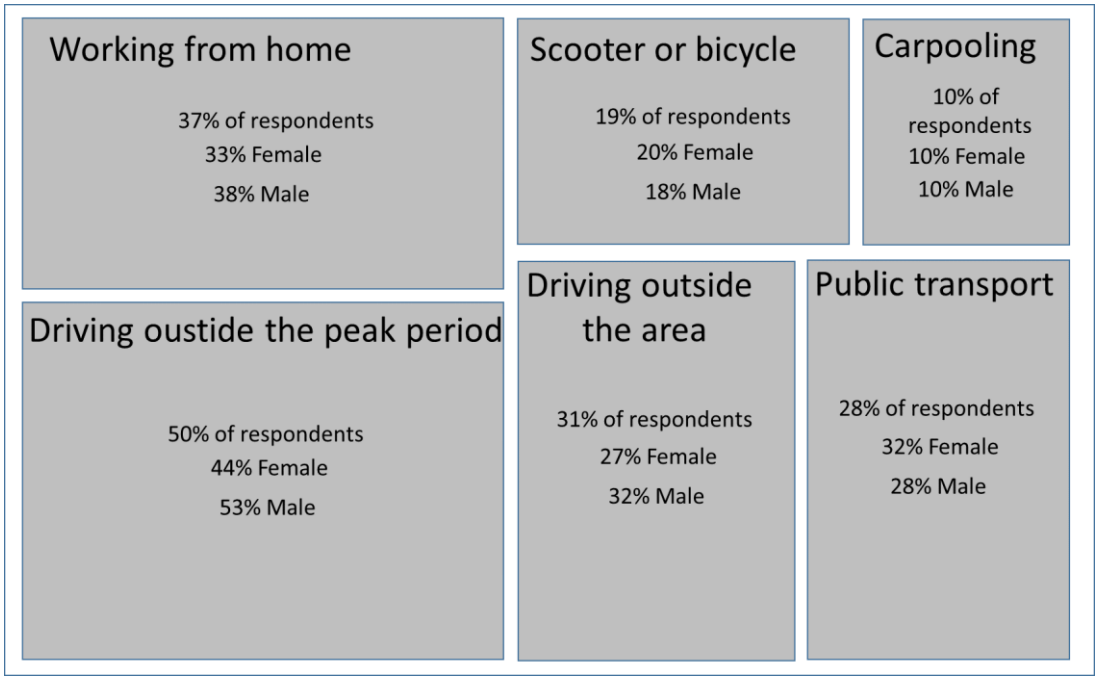
The supporting hypothesis for this question is that peak time avoidance is dependent upon, and facilitated by, flexibility and the means to change behaviour. This analysis is restricted to the 65% of participants who declared their options through the questionnaire.

6.4.1 Options available

The number and type of alternatives a participant has available are:

1. Driving outside peak time
2. Driving outside area (other route)
3. Carpool/ as passenger
4. Scooter/bicycle
5. Public transport
6. Working at another location or at home

The questionnaire respondents indicated which options from the above list were available to them. An analysis of the questionnaire responses show that the biggest percentage of participants (50%) stated that they had the option of driving outside of the peak period in the proportion 3189/6348. This was followed by 37% of participants stating that they had the possibility of working from home (2331/6348). This option was then followed by driving outside the area (31% - 1966/6348). The public transport alternative was available to 28% of the respondents (1827/6348). 19% of participants also stated that they had the possibility of using a scooter or bicycle (1211/6348). The remainder had the option of carpooling (10% - 620/6348). The options declared by the respondents and their proportions are shown in figure 6.4.1.



Source: (Author's Own Work)

Figure 6.4.1 - The options declared by the questionnaire respondents and their proportions

Figure 6.4.1 shows that there is a tendency for men to have more alternatives than women. With males tending to declare more telecommuting and driving options than females. Females declared slightly more cycling and public transport options.

6.4.2 Age education and earnings

Younger, wealthier and more educated participants also declared more options: More options are available to those, who are on average 6.4 years younger than the average age of 41, earn €7,600 per year more than the average. Also 23% more of those with a higher number of alternatives have a university degree.

6.4.3 Options and avoidance performance

A study of the four quadrants of the scatterplot in figure 6.1.1 revealed that the number or type of options declared, did not appear to make a difference in the majority of the avoidance rate ranges. However, it did confirm that those with a higher number of alternatives (those with 5 or 6 declared options) achieved slightly stronger avoidance rates above 80% in both observation periods.

The analysis showed that males tend to predominate the group which performed best (the top 10%).It was males that stated the higher number of alternatives. And those that never avoided the peak from the outset had fewer alternatives.

Time on this research project did not allow for a full statistical analysis of the data in respect of the declared options and avoidances achieved. However, without further information regarding the actual options taken, the relationship between the options and the observed avoidance performance would be inconclusive.

6.4.4 Preliminary Conclusion

Females declared slightly higher level of options regarding public transport and use of a bike or scooter. Whereas, males had more options for telecommuting, driving outside of the peak time, or outside the area.

The literature review suggests that avoidance rates are strongly linked to certain types of alternative options. These include flexibility around working time, the household or workplace obligations. Also suggested is that those with the highest number of alternatives will do so more often. Since males had more alternatives for the more significant options, and males performed slightly better than females, this could give some weight to a link between the type of options and avoidance performance. However, this is inconclusive as the actual avoidance means of each of the participants is unknown.

There are some threads of evidence to suggest a link between options and avoidance rates. However, to conclude on this would require a thorough statistical analysis and interviews with a representative sample of the participants. This is outside of the scope of this study.

6.5 Research Question 5

RQ5: Does the origin and destination of participants influence avoidance behaviour?

6.5.1 Participants with their origin and destination in Rotterdam

543 participants had their origin and destination in Rotterdam. For this group, the median avoidance rates were 50% and 56% in the high reward and lower reward periods respectively. This is 8 and 13% higher than the central avoidance values for the scheme overall which were 42% and 43%. This is statistically significant and is within a margin of error of +/- 4.09 at 95% confidence for this sample size. The Rotterdam participants also achieved slightly more avoidances at the higher rates than was found for the total participant population. Since Rotterdam has very good public transport provision, it was considered that there may be a relationship between the availability of public transport alternatives and participant performance.

6.5.2 Research question development

Dutch towns and cities have a very comprehensive urban and regional public transport network (Ministry of Transport, Public Works and Water Management, 2010). Towns and cities with a population greater than 50,000 usually have at least one train station. This is served by intercity trains as well as stop trains. Some also have metro and tram. All have interconnecting busses, public transport, parking, and cycle hire.

If participants have their homes and workplace in larger towns and cities, this may make the use of public transport a viable alternative to driving in the peak.

The finding regarding the Rotterdam based participants, led to a refinement of the research question:

Research Question 5a: Do participants have a higher propensity to avoid if their origin and destination locations are in a major town or city with population of >50,000?

6.5.3 Supplementing the data

High level postcode information was known for the origin and destination of all of the 9787 participants. This was used to establish which of the participants had their origin and destination in the larger towns and cities.

Table 6.5.1 shows the origins and destinations within the data-set that fulfil this criteria.

Alphen aan den Rijn	Haarlem	Purmerend
Amsterdam	Helmond:	Roosendaal
Breda	Hilversum	Rotterdam
Capelle aan de Ijssel	Katwijk	Schiedam
Spijkenisse	Lansingerland	's-Hertogenbosch
Delft	Leiden	Tilburg
DenHaag	Leidschendam-Voorburg	Vlaardingen
Dordrecht	Oss	Westland
Gouda	Pijnacker-Nootdorp	Zoetermeer

Source CBS 2014c

Table 6.5.1 – Origin and destination towns and cities that have a population: >50,000

Participants in the sample travelling between the above towns or cities numbered 3260 from the population of 9787. This sub-set of participants completed the questionnaire in the same proportions to the scheme population.

6.5.4 Analysis

Participants in this sub-set achieved median avoidance rates of 45% and 48% in the two observation periods. This represents an improvement of 3% and 5% on the median avoidance rates of the total scheme population. This is within the confidence interval of 1.04 for this sample size at a 95% confidence level.

Further analysis revealed that the non-avoider rate in this sub-set of the population was 1% less than that seen from the total scheme population. This could indicate that the availability of alternative transport modes could be explanatory in lowering the attrition rate of participants.

The distribution of avoidances were similar to the entire population in the 0 to 80% avoidance rate range. However, the participants with their origin and destination in a large town or city performed 4% better in the 80 to 100% range.

These high avoiders tended to include a larger proportion of males. They also had declared public transport as an alternative more than the participants in the lower avoidance rate levels. They also tended to have 1 car. 13% of these participants took the cash plus public transport reward option, as opposed to the average of 11.7% for the entire population. This giving some weight to the possibility that those with an origin and destination in towns and cities, tend to shift mode to public transport more than others.

6.5.5 Preliminary findings

The suggestion from this analysis is that good public transport links may result in better compliance and performance. It appears that higher levels of avoidance is achieved by participants who have their origin and destination in large towns or cities.

6.5.6 Further development of the research question

Analysis of other projects in the Netherlands suggest that modal shift to public transport is dependent upon its availability (MU Consult 2013).

The question was therefore extended to analyse whether these participants have a higher tendency to avoid if their origin and destination is close to a transport hub. Thus easing a modal shift.

The following research question was derived.

Research Question 5b

Do participants have a higher propensity to avoid if their origin and destination locations are near a public transport hub?

In order to address this question, the data was augmented to identify those participants who had an origin and destination with the same high level postcodes of transport hubs. Typically, these are railway stations served by intercity trains, and stop trains with other interconnecting modes. This was performed by using a combination of google maps™ (Google, 2014) and the data from the travel application 9292™ (9292, 2014). There were 189 participants in this group.

Analysis revealed that the median avoidance rate of this group of participants was 48% and 51% in the respective observation periods. This represents an improvement of 6% and 8% on the total population. It also shows a better improvement than the finding for research question 5a. This suggesting that proximity to a transport hub allowed an easier modal shift and higher avoidance rates. However, tests show that the sample size of 189 provides a margin of error of 7 at 95% confidence. Thus, the results cannot be considered to substantiate this finding.

Participants in this group were seen two times less in the traffic per month before the scheme started, compared to the population. Those that had completed the questionnaire had also declared a higher than average access to public transport as an option. These details may suggest that this sub set of the population were already users of public transport. However, this cannot be substantiated without interview.

6.5.7 Preliminary Conclusions

The suggestion from this analysis is that compliance and avoidance behaviour may be improved by having convenient access to public transport. The higher propensity to taking the cash plus public transport reward option adds some weight to this suggestion. See discussion and conclusions in section 7.

7 Discussion Conclusions and Recommendations

7.1 Discussion of results

7.1.1 Reward reduction has limited effect on performance

The analysis performed in research question one tends to support the premise that a reduction in the reward has a limited effect on congestion avoidance rates.

Whilst there were some small changes in the distribution of the avoidance rates when rewards were reduced, the overall performance of the scheme for both periods are substantially similar. When the rewards were reduced there was even a slight improvement of avoidance rates for some of the participant population. Moreover, the net number of avoidances slightly increased.

A small percentage stopped avoiding and the reduction in the reward may have caused some of the population to make a value judgement and abandon the scheme. However the causality of the reward lowering is a difficult to demonstrate without interviewing those participants.

Pricing (or rewards) play a part in behaviour change. MU Consult (2013) reported that a 10% increase in the reward level typically leads to an increase of 3.5% avoidances among participants. However the analysis of this scheme has revealed the behaviour change was relatively inelastic to the change in reward. This may be because the rewards were already significantly 20-40% higher than other schemes in the Netherlands where the level of reward is around five euros per avoidance. Therefore, since individuals do weigh costs and benefits (Ubbels, 2006), it may be that the overall benefit was still higher to many participants than the “cost” of travelling in the congested traffic. It could also mean that part of the behaviour change effect is enduring. This “enduring” behaviour change effect has been seen in other schemes across the Netherlands as reported in the Spitsvrij final report (2014).

Ben-Elia and Ettema, (2009) state that rewards can create a learning effect, but that knowledge of the reasons that influence the participation in these type of rewards schemes is limited. However, a synthesis of the studies in this area

performed by (Khademi et al., (2013) conclude that "*socio-economic and situational variables strongly affect participants' decisions".* It is reasonable to assume therefore, that the behavioural change in both observation periods is likely to be a result of a net effect of the following combination of variables:

1. Reward and time saving and the perceived value of time;
2. Time, cost and availability & knowledge of alternatives;
3. Ease and flexibility of changing behaviour in terms of work or household arrangements; and
4. Personal motivations.

The sustained and improved behaviour in the second observation period is considered likely to result from value trade-offs (Koster and Koster, 2013), discovery of alternatives and personal motivations rather than just the level of rewards (MU Consult, 2013).

The analysis performed for research question two also revealed that in the second observation period, there was a tendency for those with a higher pre-scheme reference, to achieve higher levels of avoidance. This might also indicate a "learning" period and may further underline the lack of sensitivity to reward level in this scheme.

The increase in the higher avoidance rates could also be explained by some element of human nature, where participants work to maintain or improve their behaviour change. This is perhaps in order to maximise their rewards regardless of the reward level. It also may indicate an element of fraud in the system.

The rationale for having higher levels of reward for the first period in this scheme, was to achieve high level of avoidances from the outset. This was achieved. However if the behaviour change was inelastic within this reward range, then it may be that the initial high reward period was unnecessary. If however, the continued performance was due to the learning effects of such a scheme and the enduring nature of behaviour change, then the high reward period was perhaps necessary.

7.1.2 Behavioural differences across the demographic not significant

There were some minor indications of a relationship between demographics and scheme performance analysed in research question two. However, overall it is concluded that were no really significant scheme performance differences based upon the demographics of the participants.

That said, the 7% difference in gender performance at the higher and lower ends of the avoidance rates, whilst not hugely significant in terms of numbers in this scheme, could be important if the scheme were extended to a wider population.

The reasons why females performed slightly worse than males are unknown. Similarly, it is not certain, whether the gender split proportions are representative of the wider population that are driving in the peak time[5]. The proportion of females in this scheme at 70% male and 30% female are higher than those reported for a similar scheme named SpitsScoren, which had 85% male and 15% female (Palm et al., 2012). However research shows that the gender split of the participants is not reflective of the employment rate by sex in the Netherlands. This is currently 77% male and 68% female with a sex ratio of 0.98 males/female (Eurostat, 2014). Therefore, it may be that more males decided, or were able to join the scheme than females.

The pattern detected by the analysis that males achieve more peak avoidances than women, is also confirmed across other mobility schemes (MU Consult, 2013). Some of the reasons for the gender split and performance differences, could be explained by household or childcare obligations. Ben-Elia and Ettema, (2009) state that one of the main reasons not to participate in such a scheme, stem mainly from household obligations. Geary, (2009 pp160) shows that maternal care and a child's time spent with its mother still dominates over paternal care across the world. Similarly, the phenomenon could be linked to gender related attitudes towards teleworking. An analysis

[5] it was unknown if the car owners were male or female when they were initially seen in the traffic and then invited to join the scheme,

of the differences between male and female attitudes to teleworking by Nicholas and Guzman, (2009) showed greater interest from males. However, these reasons are inconclusive and would require further research.

The analysis revealed that participants who took the cash plus public transport reward option achieved slightly higher levels of avoidances in the 80-100% rate range. This could be explained by the conclusions of Ben-Elia and Ettema, (2009) who state that the likelihood to participate in such schemes is higher when the participant is open to a change in mode. However, the difference was considered marginal for the entire population and the issue was investigated further in research question five for a sub-set of the data. The analysis of research question five seemed to have some explanatory value.

Those achieving higher levels of avoidances tended to be slightly older. However, this is considered negligible although logical, in that the older population may be more senior and have more autonomy in their jobs. This giving them more flexibility to alter their working times or to telecommute. Tillema et al., (2013) conclude that work time flexibility and telecommuting are significant in the ability to participate in such schemes. Also, the study by Nicholas and Guzman, (2009) showed a higher preference for telework by males and non-millennials over millennials. Peters et al (2004) found that household characteristics, such as number of people in the household, did not influence telecommuting practice. This was also confirmed in the analysis for research question two.

Whilst there seems to be some differences in behaviour that can be related to the general demographics of the participant population, the magnitude of these findings are not considered to be particularly conclusive. Therefore, it is not recommended that these findings be used to influence a targeting the recruitment of participants to future schemes. It appears that the reward plays a central role combined with household, organizational and mode availability factors as posited by Ben-Elia and Ettema, (2009).

Whilst it is important to understand these small differences in behaviour across the demographic, it may be difficult for scheme operators to pre-select participants based on these differences. This is because the main criteria for being invited to these schemes is based upon the frequency that number plates have been detected in the traffic.

Further research is recommended in this area and this is discussed in section 7.2.

7.1.3 Questionnaire respondents perform better

Analysis from research question three, revealed more commitment to avoiding from “the more concerned population” Questionnaire respondents had higher avoidance rates and lower attrition. They were also more predisposed to the public transport option. Overall, they were the better performing participants.

This could confirm the proposition made by Ben-Elia and Ettema (2009), who stated that personal motivation is amongst the highest incentive for avoiding rush hour in these schemes.

This would suggest that where possible, pre-selection of participants based upon intentions around personal motivations, may increase individual and scheme performance. This might therefore allow a smaller total population of participants for the same overall effect.

7.1.4 Limited evidence of a link between avoidance options and performance – (Inconclusive)

The analysis revealed limited relationships between the type or number of alternatives available to participants and the performance of the scheme.

In this scheme, as for others, in order to avoid the peak-time, participants have 4 options:

1. time-shift (travel outside the peak time);

2. work location shift (Telecommute);

3. route-shift (find an alternative route); or

4. mode-shift (to bike scooter, or public transport).

Typically, time-shifting and telecommuting implies participant flexibility to change his or her daily routine, and particularly the ability to work around any household constraints. To a larger extent these options require the cooperation of the employer.

The other two options of route shift and modal shift require the availability of a viable alternate route, or the availability of other modes. If these are available, then the adoption of these options become a value judgement on the part of the participant.

In all cases, the participant must decide if the time and cost involved are justified. This will take the form of judgement to balance the reward with the convenience or inconvenience of adopting any of these options.

The literature suggests that the ability to work from home creates the highest number of avoidances. This is followed by a change in route choice and then travelling outside the peak period. Changes to other modalities such as public transport, bicycle or scooter are less common. Public transport alternatives being dependent on its availability as a viable alternative. The Dutch empirical evidence to date suggests that people adapt easier to other routes and times of travel, than the choice of transport mode.

Flexibility has also been closely linked to the number of modal alternatives available to the participant. The majority of these claims originate from the results from the Dutch peak avoidance schemes performed to date (MU Consult, 2013).

Since it is logical that avoiding participants are adopting certain options in order to avoid, one might expect to see differences in performance that could be related to the different stated options.

However, the analysis tends suggest that there is a limited relationship between congestion avoidance rates and the number of alternatives that the participants declared. The analysis is therefore considered inconclusive.

Further investigation as to how the participants were actually avoiding the peak-time is recommended in section 7.2.

7.1.5 Origin and destination may be explanatory in avoidance behaviour

The origin and destination of participants does appear to influence avoidance behaviour. It seems likely that participants who have their origin and destination in cities, and close to a transport hub, have a higher propensity to avoid. Attrition rates appear slightly improved and the central values of the avoidance rates were more significantly improved compared to the total participant population. Also significant was the higher propensity to taking the cash plus public transport reward option, for those in large towns and cities.

Ben-Elia and Ettema, (2009), posit that the likelihood to participate and perform well in such schemes is higher when the participant is open to and has the possibility of a change in mode. The findings of this research also seem to suggest that access to public transport that would permit modal change, maybe important for scheme performance. However, whilst there is a strong suggestion of this, this finding could not be completely substantiated from the analysis of the data-set. Therefore, further research is recommended to establish actual behaviour. This specifically involving interview of a representative sample of participants.

A further development of this research may also include an analysis of journey distance and the choice of avoidance means. This further research is outlined in section 7.2.

7.1.6 Limitations of the research

The participation in these reward schemes is on a voluntary basis, and participants may be predisposed to avoiding the peak-time. Therefore, it would be inappropriate to suggest that the results of this study can be extrapolated to the entire population. This view is supported by Tillema et al., (2013).

Similarly this research focuses on the Dutch situation, and it cannot be assumed that any findings are applicable outside the Netherlands.

7.2 Recommendations for further research and practice

7.2.1 Interview-based research - reward levels

It is recommended that further research is carried out to ascertain the actual reasons for the increased avoidances and the increased attrition rate when rewards were lowered. It is recommended that this is determined through focussed interviews. This could advise a more targeted reward strategy and may allow future schemes to dispense with a high reward level to “kick start” such schemes. Furthermore, it is anticipated that before the end of this scheme, the reward levels will be further reduced. A review of the data set at that point combined with interviews may have both academic, and commercial value.

7.2.2 A further look into the demographics

Further research is recommended in the area of demographics and the performance of the scheme. Specifically, the reasons for the gender split and the 7% differences in avoidance rates between males and females. Also recommended is to study constraints that come from the employer or limitations that come from the household such as childcare and the ownership of a company car. These should be researched in the context of whether these factors affect the avoidance rate. A further question for future research should include “Are those with a travel allowance paid by their employer that is higher than the reward value, less inclined to avoid the peak?”

7.2.3 Participants actual avoidance behaviour

Actual avoidance behaviour was unknown. Also the analysis was unable to establish a link between the stated avoidance options and performance of the scheme. Therefore, further research is recommended. It is recommended that this should take the form of a focussed set of interviews with a representative sample of the participant population. This should establish their actual avoidance behaviour. This information should be subjected to a detailed statistical analysis.

7.2.4 Origin and destination and public transport

Further research is recommended to establish actual behaviour of those with their origin and destination in large towns and cities. This might involve interview of a representative sample of participants to understand whether proximity to good public transport is significant in achieving modal shift.

This could provide support for the finding from this research that origin and destination may be explanatory in avoidance behaviour. If this finding is validated, scheme operators may consider targeting recruitment of participants with their origin and destination in large towns and cities, or near a public transport hub. This may have the benefit of reducing participant numbers and the associated administration costs for the same overall result in net avoidances. They may also consider lower rewards for this group, since the outcome of these participants' personal cost benefit analysis, may be different to those with reduced access to public transport.

7.2.5 Journey distance and the choice of avoidance means

It is considered that the distances between origin and destinations may be a determining factor in the choice of avoidance means. For example, distances of less than 10km could be covered by bicycle or scooter. Longer distances by public transport or telecommuting.

It is recommended that the origin and destination distances, costs and times by car and public transport are calculated from the postcode data for a

representative sample. If this work was combined with structured interviews of the participants, it may lead to a better understanding of the influence of distance, time and cost related to avoidance.

The results of such an analysis if combined with other factors may have some explanatory value. For example, analysis of other schemes in the Netherlands shows that participants who are up to 15 km from their workplace, make fewer avoidances than people with greater commuting distance (MU Consult, 2013).

This work has already been started by the author, and for a random sample of participants the following journey data was derived.

- Distance form origin to destination by car -Using Google Maps™
- Journey time and cost by road (no traffic) -Using Google Maps™
- Journey time and cost by public transport (no traffic) –Using the Netherlands travel application 9292™ Maps

An initial analysis of this data shows some interesting comparisons between journey times and costs from road to public transport. Study of the elasticity of these variables and the value of rewards, would add great value to the understanding of the cost benefit trade off that participants carry out. It would also allow scheme operators to consider a geographic mailshot for recruitment and a differentiated reward for distance travelled.

7.2.6 Pre-selection of participants

Given the clear tendency for questionnaire respondents to perform better on this scheme: pre-selection of participants based upon intentions around personal motivations may increase individual performance. This could have the effect of requiring a smaller total population of participants for the same overall effect.

7.2.7 Targeting of employers for cooperation

Hour (2012) finds that employers are an important stakeholder in peak-time avoidance projects. Targeting employers for the explicit cooperation in the recruitment of participants may provide higher avoidance rates for future schemes. This was shown to be effective in the Spitsvrij (Peak Free) project in the Utrecht region where of the 5000 participants, 2000 were required to be via participating employers. This scheme had very high levels of avoidances of 48% and sustained behavioural change by 80% of participants when the rewards were removed (Spitsvrij, 2014). Such a focussed partnership approach could thereby require fewer participants to achieve the same overall result.

7.2.8 Limitations of recommendations for practice

A key benefit of peak-time avoidance schemes is that they provide an "education' and they facilitate behavioural change of a broad number of participants. Also commercial considerations may often focus on having as many customers as possible. Therefore reducing the participant population maybe efficient for scheme operation, but may not satisfy the broader objectives of these schemes.

7.3 Conclusions

This research provides an analysis of enterprise data relating to 10,000 participants in a peak-time avoidance scheme. The aim of this research was to examine if congestion avoidance is influenced by the demographics of the participant population. The aim was also to examine the effect of changes in financial incentives on participant attrition and congestion avoidance rates. A key objective was to examine how understanding the behavioural changes could influence reward structure, and the size of the population for future schemes.

The aim and objectives of this research was realised through a focus on five specific research questions:

1. Are congestion avoidance rates affected by a reduction in rewards?

2. Do the demographics of the population have any bearing on the participants' behaviour change, attrition rates and propensity to avoid the congestion?
3. Is there is a relationship between congestion avoidance and those who responded to the questionnaire?
4. Is there a relationship between congestion avoidance rates and the type or number of alternatives that the participants have available to them?
5. Does the origin and destination of participants influence avoidance behaviour?

Analysis of the data has identified some patterns, trends and relationships between the reward level, the demographics and the behavioural changes seen in the scheme.

The research finds that reward reduction in this scheme had a limited effect on the congestion avoidance overall. This could be because the behaviour change was inelastic within the reward range for this scheme. It could also be due to the learning effects of the participants. Future research is recommended based upon focussed interviews of participants to understand their reasons for the change in behaviour. This could advise a more targeted reward strategy and may allow future schemes to dispense with a high reward level at the launch.

The research also finds that behavioural differences across the demographic of the population are slight, and don't appear to be important for overall scheme performance. Some small differences were detected in behaviour across the demographic. However, since it may be difficult for scheme operators to pre-select participants based on demographics, it is not recommended that these findings be used to influence recruitment of participants. Further research has been suggested in this area to focus on the differences in avoidance rates detected between males and females. Also advised is a review of constraints and limitations that come from the employer,

childcare, and travel allowances provided by the employer and the use of a company car.

The research finds that questionnaire respondents had higher avoidance rates and displayed lower attrition. This supporting the hypothesis that high personal motivations may increase individual performance. The research concluded that if pre-selection of participants can be made based upon intentions and personal motivations, that this may increase overall scheme performance.

The research revealed limited relationships between the type or number of alternatives declared by the participants and the performance of the scheme. This finding is considered to be inconclusive and a body of further research work is recommended.

Finally, the research finds that the origin and destination of participants appears to influence avoidance behaviour. Specifically it seems likely that participants who have their origin and destination in cities, and close to a transport hub, have a higher propensity to avoid the peak.

Several recommendations have been made for further work. These recommendations are intended to both augment and substantiate some of the findings of this research. Also, recommendations for practice by current and future scheme operators are proposed. These recommendations for research and practice are intended to provide insights that will enable the right number and type of participants to be recruited for future schemes. They are also intended to support an appropriate targeting of incentives for future schemes. The overriding objective being to optimally balance demand for road transport and capacity with the costs of the scheme.

This research has endeavoured to surface the facts, interpret the data, and reach conclusions through reasoned arguments and relative significance of

the findings. It is hoped that this research will increase understanding in the field of travel demand management and behaviour change.

It is the author's view that meeting current and future mobility needs and through behavioural changes will require smart incentives, real-time information and efficient transport services overall. In short, to be sustainable we must move away from the 'predict and provide model and move towards mobility management'.

References

BEN-ELIA, E., ETTEMA, D., (2009) Carrots versus sticks: Rewarding commuters for avoiding the rush-hour—a study of willingness to participate. Transport Policy 16, 68–76.

BLACK, W.R., (2010) Sustainable transportation: problems and solutions. Guilford Press, New York.

BLIEMER M.C.J., DICKE-OGENIA M., and ETTEMA D., (2009) Rewarding for avoiding the peak period: a synthesis of three studies in the Netherlands, European Transport conference 2009, Noordwijk, NL.

CBS (2014a) Dutch car fleet to break 8 million barrier. Dutch National Statistics Office. [Online]. Available from: http://www.cbs.nl/en-GB/menu/themas/verkeer-vervoer/publicaties/artikelen/archief/2014/2014-4108-wm.htm Accessed 6 October 2014.

CBS (2014b) Population estimate. Dutch National Statistics Office, [Online] Available from: http://www.cbs.nl/en-GB/menu/themas/bevolking/cijfers/extra/bevolkingsteller.htm. Accessed 7 October 2014.

CBS (2014c) Large towns in the Netherlands. Dutch National Statistics Office. [Online] Available from: http://www.cbs.nl/en-GB/menu/cijfers/kerncijfers/default.htm. Accessed 10 November 2014.

DYKES, J., et al., (2013) Communication and Presentation Lecture Notes from EPM948 Communication and Presentation (PRD1 2013/14). City University, 2-5 December 2013. Recovered from Moodle. . [Last Accessed 13 September 2014].

ENOCH, M., (2012) Sustainable Transport, Mobility Management and Travel Plans. Ashgate, Farnham ; Burlington, VT.

Eurostat (2014) Employment rates by sex. [Online]. Available from: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/File:Employment_rates_by_sex,_age_group_15%E2%80%9364,_2013_(1)_(%25)_YB15.png, Accessed 25 Sept 2014.

GEARY, D.C., (2009) Male, Female: The Evolution of Human Sex Differences, 2nd Revised edition. American Psychological Association, Washington, DC.

Google Maps,. (2014). Webpage [Online]. Available from: www.google.co.uk/maps

HOUR, P., (2012). Employer attitudes towards peak hour avoidance. EJTIR 12, 373–390.

ITS (2013) 9th ITS European Congress Proceedings, Dublin, June 2013. [Online]. Available from: http://www.itsineurope.com/its9/index.php/programme/proceedings Accessed 20 October 2014.

INRIX (2014), INRIX Traffic Scorecard [Online] Available from: http://www.inrix.com/scorecard/ Accessed 20 September 2014

KAPARIAS, I,. (2013) Principles of Transport Systems Lecture Notes – Lecture 1 “Introduction to transport systems” from EPM407 Transport Strategy and Policy. City University London, Tait Building on 1 October 2013. Available from Moodle. [Last Accessed 2 Nov 2014].

KAPARIAS, I,. (2014) Research Methods Lecture Notes –from EPM410 Transport Strategy and Policy. City University London, College Building on 7 February 2014. Available from Moodle. [Last Accessed 12 Nov 2014].

KIRK, A., (2012) Data Visualization: a successful design process. Packt Publishing, Birmingham.

KNIGHT, F.H., (1924) Some Fallacies in the Interpretation of Social Cost. The Quarterly Journal of Economics 38, 582. doi:10.2307/1884592.

KOSTER, P., KOSTER, H., (2013) Commuters' Preferences for Fast and Reliable Travel. Tinbergen Institute Discussion Paper.

KHADEMI, E., TIMMERMANS,H., BORGERS, A., (2013) Temporal Effects in Adaptations of Daily Commuter Trip Choices in Response to Reward Scheme. Published paper, July 2013, Eindhoven University of Technology. The Netherlands.

LINDSEY, C.R., VERHOEF, E.T., (1999) Congestion Modelling. Tinbergen Institute.

MEIRELLES, I., (2013) Design for information an introduction to the histories, theories, and best practices behind effective information visualizations. Rockport publishers, Berverly, MA.

Ministry of Transport, Public Works and Water Management, (2010) [Online]. Available from: http://www.emta.com/IMG/pdf/brochure.pdf Accessed 22 Sept 2014.

MYATT, G.J., (2009) Making Sense of Data II: A Practical Guide to Data Visualization, Advanced Data Mining Methods, and Applications, 1 edition. ed. Wiley-Blackwell, Hoboken, N.J.

MU CONSULT. (2013). Eindevaluatie Mobiliteitsprojecten (Evaluation of mobility projects), Final Report. December 2013. [Online]. Available from: http://www.beterbenutten.nl/art/uploads/files/MuConsult%202013%20Eindrapport%20Mobiliteitsprojecten.pdf,. (Dutch Language). [Accessed 22 July 2014].

NICHOLAS, A.J., GUZMAN, I.R., (2009) Is teleworking for the millennials?, in: Proceedings of the Special Interest Group on Management Information System's 47th Annual Conference on Computer Personnel Research. ACM, pp. 197–208.

OECD, (2014). Towards Better Use of Existing Infrastructure. ITF Annual Summit 2014, Panel discussion: Liepzig, Germany 21-24 May 2014

ORTUZAR, S., de DIOS, J., WILLUMSEN, L.G., (2011) Wiley InterScience (Online service), 2011. Modelling transport. Wiley-Blackwell, Oxford.

PALM, H., KOOISTRA, A., van NOORT, P., (2010) The peak avoidance project in Rotterdam and its behavioural impacts, in: European Transport Conference, 2010.

PALM, H., KOOISTRA, A., and Van Der MEULEN, M. (2012) The behavioural impacts of rewarding scheme during two and a half years. European Transport Conference, Glasgow, Scotland, 2012.

PIGOU, A.C. (1920) Wealth and Welfare. Macmillan, London

PETERS, P., TIJDENS, K. and WETZELS, C. (2004) Employees' opportunities, preferences, and practices in telecommuting adoption, Information & Management, Vol. 41 No. 4, pp. 469-82.

RIJKSWATERSTAAT, (2014) Dutch Ministry of Transport. Beter Benutten Website [Online]. Available from: **http://www.rijkswaterstaat.nl/water/plannen_en_projecten/beter_benutten/** (Dutch). [Accessed 22 July 2014].

ROUWENDAL, J., VERHOEF, E.T., (2006) Basic economic principles of road pricing: From theory to applications. Transport Policy 13, 106–114. doi:10.1016/j.tranpol.2005.11.007

SALEH, W. SAMMER, G, (2012) Travel Demand Management and Road User Pricing: Success, Failure and Feasibility. Ashgate.

SPITSVRIJ, (2014) Peak Free Project, Utrecht. Final Report, June 2014, [Online[.Available from: http://www.spitsvrij.nl/ (Dutch Language). [Accessed 22 July 2014].

TfL, (2012) Roads-International Case Studies. Part B. September 2012, Transport for London. [Online]. Available from: http://www.tfl.gov.uk/cdn/static/cms/documents/roads-review-part-b-19-23.pdf. [Accessed 10 August 2014].

TILLEMA, T., BEN-ELIA, E., ETTEMA, D., van DELDEN, J., (2013) Charging versus rewarding: A comparison of road-pricing and rewarding peak avoidance in the Netherlands. Transport Policy 26, 4–14. doi:10.1016/j.tranpol.2012.01.003

The Economist, (2012a) Driving: The Road Less Travelled. May 5th 2012. from the Print edition. [Online]. Available from: http://www.economist.com [Accessed 2 September 2014].

The Economist, (2012b) Transport Trends: Lonesome Highway. Sept 22 2012. from the Print edition. [Online]. Available from: http://www.economist.com [Accessed 24 August 2014].

The Economist, (2013) Infrastructure funding. 2013: The Road Less Travelled. October 19th 2013. from the Print edition. [Online]. Available from: http://www.economist.com [Accessed 15 September 2014].

THEUS, M. and URBANEK, S. (2011) Interactive Graphics for Data Analysis: Principles and Examples (Computer Science and Data Analysis), Chapman & Hall / CRC.

TRAFFICNET 2014, Online Traffic Information Service [Online]. Available from: http://www.trafficnet.nl/ [Accessed daily 28 Sept 2014 – 31 October 2014].

TUFTE, E.R., (2001) The visual display of quantitative information. Graphics Press, Cheshire, Conn.

Tukey, J.W., (1977) Exploratory Data Analysis, 1st edition. Pearson, Reading, Mass.

UBBELS, B., (2006) Road Pricing. Effectiveness, Acceptance and Institutional Aspects. Ph.D. Dissertation. VU University Amsterdam, The Netherlands, Sept 2006.

Urban ITS Expert Group,. (2013) Best Practices in Urban ITS, January 2013. [Online]. Available from: http://ec.europa.eu/transport/themes/. [Accessed 03 November 2014].

Van WEE, B., (2010) The new Dutch per-kilometre driving tax. Journal for Institutional Comparisons. CESifo DICE Report 8 (2), 2010, 64-68 [Online].

Available from: https://www.cesifo-group.de/ifoHome/publications/docbase/details.html?docId=14566992 [Accessed 05 Nov 2014].

VAUS, P.D. de, (2002) Analyzing Social Science Data: 50 Key Problems in Data Analysis. SAGE.

VERHOEF, E., NIJKAMP, P., RIETVELD, P., (1996) The trade-off between efficiency, effectiveness, and social feasibility of regulating road transport externalities. Transportation Planning and Technology 19, 247–263.

VERHOEF, E., BLIEMER, M., STEG, L. (Eds.), (2008) Pricing in Road Transport: A Multi-disciplinary Perspective. Edward Elgar Publishing Ltd, Cheltenham, UK ; Northampton, MA.

VICKREY, W.S. (1969) "Congestion Theory and Transport Investment", The American Economic Review, vol. 59, no. 2, pp. 251-260.

VICKREY, W.S, (1997). Public Economics: Selected Papers by William Vickrey. Cambridge University Press, Cambridge.

WALKER, J., (2011) The acceptability of road pricing. Royal Automobile Club (RAC) Foundation for Motoring. London.

WARE, C., (2012) Information Visualization: Perception for Design, 3rd edition. Morgan Kaufmann, Boston.

World Bank (2014a) Car Ownership Statistics [Online]. Available from: http://data.worldbank.org/indicator/IS.VEH.NVEH.P3 [Accessed 06.10.2014].

World Bank (2014b) Population Density Statistics [Online]. Available from: http://data.worldbank.org/indicator/EN.POP.DNST [Accessed 12.10.2014]

ZIKMUND, W. G., BABIN, B. J., CARR, J.C., & GRIFFIN M., (2012) Business Research Methods, 9th Revised edition. South-Western College Publishing, Mason, OH.

9292,. (2014) Web Page [Online]. Available from: http://9292.nl/

Appendices

Appendix A

The Rewards system and structure

The eligibility for recruitment to the scheme, and how much participants can earn, is based upon the number of times the participant drove in the peak periods before the start of the scheme. The peak periods are Monday to Friday, during the morning between 06:30 and 09:30, and in the evening between 15:30 and 18:30. At the time of the recruitment, nothing was known about the individual driver other than the registered address of his or her vehicle, and the fact that they have been seen frequently in the peak traffic at the congested location.

In the first 40 days participants received an extra high reward (to kick-start the programme). After the first 40 days the rewards are reduced. The reward structure is shown in the tables below:

Cash Option:

Cash	Reward
First 40 (work) Days	€7.50
After 40 days	€6

Cash plus Public Transport Option:

Public Transport & Cash	Reward
First 40 (work) Days	€9
After 40 days	€8

By avoiding the rush hours, the scheme's participants can earn up to a maximum of 150 euros per month in cash in the first 40 days. They can also choose to take the cash plus public transport option[6] where they can earn up

[6] Note: the cash option is paid entirely in cash, and the public transport option is paid partly in cash and partly on participant's public transport (OV chip) card.

to a maximum of 180 euros per month in a blend of cash and credit to their public transport smartcard. Their rewards are limited by their reference value – i.e. a relative scale based mainly upon how many times they were seen in the traffic prior to the start of the scheme

After the first 40 days have elapsed, the maximum cash that can be earned with the cash option is 120 euros per month. And if participants opted for the cash plus public transport option they can earn up to 160 euros per month monetary equivalent.

Appendix B

Research ethics checklist

Research Ethics Checklist

School of Informatics BSc, MSc, MA Projects

If the answer to any of the following questions (1 – 3) is NO, your project needs to be modified.		*Delete as appropriate*
1.	Does your project pose only minimal and predictable risk to you (the student)?	**Yes**
2.	Does your project pose only minimal and predictable risk to other people affected by or participating in the project?	**Yes**
3.	Is your project supervised by a member of academic staff of the School of Informatics or another individual approved by the module leaders?	**Yes**

If the answer to either of the following questions (4 – 5) is YES, you MUST apply to the University Research Ethics Committee for approval. (You should seek advice about this from your project supervisor at an early stage.)		*Delete as appropriate*
4.	Does your project involve animals?	**No**
5.	Does your project involve pregnant women or women in labour?	**No**

If the answer to the following question (6) is YES, you MUST complete the remainder of this form (7 – 19). If the answer is NO, you are finished.		*Delete as appropriate*
6.	Does your project involve human participants? For example, as interviewees, respondents to a questionnaire or participants in evaluation or testing?	**No – see note**

If the answer to any of the following questions (7 – 13) is YES, you MUST apply to the Informatics Research Ethics Panel for approval and your application may be referred to the University Research Ethics Committee. (You should seek advice about this from your project supervisor at an early stage.)	*Delete as appropriate*

7.	Could your project uncover illegal activities?	**No**
8.	Could your project cause stress or anxiety in the participants?	**No**
9.	Will you be asking questions of a sensitive nature?	**No**
10.	Does your project rely on covert observation of the participants?	**No**
11.	Does your project involve participants who are under the age of 18?	**No**
12.	Does your project involve adults who are vulnerable because of their social, psychological or medical circumstances (vulnerable adults)?	**No**
13.	Does your project involve participants who have learning difficulties?	**No**
The following questions (14 – 16) must be answered YES, i.e. you MUST COMMIT to satisfy these conditions and have an appropriate plan to ensure they are satisfied.		*Delete as appropriate*
14.	Will you ensure that participants taking part in your project are fully informed about the purpose of the research?	**N/A**
15.	Will you ensure that participants taking part in your project are fully informed about the procedures affecting them or affecting any information collected about them, including information about how the data will be used, to whom it will be disclosed, and how long it will be kept?	**N/A**
16.	When people agree to participate in your project, will it be made clear to them that they may withdraw (i.e. not participate) at any time without any penalty?	**N/A**
The following questions (17 – 19) must be answered and the requested information provided.		*Delete as appropriate*
17.	Will consent be obtained from the participants in your project? Consent from participants will be necessary if you plan to gather personal, medical or other sensitive data about them. “Personal data” means data relating to an identifiable living person; e.g. data you collect using questionnaires, observations, interviews, computer logs. The person might be identifiable if you record their name, username, student id, DNA, fingerprint, etc.	**N/A**

18.	Have you made arrangements to ensure that material and/or private information obtained from or about the participating individuals will remain confidential? .	**Yes – see note**
19.	Will the research be conducted in the participant's home or other non-University location? *If **YES**, provide details of how your safety will be preserved:*	**No**

P. Bews Notes. This project does not directly involve human participants as interviewees, respondents to a questionnaire or participants in evaluation or testing.

The data supplied is about the behaviour and demographics of participants in a congestion management scheme. The information in the data-set being analysed for the research has been collected and supplied to me by the scheme's operator for the purpose of this research.

The information has been supplied in a way that will not allow participants to be identified individually. The information in the data-set has been completely anonymised for privacy by the scheme's operator and to their satisfaction to ensure that there is no traceability to the human participants themselves before supplying the data-set to me for the purpose of research. For example; all names or any other means of identification such as participant i/d's were removed from the data by the scheme's operator prior to its release. Also, participants' travel origin and destinations that have been supplied in the data-set have been supplied only with the postcode digits that identify the general geographic area of the participants 'origin and destination. This means that origin and destination information is aggregated and non-traceable to individuals. Moreover, with the supplied data-set any further processing or transformation of the data for the purpose of the research will not enable any traceability to individuals

In order to further protect any real or perceived privacy issues, the original data will not be published with the dissertation. Only the descriptive statistics and data visualisations at an aggregate level that describe facts, detect patterns, develop explanations and test hypotheses will be detailed in the submitted dissertation.

The anonymised information has been expressly supplied for the purpose of this MSc research. The data-set will be stored on a computer of the researcher to perform the analysis. After the research study is completed all of the data will be destroyed.

Appendix C

The specification of the data-set

The following is a summary of the data requested and received from the scheme operators; BNV Mobility BV:

1. Travel behaviour patterns prior to scheme – The “Reference Level” (11000 records)
2. Avoidance rates during the scheme (11000 records)
    a. Avoidance rate during the First 40 Days
    b. Avoidance rate after 40 days
3. Personal Information (11000 records)
    a. Gender
    b. Year of birth
4. Vehicle ownership (11000 Records)
    a. Total number of cars in household
    b. Number of cars that are privately owned
    c. Number of cars that are company cars
    d. Number of cars that are leased
5. Origin and destination information based on high level postcodes (11000 records)
6. Typical travel time in minutes (>2000 Records)
7. No of kms travelled per year (>6000 records)
8. Payment of travel expenses (>3000 Records)
9. Other Personal Information (>6000 records)
    a. Marital Status
    b. Number of persons in household

c. Income range

d. Education

10. Avoidance options available (>6000 records)

a. Driving outside rush hours

b. Driving outside area (other route)

c. Carpool/ as passenger

d. Motorcycle

e. Scooter/moped/bicycle

f. Public Transport

g. Working home

Appendix D

Normality tests

By observing the avoidance patterns in the histogram charts in figure 6.1.3, the lack of symmetry and the fact that the distributions are relatively flat with peaks around the 20%-40% and 80-100% avoidance rates indicate that the distributions are not normal. This lack of symmetry is particularly obvious by examining the histogram of the second 40 day period. As well as examining the histograms of the data, a simple normality test was performed by taking the mean and standard deviation to construct an interval within which 95% of the values would be expected to lie (i.e. within the interval Mean+/- 1.96 standard deviations). Applying this test created limits that were not feasible and that only exclude -1% to -2% from each data-set rather than the +/- 2.5% that would be expected. This simple test confirmed that the distributions are non-normal. See Table D1 below.

	First 40 day Period – High Reward	**Second 40 Day Period – Lower Reward**
Number of Participants	9787	9787
Mean avoidance rates	44%	45%
Standard Deviation	0.3	0.34
Median avoidance rates	42%	43%
Skew P	0	0.16
Excess Kurtosis	-0.5	-0.55
Normality test: Mean + – 1.96 SD	+103% -15%	112% + -22%

Table D1 – Summary statistics and normality tests

In a normal or approximately normal distribution, the parametric statistics that provide central values, standard deviation etc., would be valid statistical measures and tests. However, according to Vaus (2002), although not completely scientifically valid, parametric statistics do not seem to have a severe effect on the results in terms of central tendency for certain non-normal data. Therefore since the distributions are only slightly skewed and flat with one short tail, the median avoidance rate of 42% and 43% rather than the mean are considered representative as central values for the data. This median value indicates a very small growth in avoidance rate when the rewards were reduced. However, this growth is not considered to be statistically significant.

Appendix E

Chi Square Tests

E1

Chi Squared Tests – Avoidances and Non-Avoidances vs high rewards and low rewards

In order to understand the relationship between the two categorical variables of Avoidances and non-avoidances during the high reward situation and the low reward situation a Chi Square test was performed.

	High Reward	Low Reward	Totals
Avoiders Observed	9303	8858	18161
Avoiders Expected	18161x9787/19574 =9080.5	18161x9787/19574 =9080.5	
Non-Avoiders	484	929	1413
Non-Avoiders Expected	1413x9787/19574 =706.5	1413x9787/19574 =706.5	
Totals Observed	9787	9787	19574

X^2 = Sum $(O-E)^2/E$

$X^2 = (9303-9080.5)^2 /9080.5 + (8858-9080.5)^2 / 9080.5 + (484-706.5)2 / 706.5 + (929 – 706.5)2 /706.5$

$X^2 =5.452 + 5.452 + 70.073 + 70.073$

$X^2 = 151.05$

Chi-square (X^2) value for 1 degree of freedom and P= <=0.05 is 3.84145882

Therefore this result is significant at p=>=0.05

The results from the Chi-square test indicate that the observed frequency in avoidances from the first to the second observation period differed significantly from what would be expected due to chance alone;

$$X^2 (1, N=9787) = 151.05 \; p <= 0.05.$$

The problem X^2 was calculated to be 151.05 and the critical X^2 value for one degree of freedom and a probability of 0.05 was 3.841. Therefore, the variation is considered too large to be due to chance alone.

E2

Chi Squared Tests – Gender vs Avoidances and Non-Avoidances

In order to understand the relationship between the categorical variables of gender and the frequency of avoidances and non-avoidances, a Chi Square test was performed. This test was performed for the high reward situation and the low reward situation. It was also performed for the avoidance rates in the high reward situation.

Did they avoid or not in the high reward situation?

Null Hypothesis ($H1_0$): Gender has no effect on whether a participant avoids congestion or not in the high reward situation

Alternative Hypothesis ($H1_A$): Gender influences whether a participant avoids congestion or not in the high reward situation

	Avoided	Did Not Avoid	Totals

Female	2829	146	2975
Females Expected	2828	147	Delta 1
Male	6474	338	6812
Males Expected	6475	337	Delta 1
Totals Observed	9303	484	9787

X^2 = Sum $(O-E)^2/E$

X^2 = 0,013

Chi-square (X^2) value for 1 degree of freedom and P= <=0.05 is 3.84145882

Therefore this result is not significant at p=>=0.05 and the null hypothesis is accepted

Did they avoid or not when the rewards were lowered

Null Hypothesis ($H1_0$): Gender has no effect on whether a participant avoids congestion or not when rewards are lowered

Alternative Hypothesis (*$H1_A$*): Gender influences whether a participant avoids congestion or not when rewards are lowered

	Avoided	Did Not Avoid	Totals
Female	2694	281	2975
Females Expected	2692	282	Delta 2
Male	6164	648	6812
Males Expected	6165	646	Delta 2

Totals Observed	8858	929	9787

X^2 = Sum $(O-E)^2/E$

X^2 = 0,0109

Chi-square (X^2) value for 1 degree of freedom and P= <=0.05 is 3.84145882

Therefore this result is <u>not</u> significant at p=>=0.05 and the null hypothesis is accepted

Avoidance Rate / High Reward

Null Hypothesis ($H1_0$): Gender has no influence on the congestion avoidance rates

Alternative Hypothesis (*$H1_A$*): Gender influences congestion avoidance rates

	Avoidance Rate 0-60%	Avoidance Rate more than 60%	Totals
Female	2061	768	2829
Females Expected	1922	906	Delta 139
Male	4284	2226	6570
Males Expected	4422	2087	Delta 139
Totals Observed	6345	2994	9339

X^2 = Sum $(O-E)^2/E$

X^2 = 44,95

Chi-square (X^2) value for 1 degree of freedom and P= <=0.05 is 3.84145882

Therefore this result is significant at p=>=0.05 and the alternative hypothesis must be accepted

E3

Chi Squared Tests – Vehicle numbers in household vs Avoidances Rates

In order to understand the relationship between the categorical variables of the number of vehicles in the household and the frequency of avoidances a Chi Square test was performed.

Vehicle ownership vs <60% avoidance rate and 61-100% avoidance rate in the High Reward situation

Null Hypothesis ($H1_0$): Vehicle ownership levels have no influence on avoidance levels.

Alternative Hypothesis ($H1_A$): Vehicle ownership levels do have an influence on avoidance levels.

	Avoidance Rate <60%	Avoidance Rate more than 60%	Totals
One Vehicle in Household	3054	1513	4567
Number Expected	3142	1425	Delta 88
Two Vehicles in Household	3178	1312	4490
Number Expected	3090	1400	Delta 88
Totals Observed	6232	2825	9057

X^2 = Sum $(O-E)^2/E$

$X^2 = 16.115$

Chi-square (X^2) value for 1 degree of freedom and P= <=0.05 is 3.84145882

Therefore this result is significant at p=>=0.05 and the alternative hypothesis must be accepted.

E4

Chi Squared Tests – Cash Vs PT Options

In order to understand the relationship between the categorical variables of gender, age and the choice of reward (cash or Cash & Public Transport) two Chi Square tests were performed.

Gender vs Choice of Reward

Null Hypothesis ($H1_0$): Gender does not have any influence in the choice of reward

Alternative Hypothesis (*$H1_A$*): Gender does have an influence on the choice of reward

	Cash Reward	Cash Plus PT Reward	Totals
Females	2598	377	2975
Females Expected	2625	349	Delta 27
Males	6040	772	6812
Males Expected	6012	799	Delta 27
Totals Observed	8638	1149	9787

X^2 = Sum $(O-E)^2/E$

X^2 = 3.5847

Chi-square (X^2) value for 1 degree of freedom and P= <=0.05 is 3.84145882

Therefore this result is Not significant at p=>=0.05 and the null hypothesis that Gender does not have any influence in the choice of reward must be accepted.

Age vs Choice of Reward

Null Hypothesis ($H1_0$): Age does not have any influence in the choice of reward

Alternative Hypothesis (*$H1_A$*): Age does have an influence on the choice of reward

	Cash Reward	Cash Plus PT Reward	Totals
>40 years old	4477	677	2975
Numbers Expected	4549	605	Delta 72
<40 Years Old	4161	472	6812
Numbers Expected	4089	544	Delta 72
Totals Observed	8638	1149	9787

X^2 = Sum $(O-E)^2/E$

X^2 = 20.46

Chi-square (X^2) value for 1 degree of freedom and P= <=0.05 is 3.84145882

Therefore this result is significant at p=>=0.05 and the alternative hypothesis that age does have any influence in the choice of reward must be accepted.

E5

Chi Squared Tests – Car ownership Vs PT Options

In order to understand the relationship between the categorical variables of car ownership levels and the choice of reward (cash or Cash & Public Transport) a Chi Square test was performed.

Car ownership vs Choice of Reward

Null Hypothesis ($H1_0$): car ownership levels do not have any influence in the choice of reward

Alternative Hypothesis (*$H1_A$*): Car ownership levels do have an influence on the choice of reward

	Cash Reward	Cash Plus PT Reward	Totals
One Vehicle in Household	3893	674	2975
Number Expected	4031	536	Delta 138
Two or more Vehicles in Household	4745	475	6812

Number Expected	4607	612	Delta 138
Totals Observed	8638	1149	9787

X^2 = Sum $(O-E)^2/E$

X^2 = 75.2679

Chi-square (X^2) value for 1 degree of freedom and P= <=0.05 is 3.84145882

Therefore this result is significant at p=>=0.05 and the alternative hypothesis that the level of car ownership does have any influence in the choice of reward must be accepted.