# IMPROVING ROAD TRANSPORT ENERGY EFFICIENCY THROUGH DRIVER TRAINING

By

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# ABSTRACT

The fuel consumed by all types of road vehicles is the most significant component of road transport energy use, accounting for about 80% of the total, and is significantly affected by driving style. The main aim of the research was to improve the effectiveness and efficiency of driver training for fuel economy for drivers involved in different roles in the management and operations of a road network in England. A unique approach to driver training was designed and tested with 94 drivers. The improvement in fuel economy (in terms of MPG) for the first month after the training was observed to be about 6% for the heavy goods vehicle drivers, 7% for the medium duty vehicle drivers and 3% for the light duty vehicle drivers. The improvements reduced at varying rates after the training and subsisted for 5, 7 and 4 months respectively for the heavy, medium and light vehicle drivers, thus suggesting the need for regular refresher training. The behaviours of the drivers were also observed to change as a result of the training, towards styles more suited to achieving a better fuel economy. The results suggest that both linear and logarithmic models could be suited to predicting the drivers' performances and, thus, they could be used to predict fuel efficiency related to driver performance in integrated models of the type of HDM-4 which currently lack a fuel consumption capability. The driver training methodology developed and tested in this study was found to be more cost effective than the Safe And Fuel Efficient Driving (SAFED) training method recommended by the Department for Transport (DfT) because of its low cost and also due to the fact that it can be applied or reapplied easily when needed.

# DEDICATION

This thesis is dedicated to the memory of my late father Velente Ojok.

# ACKNOWLEDGEMENT

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AHP | Analytical Hierarchy Process |
| AMAP | Automobile and Manufacturing Advanced Practice |
| ANOVA | Analysis of Variance |
| ARFCOM | Australian Road Research Board (ARRB) Fuel Consumption Model |
| ARRB | Australian Road Research Board |
| ATM | Active Traffic Management (or now Managed Motorways in the UK) |
| BIS | Department for Business, innovation and Skills (UK) |
| CANbus | Controller Area Network bus |
| CCTV | Closed Circuit Television |
| CI | Confidence Interval |
| COBA | Cost Benefit Analysis |
| CPC | Certificate of professional Competence |
| DBI | Driver behaviour Inventory |
| DBQ | Driver Behaviour Questionnaire |
| DECC | Department of Energy and Climate Change (UK) |
| DEFRA | Department for Environment, Food and Rural Affairs (UK) |
| DfT | Department for Transport (UK) |
| DMRB | Design Manual for Roads and Bridges (UK) |
| DROPLET | Driver Optimisation for Low Emissions Transport |
| DSA | Driving Standards Agency (UK) |
| DSQ | Driving Style Questionnaire |
| ECU | Electronic Control Unit |
| EU | European Union |
| FEDIC | Fuel Economy Driver Interface Concept |
| FMS | Fuel Management System |

| | |
|---|---|
| GBP | Great Britain Pound |
| GDE | Goals for Driver Education |
| GDP | Gross Domestic Product |
| GPRS | General Packet Radio Service |
| GPS | Global Positioning System |
| HA | Highways Agency (UK) |
| HDM-4 | Highway Development and Management Tool |
| HGV | Heavy Goods Vehicle |
| HMI | Human-Machine Interface |
| HRD | Human Resource Development |
| IBM | International Business Machines (Corporation) |
| ICE | Institution of Civil Engineers |
| IEA | International Energy Agency |
| IRI | International Roughness Index |
| ISA | Intelligent Speed Adaptation |
| ISOHDM | International Study of Highway Development and Management |
| ITS | Intelligent Transport Systems |
| IVDR | In-Vehicle Data Recorder |
| JAUPT | Joint Approvals Unit for Periodic Training (UK) |
| LCV | Light Commercial Vehicle |
| LIN | Local Interconnect Network |
| LV | Large Vehicle |
| MAC | Managing Agent Contractor |
| MADM | Multiple Attribute Decision Making |
| MCA | Multi-Criteria Analysis |
| MCMC | Markov Chain Monte Carlo |
| MDSI | Multi-dimensional Driving Style Inventory |
| MIT | Massachusetts Institute of Technology |

| | |
|---|---|
| MODM | Multiple Objective Decision Making |
| MPG | Miles per Gallon |
| NHM | Normalised Hierarchy Matrix |
| PIARC | World Road Association |
| PTT | Netherlands Postal and Telecommunications Services |
| RAG | Red Amber Green |
| RHMF | Road Haulage Modernisation Fund (UK) |
| RPM | Revolutions per Minute |
| SAFED | Safe and Fuel Efficient Driving (UK) |
| SATNAV | Satellite Navigation |
| SD | Standard Deviation |
| TechMAC | Technology MAC |
| TRL | Transport Research Laboratory (UK) |
| TRUCKSIM | Truck Simulator |
| UK | United Kingdom |
| UN | United Nations |
| USA | United States of America |
| USB | Universal Serial Bus |
| VCA | Vehicle Certification Agency (UK) |
| VMS | Variable Message Sign |
| VOC | Vehicle Operating Cost |
| VP | Vector of Priorities |
| VSP | Vehicle-Specific Power |
| WBCSD | World Business Council for Sustainable Development |
| Web-TAG | DfT Website for Transport Appraisal Guidance (UK) |

# DEFINITIONS

*Area 9* refers to the Highways Agency (HA) Managing Agent Contractor (MAC) contract covering the West Midlands, Herefordshire, Worcestershire, Shropshire, Warwickshire and Staffordshire. It involves the management and operation of the motorways and trunk road network in these areas.

*Amey* Amey (plc.) is one of the UK's leading public services providers managing and supporting the infrastructure and public services that everyone uses, mainly in the UK. With over 20,000 employees, Amey is one of the largest of such providers.

*Driver Management* refers to the operation of business fleets where drivers are managed in terms of aspects including performance, training, motivation and vehicle fuel use.

*Driving Attribute* refers to the factors that a driver could influence to improve vehicle fuel economy during a driving task.

*Multi-Vehicle Driver* refers to a driver who uses at least two vehicle categories (for example, heavy, medium and light) over a period of time to carry out an activity involved in the company's business.

# LIST OF NOTATIONS

| | |
|---|---|
| $a$ | Acceleration in m/s$^2$ |
| $a0$ to $a2$ | Regression coefficients |
| $AFa$ | Projected frontal area of the vehicle in m$^2$ |
| $A_i$ | Weight assigned to the training attribute $i$ based on the influence of the attribute $i$ on vehicle fuel consumption |
| $atan$ | Arc tan in radians |
| $b_{11}$, $b_{12}$, $b_{13}$ | Rolling resistance parameters |
| $CD$ | Aerodynamic drag coefficient |
| $CR$ | Coefficient of rolling resistance |
| $CR_1$ | Rolling resistance tyre factor |
| $CR_2$ | Rolling resistance surface factor |
| $CRa$ | Consistency ratio |
| $C_s$ | Tyre stiffness in kN/rad |
| $df$ | Degree of freedom |
| $e$ | Super-elevation in m/m |
| $EA$ | Element $A$ of the defined attributes |
| $EB$ | Element $B$ of the defined attributes |
| $EMRAT$ | Ratio of effective mass to mass |
| $f$ | Side friction factor |
| $F_a$ | Aerodynamic force opposing motion in N |
| $f_b$ | Boolean function |
| $FCLIM$ | Climatic factor related to the percentage of driving done in snow and rain |
| $F_{cr}$ | Curvature force in N |
| $F_f$ | Side friction force in N |
| $F_g$ | Gradient force in N |
| $F_i$ | Inertial resistance in N |
| $F_r$ | Rolling resistance in N |
| $g$ | Acceleration due to gravity in m/s$^2$ |

| | |
|---|---|
| $GR$ | Gradient as a decimal |
| $IFC$ | Instantaneous fuel consumption in ml/s |
| $IFC_{min}$ | Minimum fuel consumption in ml/s |
| $k_0$ and $k_1$ | Constants |
| $M$ | Vehicle mass in kg |
| $M'$ | Effective mass in kg |
| $M_e$ | Inertial mass of the engine and drive-train in kg |
| $M_w$ | Inertial mass of the wheels in kg |
| $n$ | Total number of observations |
| $N$ | Number of elements of each rows of the hierarchy (comparison) matrix NHM, that is, the number of selected criteria (attributes) |
| $NM_{ij}$ | Normalised value of matrix cell described by row $i$, column $j$ |
| $N_o$ | Number of observations |
| $N_w$ | Number of wheels |
| $p$ | Observed significance level |
| $PC$ | Pair-wise comparison of elements $A$ and $B$ |
| $P_{TOT}$ | Total vehicle power requirements in kW |
| $Ra$ | Radius of the curve in m |
| $R$ | Regression constant |
| $RI$ | Random consistency index |
| $RW_{ij}$ | Value of the hierarchy (or comparison) matrix cell described by row $i$, and column $j$ |
| $T_0$ | Overall influence of the driving attributes on vehicle fuel economy, can be assumed to be equal to the maximum possible influence of that driver training can have on vehicle fuel consumption |
| $W_i$ | Value of the column matrix cell described by row $i$ |
| $S$ | Standard error |
| $TS_i$ | Importance factor that can be assigned to an attribute $i$ due to the traffic system or driving environment |
| $v$ | Vehicle velocity in m/s |
| $v_r$ | Speed of the vehicle relative to the wind in m/s |

| | |
|---|---|
| $V_w$ | A measure of value |
| $w$ | Mean (or modal) weight of a particular factor affecting vehicle fuel consumption on a scale of 1 to 5 |
| $W$ | Wilcoxon rank of the absolute differences between the data and the hypothesised median |
| $x$ | Independent variable |
| $Y$ | Response (dependent) variable |
| $Z$ | Observed statistic |
| $\emptyset$ | Slip angle in radians |
| $\Delta FUEL_C$ | Additional fuel consumption due to accelerations (congestion) in ml/s |
| $\Delta FUEL_T$ | Reduction in fuel consumption due to due to training in fuel efficiency in ml/s |
| $\Delta MPG$ | Effective change in MPG |
| $\theta$ | Angle of incline in radians |
| $\rho$ | Mass density of air in kg/m$^3$ |
| $\alpha$ | Statistical significance level |
| $\beta o$ *to* $\beta_n$ | Model (regression) constants |
| $\lambda_{max}$ | Degree of inconsistency is measured by the principal Eigen value of the comparison matrix (C) is a pair-wise comparison matrix of size $N$ |
| $\xi$ | Fuel-to-power efficiency factor in ml/kW/s |
| $\sigma$ | Standard deviation |
| $\phi$ | Level of consistency needed, and $0 < \phi \leq 1$ |

# CHAPTER 1 INTRODUCTION

## 1.1 Background

Energy is an essential input for modern economic development as it enables, amongst other things, transportation, industrial production, provision of shelter, and communication and related activities which accelerate such development (Apergis and Payne, 2011; Kashai et al, 2012). In transportation terms, millions of people in the UK and billions globally depend on road transport to access jobs, to receive and dispatch goods and services, for leisure trips and in many cases transport provides their livelihoods. Currently, transport accounts for over 25% of total energy consumption in the UK, of which 80% is due to road transport (BIS, 2008). The current world population of about 7 billion is expected to reach over 9 billion by 2050 (UN, 2011). Consequently, transport activity and transport energy demand are likely to grow substantially.

Vehicle fuel consumption is the most significant component of road transport energy use, accounting for about 80% of the total (Stripple, 2001; Odoki and Akena, 2008). Fossil-based fuels (diesel and petrol) are predicted to remain the dominant energy carriers for transport for some decades to come (Rout et al, 2008; Shafiee and Topal, 2009; Owen et al, 2010; Lior, 2012). On the supply side, the global conventional oil reserve is becoming an increasingly scarce resource and production has been predicted to peak at some point during the period 2005 to 2015 (Shafiee and Topal, 2009; Lior, 2012; Nel and Cooper, 2009; and; Rout et al, 2008). Consequently, the prices of these fossil fuels have increased significantly over the past decade and it is generally agreed that they are likely to continue to rise (Rout et al, 2008; Lior, 2012; Owen et al, 2010). Also, the consumption of conventional fossil fuels such as oil, gas and coal is argued to make a significant contribution to global warming (Dincer, 1999; Nel and Cooper, 2009; Lior, 2012) leave alone the optimism regarding shale-oil, which potentially could have pronounced negative impacts on many aspects of life including ecology, water, food supply (Lior, 2012) and infrastructure (Anyala et al, 2011). Consequently energy efficiency has become a fundamental area of concern in the transport industry and, specifically, the road transport sector. According to the Institution of Civil

Engineers (ICE) (ICE, 2008) improving energy efficiency is not only a vital starting point to enable a transition to a lower carbon economy, but could also provide huge savings in monetary terms.

There are several factors that influence vehicle fuel consumption which can be broadly classified as:

- Economic factors – supply, demand and cost of transport and related energy;
- Socio-technological factors – traffic operating environment or system (e.g., vehicle, road, driving and the existing environment);
- Socio-economic and political factors – (climate change, sustainability and energy security).

Driver training for fuel economy is emerging as a cost effective and, potentially, an efficient way of influencing driving style to improve vehicle fuel economy (Evans, 1979; Siero et al, 1989; Nader, 1991; Ericsson, 2001; van der Voort et al, 2001; af Wåhlberg, 2002; Parkes and Reed, 2005; af Wåhlberg, 2006; af Wåhlberg, 2007; Zarkadoula et al, 2007; Beusen et al, 2009; Symmons and Rose, 2009; Manser et al, 2010; Scott et al, 2012; Turpin and Scott, 2010; Luther and Baas, 2011). The applications of driver training for fuel economy are not only scarce but the transfer of the benefits observed during training to real world driving has been deficient in most cases (af Wåhlberg, 2007; Turpin and Scott, 2010; Luther and Baas, 2011). Therefore, the doctoral research was focused on the influence of driver training for fuel economy targeting on-road vehicle fuel consumption.

## 1.2 Problem Statement

The application of driver training with a focus on fuel economy to drivers involved in the maintenance and operations of road networks are not only scarce but the transfer of the benefits observed during training to real world driving for such drivers have hardly been documented. Therefore, the research hypothesis was to investigate if it is possible to design and apply a more effective and efficient driver training for fuel economy for drivers involved in road network maintenance and operations than exists currently. Once the benefits and their decay over time have been established, the author expects to be able to express the change in performance in a mathematical term that would be suitable for integration in a road management tool.

## 1.3 Aims and Objectives

### 1.3.1 Aims

The aims of the research is to improve the understanding of fuel consumption as a component of road transport energy, and to improve the effectiveness and efficiency of driver training for fuel economy for drivers involved in road network maintenance and operations. This would support the development of a basic model of fuel efficiency related driver performance, which could be integrated into a management tool like the Highway Development and Management (HDM-4).

#### *1.3.1.1 Objectives*

The detailed research objectives are as follows:

1. To review and analyse vehicle fuel consumption as a component of the total road transport energy use and to identify the factors that affect vehicle fuel consumption;
2. To review the influence of driving style on vehicle fuel consumption;
3. To review existing driver training programmes for fuel economy;
4. To improve the effectiveness of driver training for fuel economy by identifying and prioritising the influence of the driving attributes which affect fuel economy.
5. To use the outcome from objective number (4) above to design, apply and investigate the benefits of a cost effective driver training for fuel economy relevant to drivers involved road network maintenance and operations;
6. To model the driver fuel efficiency performance of the tested training in order to support the improvement in road user cost (RUC) models used in road management tools like HDM-4; and,
7. To compare the costs and benefits related to such training in (5) with those from a recommended national training method for fuel economy in the UK (England).

The results of the study are expected to allow the creation of a single mathematical model that could be integrated into a road management tool like HDM-4, to allow inclusion of the driver performance in the overall optimisation of road transport costs or management.

## 1.4 Research Scope

This research work reported in this thesis covers influencing drivers, involved in road network maintenance and operations of motorway and trunk road network in the West Midlands in the United Kingdom (UK), to improve their fuel economy by training them to drive in a more fuel economy oriented manner. To this end, the factors affecting fuel consumption were reviewed. The influence of driving style on fuel economy was also reviewed and so was the existing driver training for fuel economy. The focus was on fossil-based fuels and, in particular diesel which is the main fuel used to propel vehicles involves in road maintenance work. Shale-oil was not considered in this research due to its late emergence.

## 1.5 Structure of the Thesis

The structure of the report is summarised in Table 1-1.

Table 1-1: Structure of the report

| Chapter | Title | Content |
|---|---|---|
| 1 | Introduction | This Chapter contains the research background, problem statement, aims, objectives, scope and structure of the thesis. |
| 2 | Factors Affecting Vehicle Fuel Consumption | This Chapter addresses objective 1 as follows:<br>• Vehicle fuel consumption is shown as a component of total road transport energy use.<br>• The impacts of energy use associated with vehicle fuel consumption are then outlined.<br>• A framework is outlined for structuring and assessing the factors that affect vehicle fuel consumption, including the driver influence, the main topic of the research.<br>• Besides the literature which suggests the potential benefits of driver training for fuel economy, a preliminary investigation, based the used of questionnaire, is carried out to show that driver training is considered in the transport industry as a potentially important method for improving on-road vehicle fuel economy. |

| Chapter | Title | Content |
|---|---|---|
| 3 | Driving Style and Fuel Economy | This Chapter addresses objective 2. In this Chapter literature review is carried out regarding driving style; its influence on vehicle fuel consumption and the evidences where driver training for fuel economy has been used to influence driving style. Driving style is also defined including the reason for its variability among drivers. The review of the literature regarding the use of driver training to influence driving style for vehicle fuel economy is then provided. |
| 4 | Driver Training for Fuel Economy | This Chapter addresses objective 3. It contains literature reviews regarding driver training for vehicle fuel economy including the methods for capturing driver training data, and the driving attributes related to fuel economy. The review identifies the driving attributes and how they influence fuel economy. The review also facilitates the design of a company-based driver training for fuel economy reported in Chapter 6. |
| 5 | Prioritising Driving Attributes for Fuel Economy | This Chapter addresses objective 4. In order to ensure that appropriate focus is given to the most influential attributes (identified in Chapter 4) during driver training, the attributes are prioritised in term of their influence on fuel economy. A rationale method which involves pair-wise comparison of the attributes in terms of their influence of vehicle fuel consumption, known as Analytical Hierarchy Process (AHP) is used. |
| 6 | Company Driver Training for Fuel Economy | This Chapter partly addresses objective 5. This Chapter concerns the training for fuel economy of drivers working for Amey in the management and the operation of the motorway and the trunk road network in the West Midlands in the United Kingdom. The methodology used is presented in this chapter and the results in Chapter 7. The influence of the training on the performances of the drivers in terms of miles travelled per gallon of fuel consumed is monitored over the study period. Additional information concerning demography and driver behaviour related to the training is also collected by means of a driving style questionnaire (DSQ) before and after the training. The data from the DSQ is used to assess the influence of the training. |
| 7 | Training Analysis Results | This Chapter addresses objectives 5 and 6 by summarising the analysis results concerning the training described in Chapter 7. |
| 8 | Discussion | This Chapter provides the discussion of the thesis and addresses objective 7 by comparing the costs and benefits the training herein with the recommended national training for fuel economy in the UK (England) called safe and fuel efficient driver (SAFED) training. |
| 9 | Conclusion | This Chapter contains the conclusion of the research and the recommendations for future research work. |

# CHAPTER 2 VEHICLE FUEL CONSUMPTION

## 2.1 Introduction

Chapter 2 addresses the first objective of the research by outlining the factors which affect vehicle fuel consumption, including driver training for fuel economy. The importance of fuel consumption on the total road transport energy use is demonstrated. The importance of the influence of the driver, as one of the factors affecting vehicle fuel consumption, is also demonstrated. The contents of Chapter 2 are as follows:

- Fuel consumption is shown to be the main component of the total road transport energy use in Section 2.2. The impacts of energy use associated with vehicle fuel consumption are briefly discussed in Section 2.2.2. Fuel economy is defined in Section 2.2.3, and;
- Before addressing the influence of the driver on vehicle fuel consumption an overview of the other traffic operating factors that affect vehicle fuel consumption are summarised. A framework is used to outline such factors in Section 2.3. Besides the literature that already suggests that there are potential benefits of driver training for fuel economy (see Chapter 3 and Chapter 4) in terms of fuel savings, a preliminary investigation using a subjective questionnaire is summarised in Section 2.4 to compare the influence of driver behaviour, through training aimed at improving on-road vehicle fuel consumption, with the other factors.

## 2.2 Vehicle Fuel Consumption

### 2.2.1 Fuel Consumption and Total Road Transport Energy Use

In its basic technical form, road transport involves the interactions between the vehicle, road, driver and the immediate environment (natural or non-natural). This concept can be used for analytical purposes to categorise the components of the total road transport energy use as follows (Santero et al, 2010; Kerali et al, 2000):

1. Extraction of energy from different sources for transport use;
2. Construction phase – energy use in the manufacture of road transport vehicles and the road network. This includes the associated processes in the materials manufacturing

process, from the extraction of raw materials (e.g., crude oil) to their transformation into a material to be used to construct the road network or vehicle (e.g., asphalt). It also includes any associated transportation;

3. Use phase – energy use in the operation of road transport vehicles and associated infrastructure or road network;
4. Maintenance phase – energy use in the maintenance of transport vehicles and of the road network;
5. End of life phase – energy use in the disposal of vehicles and infrastructure at the end of their service lives.

Several authors (Odoki and Akena, 2008; Beuving et al, 2004; Stripple, 2001; Audesley, 1997) identified the relative energy requirements of these phases of the road/vehicle life cycle as shown in Figure 2.1, from which it can be seen that the energy required for the operation of road vehicles constitutes the largest proportion (over 80%) of the total transport energy use. Of the sub-components of the energy requirement for operating the vehicles, vehicle fuel consumption is the main component, requiring over 90% of the energy based on the traditional fossil oils types for transport fuel (i.e., diesel and petrol) (Odoki and Akena, 2008 in Figure 2.2; Bennett and Greenwood, 2003). The contribution of tyre/wheel wear, in terms of this classification of energy use, is not significant, however, tyre type, tyre pressure and tyre condition have significant impacts on vehicle fuel consumption through their influence on rolling resistance (Bennett and Greenwood, 2003). Therefore, it can be deduced that fuel consumption is not only the most significant component of vehicle operation energy use, but of the total road transport fossil fuel energy use.

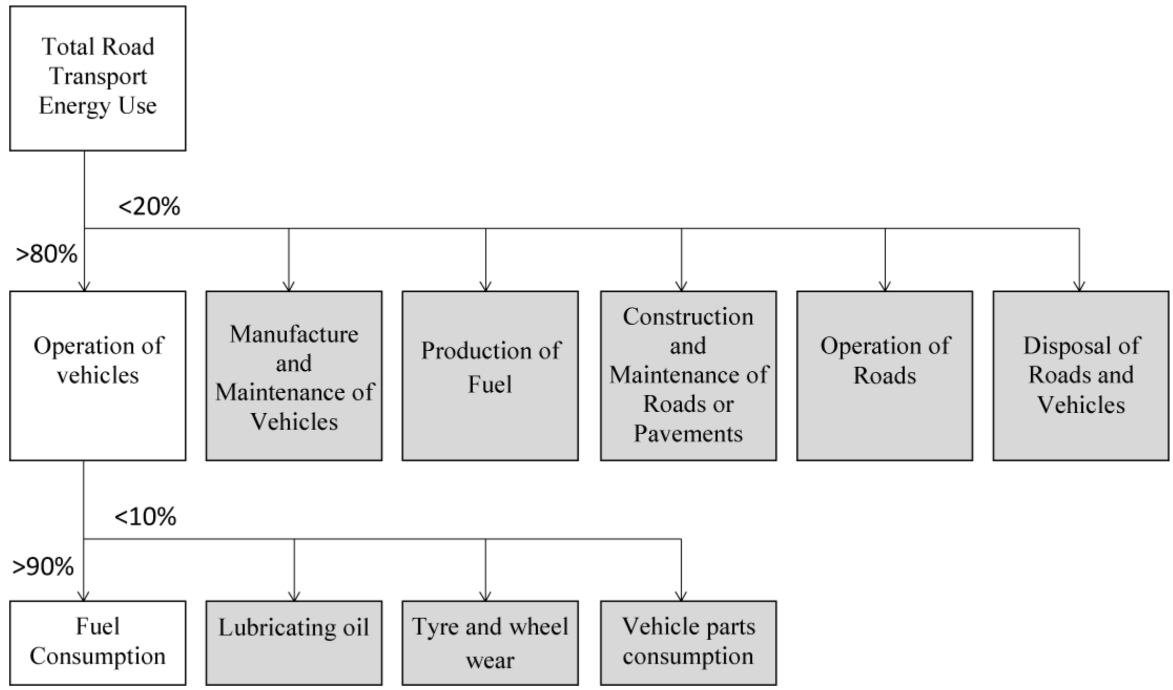



Figure 2.1: Vehicle fuel consumption as a component of total road transport energy use (after Odoki and Akena, 2008; Beuving et al, 2004; Stripple, 2001; Audesley, 1997)

| Vehicle type | Surface condition | Energy: $\times 10^{-3}$ MJ/km | | | | Total |
|---|---|---|---|---|---|---|
| | | Fuel | Tyre | Lubricating oil | Vehicle repair and parts | |
| Motor-cycles | Good | 1 430·0 | –* | 20·0 | –* | 1 450·0 |
| | Poor | 1 160·0 | –* | 20·0 | –* | 1 180·0 |
| Cars | Good | 2 690·0 | 10·0 | 30·0 | 0·1 | 2 730·1 |
| | Poor | 3 070·0 | 4·0 | 30·0 | 0·3 | 3 104·3 |
| LGV | Good | 4 390·0 | 10·0 | 50·0 | 0·2 | 4 450·2 |
| | Poor | 3 610·0 | 10·0 | 40·0 | 0·5 | 3 660·5 |
| Light trucks | Good | 8 220·0 | 30·0 | 100·0 | 0·3 | 8 350·3 |
| | Poor | 7 150·0 | 20·0 | 90·0 | 0·7 | 7 260·7 |
| Heavy trucks | Good | 23 590·0 | 80·0 | 210·0 | 0·5 | 23 880·5 |
| | Poor | 19 600·0 | 80·0 | 200·0 | 1·0 | 19 881·0 |
| Buses | Good | 7 160·0 | 20·0 | 100·0 | 0·1 | 7 280·1 |
| | Poor | 6 360·0 | 20·0 | 100·0 | 0·4 | 6 480·4 |

*Insignificant.

Figure 2.2: Vehicle operation energy use on a good condition paved bituminous road and a poor condition paved bituminous road (Odoki and Akena, 2008)

The work by Odoki and Akena (2008) which highlighted that fuel consumption is a significant component of road transport energy (Figure 2.1 and Figure 2.2) is provided in Appendix F-1.

### 2.2.2 Impacts of Vehicle Fuel Consumption

Vehicle fuel consumption has been shown to be the biggest component of total road transport energy use in Section 2.2.1. The impacts of road transport energy use (and therefore vehicle fuel consumption) are well documented and can be classified as follows:

- Economic (development);
- Price;
- Environmental and social;
- Sustainability.

These impacts are discussed briefly in the following sections.

#### *2.2.2.1 Economic (Development) Impacts*

Many authors (Owen et al, 2010; Chen et al, 2012; Al-Iriani, 2006; Kashai et al, 2012; Payne, 2010; Apergis and Payne, 2011; Lozano and Gutierrez, 2008) recognise the relationship between energy consumption and Gross Domestic Product (GDP), a measure of economic activity. Furthermore, the causal relationships between energy consumption and economic growth have been investigated by a number of researchers (Payne, 2010; Apergis and Payne, 2011; Kashai et al, 2012) under four hypotheses, namely, growth (that energy is a pre-requisite for economic growth), conservation (that economic growth is less energy-dependent), neutrality (that there is no causal relationship between energy consumption and economic growth) and feedback (that there is a bidirectional relationship between energy consumption and growth) and the literature confirms the link between energy consumption and economic growth.

#### *2.2.2.2 Price Impacts*

The prices of fossil fuels have accelerated over the past decade and are predicted to continue to rise (Rout et al, 2008; Lior, 2012; Owen et al, 2010). Several factors contribute to such price increases, including demand from developing economies and politically inspired price hikes to deter human-induced emissions (Rout et al, 2008). The increases in price have a major financial (economic) impact on fuel consumers. Fuel consumption constitutes a significant proportion of vehicle operation costs (VOC) in monetary terms, typically up to 40% of the total VOC (Bennett and Greenwood, 2003). Consequently, persistent increases in vehicle fuel price put a significant constraint on the profitability of businesses which rely on transport. Besides there are strong speculations that a price threshold exists for fossil fuels (oil in particularly) which, if exceeded, could plunge the world into a recession of its own (Owen et al, 2010; IEA, 2012). The discovery of significant quantities of shale-oil may have an effect of delaying this recession.

#### *2.2.2.3 Environmental and Social Impacts*

Global warming as a result of rising temperatures, believed to be due to greenhouse gas emissions, is the most debated cause of environmental and social impacts of the consumption of conventional fuels like oil, gas and coal (Dincer, 1999; Nel and Cooper, 2009; Lior, 2012). Transport already accounts for 26% of global $CO_2$ emissions, with road transport being the major contributor (Chapman, 2007; Peters-Stanley et al, 2011). Global temperature is believed to have been rising for the past 50 years with evidence of major melting of the polar ice caps and increased variability in weather conditions. These conditions have a pronounced negative impacts on many aspects of life including ecology, water, food supply (Lior, 2012) and infrastructure (Anyala, 2011). With potentially reduced food production due to the effects of global warming, the conversion of food to fuel (bio-fuels) puts an even greater stress on food supply which is likely to increase the prices of foods, especially where large quantities of the food are converted (Lior, 2012).

#### *2.2.2.4 Sustainability Impacts*

The sustainability issues related to the conventional (fossil) oil appear to centre primarily on its global reserve. The discovery and use of global conventional oil reserve is believed to follow an approximate bell-shaped curve therefore, dictating the availability or consequential consumption of the oil as shown in Figure 2.3. Owen et al (2010) extensively discusses two independent methods to examine the status of the global conventional oil reserves; the first method involves a review of proven and probable reserves data and the second one amends public data to account for speculative and false additions.

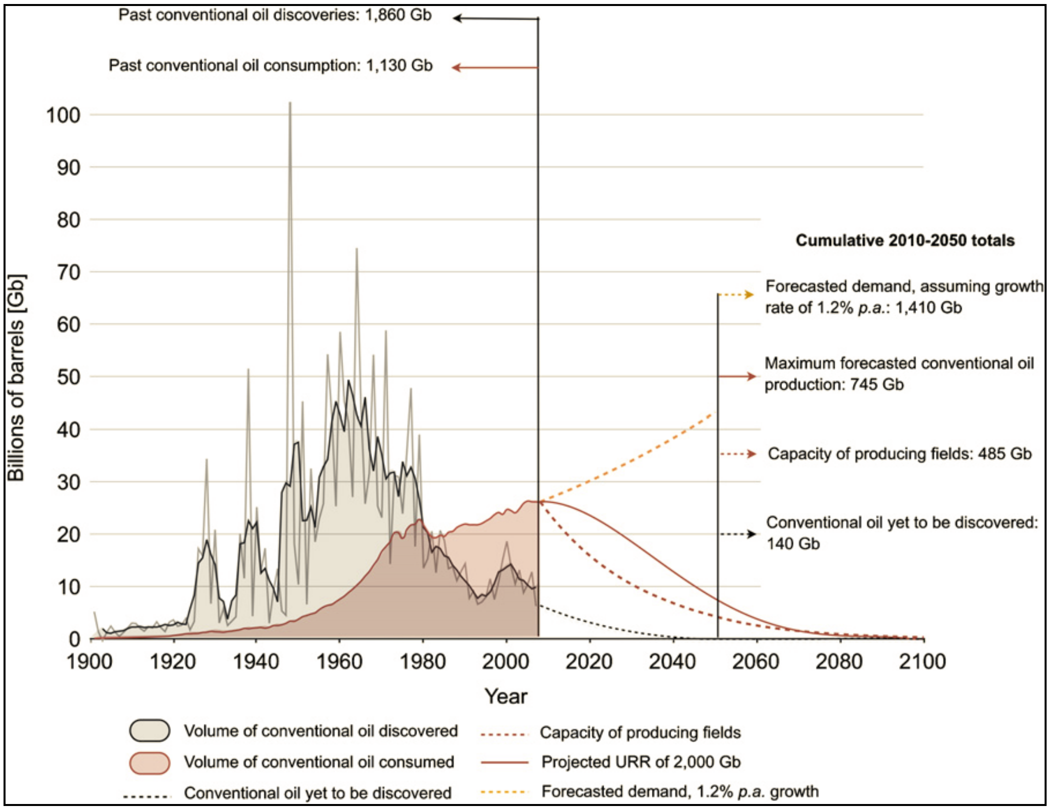



Figure 2.3: Annual backdated proven and probable reserves analysis showing peaking of oil (Owen et al, 2010)

In both cases, the study shows that the peaking of oil production occurs in the period 2005 to 2015. The hypothesis of peaking of oil (over a similar period of 2005 to 2015) is widely supported by many authors including Shafiee and Topal (2009), Lior (2012), Nel and Cooper (2009) and Rout et al (2008).

The predicted trend in global conventional oil reserves is likely, among other impacts, to accelerate increases in oil (fuel) price based on the principle of supply and demand, and to increase socio-economic concerns related to energy security. Even with the optimism regarding shale-oil resources, Ahmed (2013) reports that the shale oil and shale gas resource estimates are thought to be highly uncertain and would remain so until they are extensively tested with production wells.

### 2.2.3 Fuel Economy

Fuel economy is a type of performance measure. According to Virtos (2010), Harbour (2009) defines performance measurement as ‘a process of measuring actual outcomes or the end goal of performance as well as the means of achieving that outcome as represented by in-process measures’. Virtos (2010) also provides an extensive review of literature regarding the types and the classification of other performance measurements.

Fuel economy can be related to the efficiency of consuming fuels to produce a measureable outcome such as distance travelled, as illustrated in Figure 2.4. Fuel economy improvement interventions try to maximize the beneficial outputs and it has mainly been related to miles per gallon (MPG) which is the most widely used method for measuring vehicle fuel economy (Virtos, 2010). Litres per 100 kilometers (L/100km) another standard method used for measuring vehicle fuel economy.

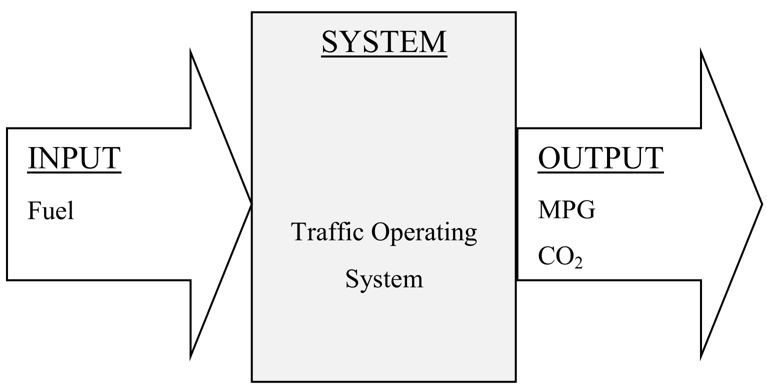



Figure 2.4: Attributes that can be used to define fuel efficiency (economy)

Improving fuel economy can be directly associated with the benefits of reducing road transport energy use or fuel consumption as described in Section 2.2.2. The following sections provide a summary regarding the various factors that influence vehicle fuel consumption.

## 2.3 Factors Affecting Vehicle Fuel Consumption

The influence of driver behaviour on vehicle fuel consumption is just one of the many socio-technological factors which affect vehicle fuel consumption. This section uses a framework based on the traffic operating environment (Figure 2.5) to summarise the socio-technological factors which are known to influence vehicle fuel consumption in order to provide broader background knowledge to the readers regarding such factors.

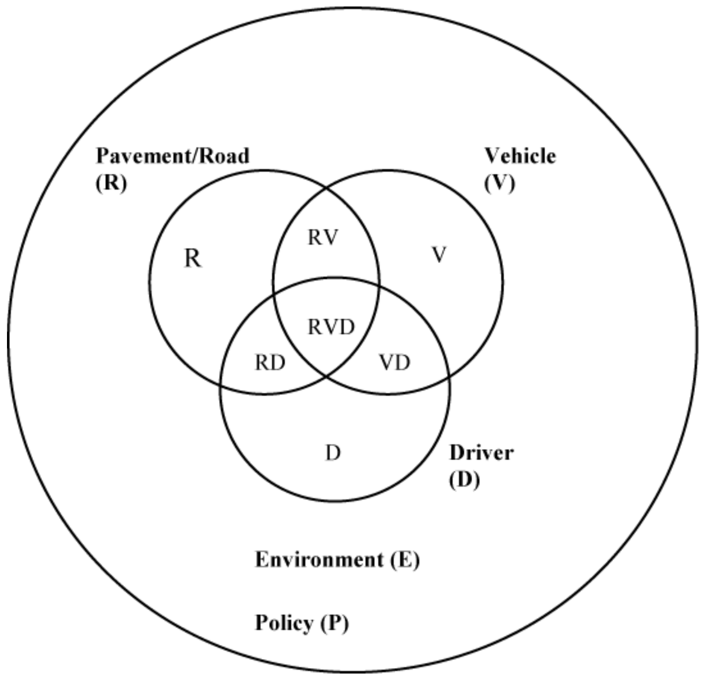



Figure 2.5: A simplified model representation of the components of the road traffic operating system

### 2.3.1 Traffic Operating Model

The traffic operating system model shown in Figure 2.5 consists of the interactions of the road vehicle, the road (or pavement) and the driver, these being influenced by the natural environment and associated policies. In reality, the traffic operating system is more complex than what the model shows, however, this model has been found suitable for assessing the socio-technological (operational) factors which affect road transport energy use due to vehicle fuel consumption (Kobayashi et al, 2009; Odhams et al, 2010; Murrell, 1975; Bennett and Greenwood, 2003, Odoki and Akena, 2008) as summarised below. Similar concepts have been used in road safety studies (Cacciabue and Carsten, 2010; Doi, 2006; Wettel and Lundebye, 1997). In Figure 2.5, R is a pavement-related factor, V is a vehicle-related factor, D is a driver-related factor, RV is a factor that relates to pavement-vehicle interaction, RD is a factor that relates to pavement-driver interaction, VD is a factor that relates to vehicle-driver interaction and RVD is a factor that relates to vehicle-pavement-driver interactions. Theses interactions occur within a natural environment (E) that includes atmospheric temperature, rain, moisture, visibility (e.g., night and fog), wind, snow and altitude. The pavement, vehicle and driver interactions are all influenced by existing policies and thus the inclusion of the 'P' component.

### 2.3.2 Framework for Factors Affecting Vehicle Fuel Consumption

Many authors have tried to identify the factors which affect road vehicle fuel consumption. Murrell (1975) used a simple synthetic and mechanistic approach based on the consumption of fuel to overcome resisting forces to vehicle motion, which is, rolling friction, aerodynamic drag, inertia, drive-train losses, accessories and engine heat losses. Bennett and Greenwood (2003) developed vehicle (passenger and freight) fuel consumption models based on a similar principle to that was used by Murrel (1975). In their model, vehicle operating costs (VOC), and in particular fuel consumption, is assumed to be proportional to the forces acting on the vehicle (resistance to motion) and therefore the fuel consumption of the vehicle can be established by quantifying the magnitude of the forces opposing motion. Kobayashi et al (2009) identify the most important factors which could improve fuel economy including maximising the conversion of fuel to useful work by improving drivetrain efficiency (5%-7%), recapturing engine energy losses (61-62%) and reducing the forces opposing vehicle motion (Traction energy demand).

Odhams et al (2010) describe a study which investigated factors affecting the fuel consumption of heavy goods vehicles (HGV). Their method of analysis was based on mechanistic principles as used in the other studies above and they identified performance factors associated with the components of the road traffic operating system (Figure 2.5) related to vehicle fuel consumption as follows:

1. Vehicle design factors – including vehicle length, mass and volume; engine efficiency; rolling resistance due to the drive train, tyres, and cornering forces; aerodynamic drag and regenerative braking;
2. Logistical factors – including the spatial structure of the supply chain and vehicle routing; vehicle utilization, and vehicle speed;

3. External factors – including the drive cycle (related to speed and elevation profile), the effects of traffic congestion; driver behaviour, and weather conditions.

Odhams et al (2010) modelled driver behaviour based on the assumption that the driver has three controlling parameters, namely:

- A demanded acceleration that determines the throttle positioning during acceleration phase;
- The final vehicle speed that determines the driver's target speed during a constant-speed phase;
- A vector of maximum allowable engine speeds (each gear being assigned one speed), to indicate when a gear change is needed.

Based on the above literature and the traffic operating model shown in Figure 2.5, the factors that affect vehicle fuel consumption can be structured and assessed using the framework shown in Figure 2.4. The framework is defined in the following paragraphs.

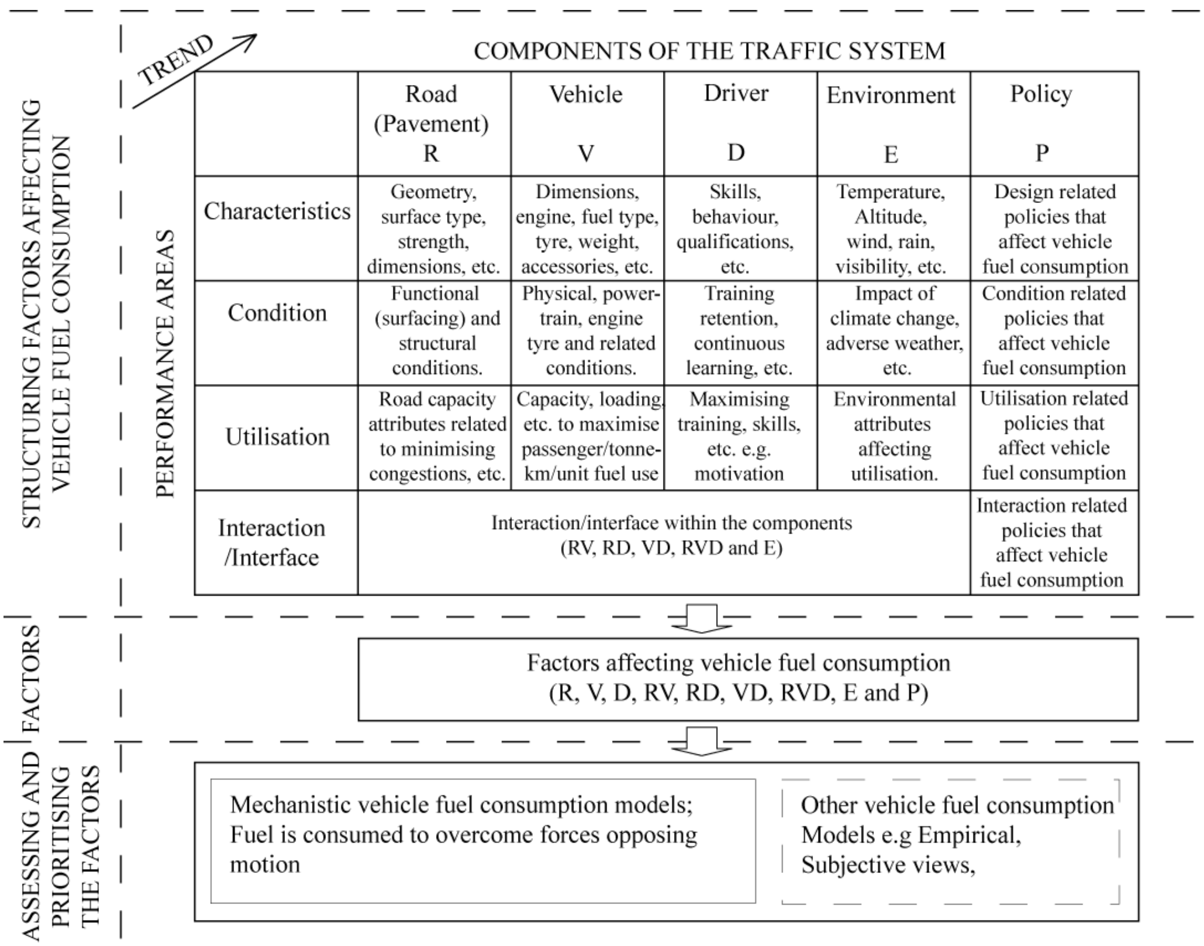



Figure 2.6: A framework for structuring and assessing the factors affecting vehicle fuel consumption (road transport energy use)

### 2.3.3 Design (Physical) Characteristics

#### *2.3.3.1 Road Design Factors*

Each road type is associated with unique design characteristics. The road design influences vehicle fuel consumption because the design features influence the resistance to motion which is related to the power requirements of the vehicle. According to Kulakowski (1994), and Bennett and Greenwood (2003) the following are the key physical road factors that are well known to affect fuel consumption:

- Road dimensions;
- Road texture;
- Initial road roughness (mega-texture);

- Road profile (alignment); and,
- Road surface types.

Using mechanistic principles, several authors including Cenek (1994), Bennett and Greenwood (2003) and Kulakowski (1994) have shown that road design factors affect vehicle fuel consumption by either increasing or reducing the forces opposing motion of the vehicle.

#### *2.3.3.2 Vehicle Design Factors*

The classification of road vehicles in terms of use parameters has become more evident (Toyota, 2008; TheGreenCarWebsite, 2009) suggesting the importance of energy use in the sector. There are several vehicle design characteristics that are thought to affect fuel consumption including the following:

- Vehicle weight (see Biggs and Akcelik, 1987; WBCSD, 2004);
- Vehicle size and aerodynamic characteristics (see Coyle and Brown, 2004);
- Vehicle power-train parameters including engine size, engine efficiency and drag (see Tolouei and Titheridge, 2009);
- Vehicle accessories (see Bennett and Greenwood, 2003);
- Vehicle tyres (see Elder, 1983; Weiss et al, 2000 and Bennett and Greenwood, 2003).

The influence of the vehicle design characteristics on fuel consumption has been related by means of the mechanistic principles in Bennett and Greenwood (2003). Figure 2.7 shows the trends in the weight of European car from 1970 to 2002.

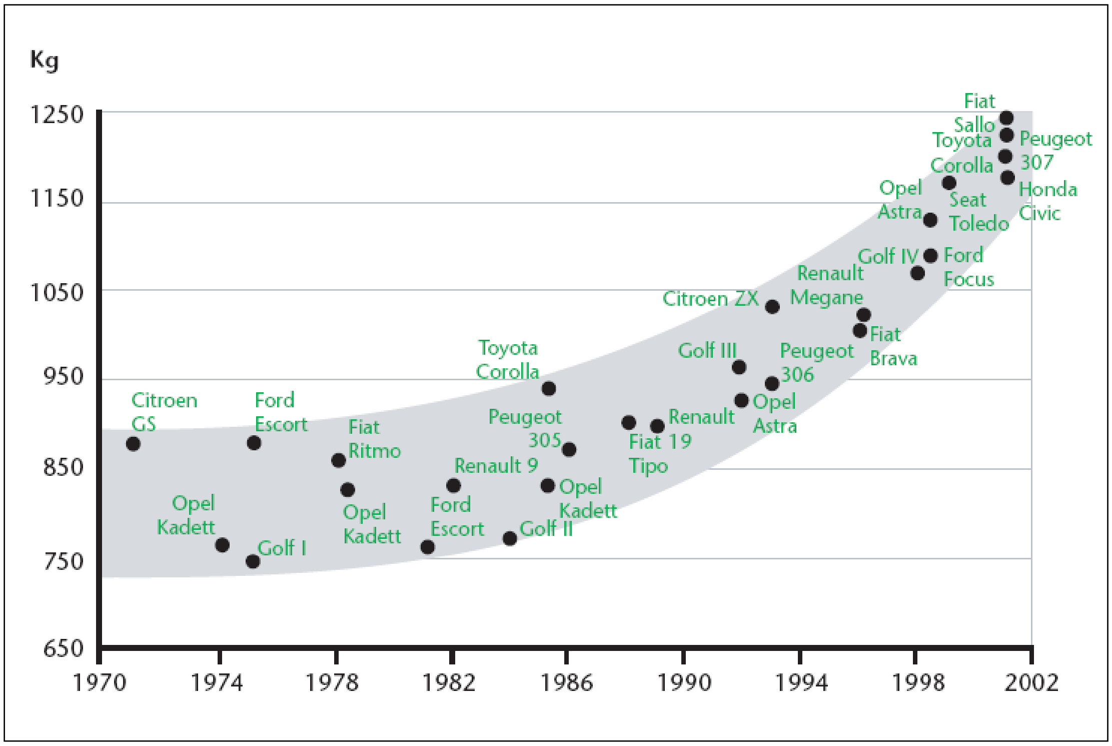



Figure 2.7: Increasing mass of European cars at time of model introduction (WBCSD, 2004)

There are many reasons for the increase in the mass of entry level European cars that is evident in Figure 2.7. Safety related increases include the strengthening of doors to reduce the consequences of side-impacts, the addition of air-bags and the protection of fuel tanks (see Ahmad and Greene, 2005; Chen and Ren, 2010). Also, the size of small cars has soared to accommodate taller and larger users. At the same time, air-conditioning, sophisticated suspension systems and entertainment systems have become expected attributes of modern cars, leading not only to a mass increase but also additional secondary (electrical) energy use. Although vehicle aerodynamics have improved, many of the above factors translate into greater fuel consumption.

Figure 2.8 shows the factors chosen to be addressed by General Motors Corporation as it invested USD 2.7 billion to develop a car that had significantly lower fuel consumption (Bennett and Greenwood, 2003). Unfortunately, some of the factors mentioned above are reducing the benefits deriving from the significant research investment into more efficient cars.

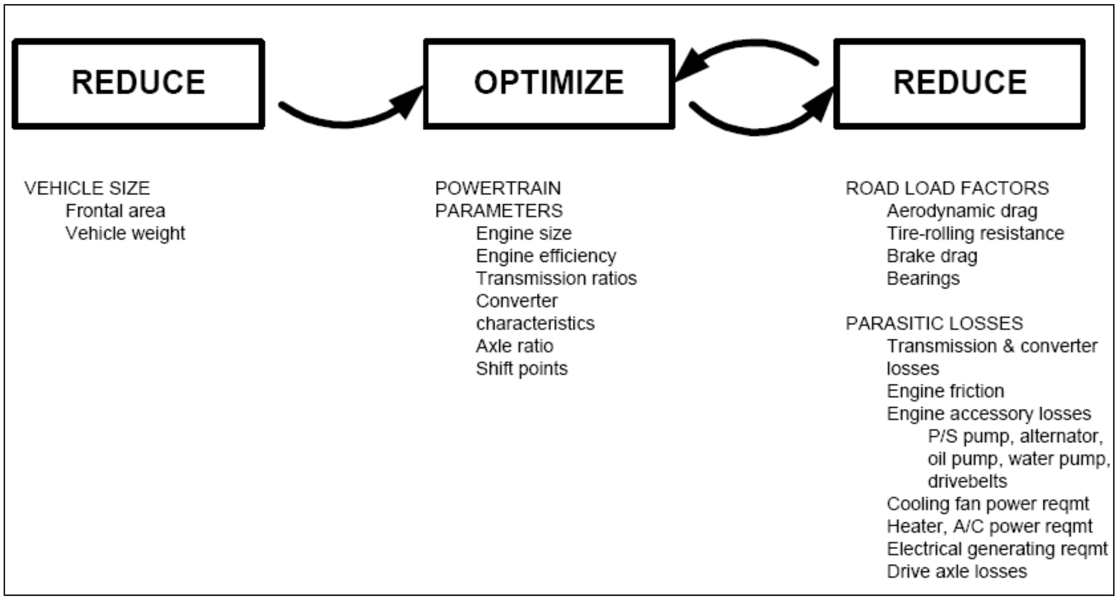



Figure 2.8: General Motors technical measures for reducing fuel consumption (Bennett and Greenwood, 2003)

### *2.3.3.3 Driver Characteristics*

It is known from literature including (French et al, 1993; af Wåhlberg, 2007; Manser et al, 2010) that driving style influences vehicle fuel consumption and driving style has been associated with particular driver characteristics. Especially for novice drivers the characteristics have been linked to the following parameters as described in Section 3.2.2 after Cacciabue and Carsten (2010):

1. Experience;
2. Attitudes or personality;
3. Task demand;
4. Driver state; and,
5. Situation awareness or alertness.

### *2.3.3.4 Environmental Factors*

Environmental factors like temperature, rainfall, altitude, wind, visibility (day, night, fog) and season (winter, spring, summer and autumn) can influence fuel consumption by influencing road, vehicle and driver factors. Some of the literature, for example, includes GoodyearGoodyear (2008) which suggests that engine efficiency is generally expected to increase with an increase in temperature except for non-turbo charged diesel engines which may be adversely affected; Bennett and Greenwood (2003) accounts for the effect of water and snow covered road on vehicle rolling resistance when modelling VOC; Goodyear (2008) suggests also that the effect of altitude on engine fuel economy performance depends on the particular engine design and whether or not it is supercharged or tuned for high-altitude operation; Siques et al (2007) account for the reduction in drivers' performance at higher altitudes to upper respiratory tract problems due to less concentration of oxygen per breath; and, to avoid excessive fuel consumption in sustained strong headwinds, Goodyear (2008) suggests a decrease in highway speed.

### 2.3.4 Condition Factors

#### *2.3.4.1 Road Condition*

Road roughness or international roughness index (IRI) is the primary measure of road condition as shown in Figure 2.9.

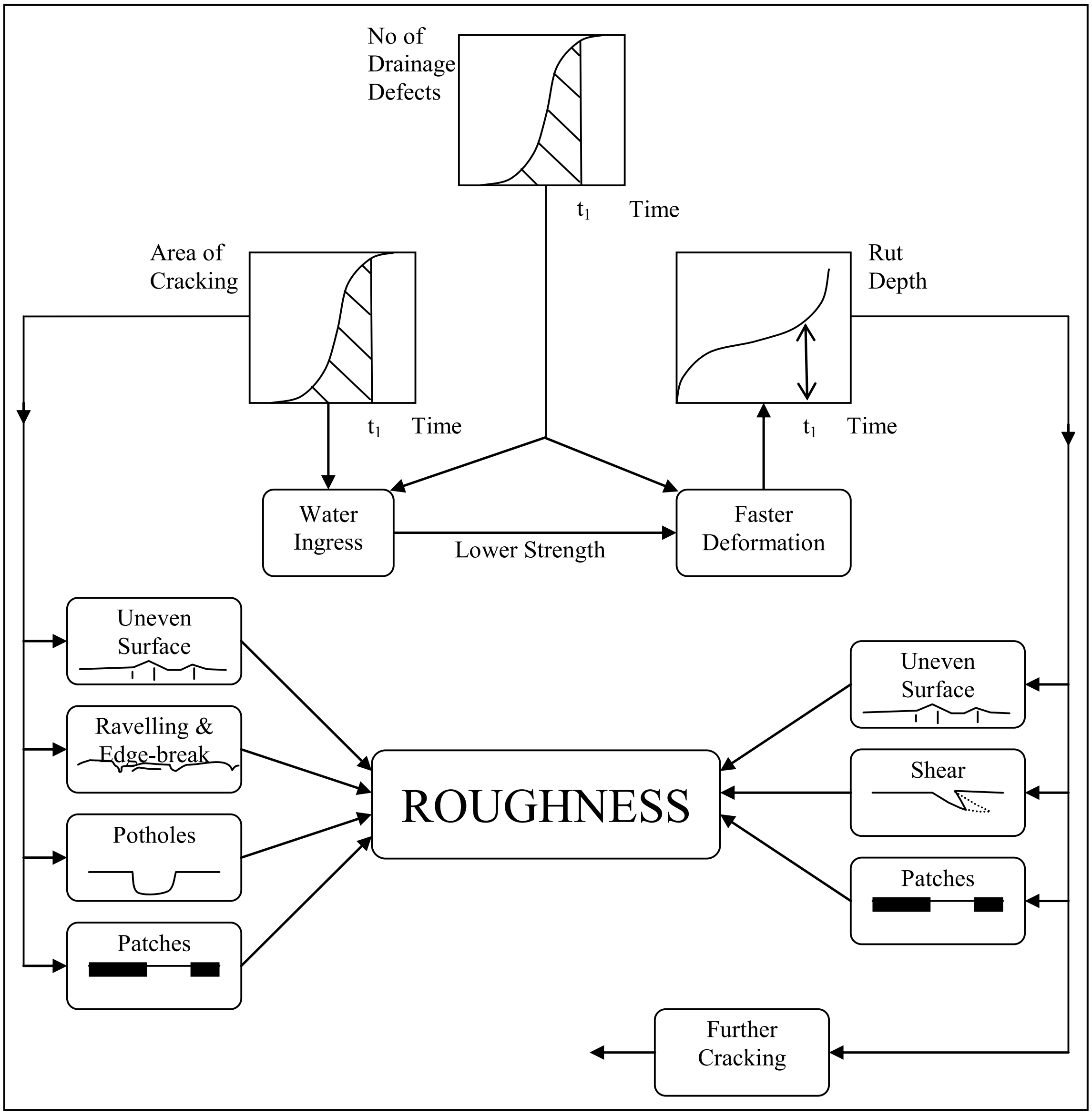



Figure 2.9: Road roughness as a primary measure of road condition (after Paterson, 1998)

Morosiuk et al (2004) models road condition using IRI as a measure of road condition and their work shows that road condition deteriorates over time due to traffic loading and environmental impacts. Cenek (1994) identified roughness as a primary factor in influencing vehicle fuel consumption. Bennett and Greenwood's (2003) mechanistic model for estimating vehicle fuel consumption shows that the static coefficient of rolling resistance increases with an increase in roughness.

#### *2.3.4.2 Vehicle Condition*

As vehicles get older, their operating costs increase (Chesher and Harrison, 1987). According to McKinnon et al (1993) fuel efficiency can be impaired by a wide variety of vehicle defects, the most common of the fuel-related defects being fuel leaks either in the supply or injection systems, representing approximately 44% of the total. Wheels and tyres that are misaligned and under/over-inflated respectively can account for a further 21% of fuel-related faults. A one-degree misalignment of one of the axles on a multi-axle trailer will raise fuel consumption by roughly 3%, while a two-degree misalignment will increase it by 8%. The other major category of fuel-related faults, constituting 17% of the total, is associated with the engine. McKinnon et al (1993) also note that the condition and maintenance of tyres can be even more important than that of the vehicle because of the frequency of tyre replacements, and because tyres are the interface between the vehicle and the road surface where a lot of forces act.

#### *2.3.4.3 Driver Training*

Driver training for fuel economy is the main topic of this research. Thus, the following Chapters cover only driver training for fuel economy. Nonetheless in Section 2.4 a preliminary study to determine the relative importance (or rank) drive influence on vehicle fuel consumption as compared to the other factors is reported to provide a better understanding of the factors.

#### *2.3.4.4 Natural Environmental Condition*

Climate change can be used to imply natural environmental condition (Anyala et al 2011) thereby the effects of such conditions might result in creating extreme values of the factors outlined in Section 2.3.3.4.

### 2.3.5 Utilisation

In this context utilisation refers to the maximisation of the performance of the components of the traffic system in terms of energy use. For the road (pavement) component, this can be related to road space utilisation in a way that optimises vehicle fuel consumption. Road space utilisation (congestion) is currently a subject of major concern especially in urban and sub-urban areas where most fuels are consumed. In the UK, for example, congestion is predicted to rise considerably and, if appropriate measures are not taken to address the issue, it is estimated that by 2025 congestion will cost the UK economy GBP 22 billion per year (DfT, 2006b). For vehicles, utilisation can be related to maximisation of vehicle tonne-km or passenger-km (McKinnon, 1999; Odhams et al, 2010) per unit of fuel (energy) consumed. Utilisation can be related to maximising drivers' knowledge, skills and training to improve vehicle fuel consumption efficiency as suggested by McKinnon et al (1993) and DfT (2006c).

### 2.3.6 Interaction (Interface)

The traffic operating system involves the interactions of the road, vehicle and driver within a natural environment as illustrated in Figure 2.5. In terms of vehicle fuel consumption, literature suggests that by improving the interfaces between these components fuel economy can be maximised, for example, road (surfacing) and vehicle (tyre) interface (Goodyear; 2008), driver and vehicle interface (Manser et al, 2010; Jamson et al, 2012), driver and road interface (Varaiya, 1993). The driver-vehicle interface is discussed further in Section 3.3.4 as a feedback method for improving vehicle fuel economy.

## 2.4 Preliminary Investigation on Driver Influence

The influence of driver training on fuel economy, which is the key topic of this research, has become an important subject in transport energy use and substantial literature (Evans, 1979; Siero et al, 1989; Nader, 1991; Ericsson, 2001; van der Voort et al, 2001; af Wåhlberg, 2002; Parkes and Reed, 2005; af Wåhlberg, 2006; af Wåhlberg, 2007; Zarkadoula et al, 2007; Beusen et al, 2009; Symmons and Rose, 2009; Scott et al, 2012; Turpin and Scott, 2010; Luther and Baas, 2011) already suggest that there is a significant benefit in terms of the improvement in the vehicle fuel economy. Much of the literature review regarding the influence of the driver or driving style on vehicle fuel consumption is provided in Chapter 3.

In this section, however, the author reports on a prioritisation study which was carried out to determine the relative importance (or rank) of the factors which affect vehicle fuel consumption based on the framework developed. The study used a subjective survey of selected individuals in the UK. There are limited literature related studies where the factors affecting vehicle fuel consumption have been prioritised or ranked (Kobayashi *et al*, 2009; Murrel, 1975; Bennett and Greenwood, 2003; Amann, 1997; Tolouei and Titheridge, 2009).

### 2.4.1 Method

#### *2.4.1.1 Concept*

The factors which influence fuel consumption in road vehicle operation were categorised under 8 resistances, as shown in Table 2-1 to facilitate the prioritisation study. This was based on a modified Australian Road Research Board (ARRB) Road Fuel Consumption Model (ARFCOM) structured to include the influence of the driver in the form of training for fuel efficiency, as shown in Figure 2.10 and summarised by Equation 2.1 after Bennett and Greenwood (2003). The main data requirement for the study was the ranking of the relative influences of the factors given in Table 2-2 on vehicle fuel consumption by selected individuals from the UK.

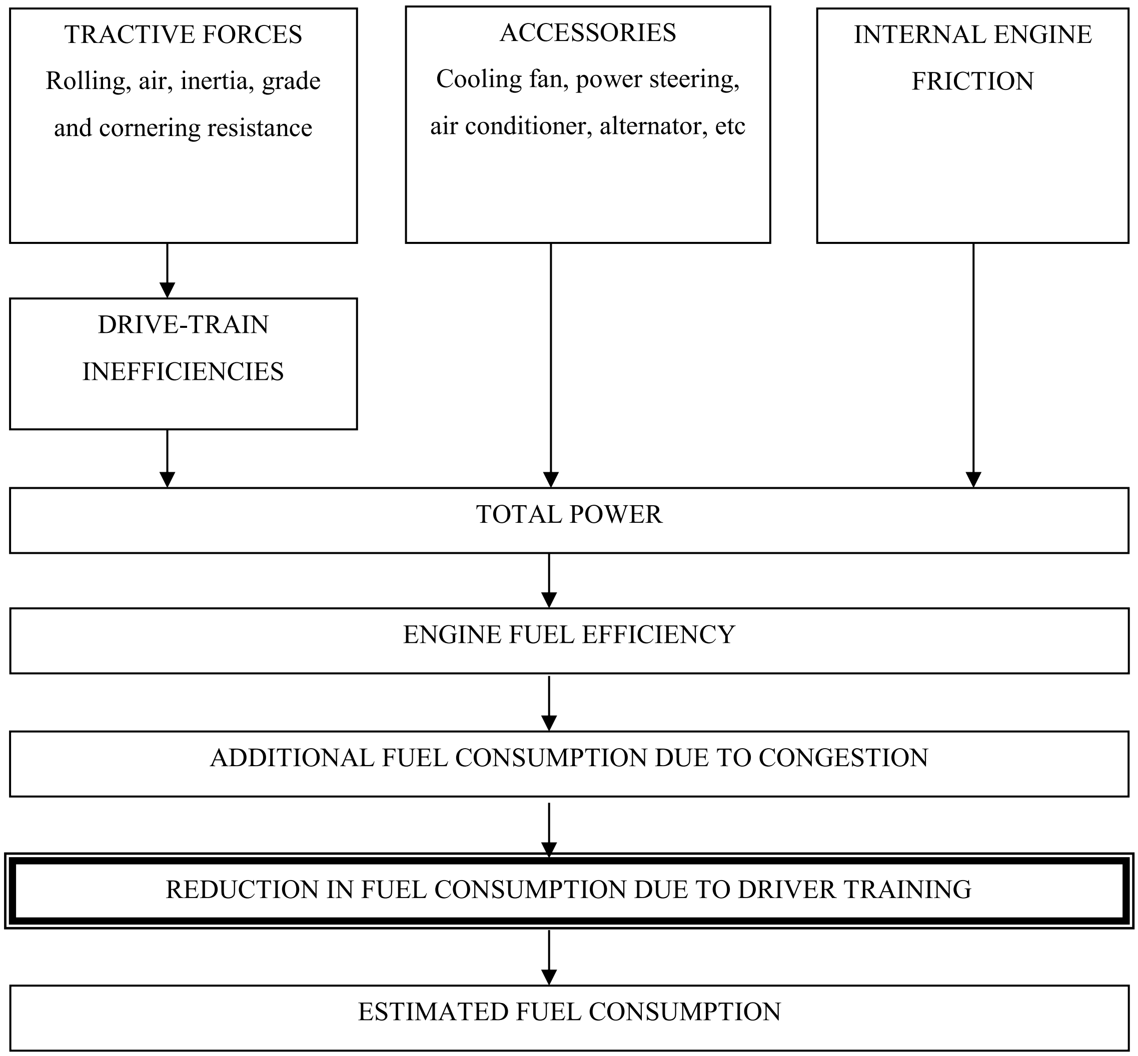



Figure 2.10: ARFCOM approach to modelling fuel consumption (modified after Bennett and Greenwood, 2003)

Equation 2.1 $$IFC = max[IFC_{min}, \xi P_{TOT}(\Delta FUEL_C \times \Delta FUEL_T)]$$

Where: $IFC$ is the instantaneous fuel consumption in ml/s, $IFC_{min}$ is the minimum fuel consumption in ml/s, $\xi$ is the fuel-to-power efficiency factor in ml/kW/s, $P_{TOT}$ is the total vehicle power requirements in kW, $\Delta FUEL_C$ is the additional fuel consumption due to acceleration events (congestion) in ml/s and $\Delta FUEL_T$ is the reduction in fuel consumption due to training drivers in fuel efficiency, also in ml/s.

#### *2.4.1.2 Participants*

34 people including 9 vehicle fleet technical managers, 11 road asset engineers and 14 fuel efficient driver trainers from across the UK participated in the study. The selection was primarily based on the roles of the individuals other than their demography. The selection of the participants was linked to the components of the proposed traffic operating model and the framework shown in Figure 2.5.

#### *2.4.1.3 Materials and Design*

Two questionnaires were employed: first, a quantitative approach in the form of a closed-ended questionnaire was designed and used to collect data from the participants where the influence of each of the factors was scored on an influence scale of 1 to 5 (1 = very low, 2 = low, 3 = medium, 4 = high, 5 = very high) (Appendix A-1); secondly, a qualitative approach in the form of structured interview/feedback was used (Appendix A-2). The use of both the quantitative and qualitative methods of data collection can ensure improvement in the quality of the results (Jick, 1979) through checks and validation.

#### *2.4.1.4 Procedure*

The participants were asked to complete the closed ended questionnaire either online or through a return email. This was followed by the qualitative or descriptive session which involved a face-face interview, or telephone interview depending on the location and choice of the participants. The weights (1 to 5) could be converted into a linear measure using a value function given by Equation 2.2 (Odoki et al, 2013).

Equation 2.2 $$V_w = k_0 + k_1 \times w$$

Where: $V_w$ is the measure of value and, $w$ is the mean (or modal) weight of a particular factor on a scale of 1 to 5 and, $k_0$ and $k_1$ are constants. In certain cases, the data may be translated using a different method to one generalised in Equation 2.2; the resulting data sets may be assessed to determine the statistical effects of the translation. In this cased the original data sets were retained as collected, that is, from Equation 2.2, $k_0=0$ and $k_1=1$, thus non-parametric in nature.

### 2.4.2 Analysis and Results

The analysis involved the use of descriptive statistical methods and plots. Table 2-1 gives the modal values from the participants which show that they believe vehicle related factors (Table 2-2) to be the most influential in affecting vehicle fuel consumption. The results also show higher variability in the data for the heavy vehicle than the car drivers. Overall, the least variable data was from the driver training participants.

Table 2-1: Modal values and standard deviations (SD) representing the influence of the resisting forces by individual group for car and heavy goods vehicle (HGV)

| Individual Group | Vehicle Fleet | | | | Driver Training | | | | Road Asset | | | | Group | | | | Group: Improving Transport Energy Efficiency | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *N* | 9 | | | | 14 | | | | 11 | | | | 34 | | | | 34 | | | |
| | Car | | HGV | | Car | | HGV | | Car | | HGV | | Car | | HGV | | Relative Potential | | Relative Cost | |
| | Modal Value | SD | Modal Value | SD | Modal Value | SD | Modal Value | SD | Modal Value | SD | Modal Value | SD | Modal Value | SD | Modal Value | SD | Value | SD | Modal Value | SD |
| Aerodynamic resistance | 1.0 | 0.5 | 2.0 | 0.4 | 1.0 | 0.5 | 1.0 | 0.5 | 1.0 | 0.5 | 1.0 | 1.0 | 1.0 | 0.5 | 1.0 | 0.7 | 1.0 | 0.4 | 1.0 | 0.4 |
| Rolling resistance | 1.0 | 0.4 | 1.0 | 1.1 | 1.0 | 0.4 | 2.0 | 0.7 | 1.0 | 0.5 | 1.0 | 0.7 | 1.0 | 0.4 | 1.0 | 0.8 | 1.0 | 0.3 | 2.0 | 0.4 |
| Inertial resistance | 1.0 | 0.5 | 1.0 | 0.5 | 1.0 | 0.5 | 3.0 | 0.5 | 1.0 | 0.5 | 2.0 | 0.6 | 1.0 | 0.5 | 2.0 | 0.6 | 1.0 | 0.5 | 1.0 | 0.7 |
| Gradient resistance | 1.0 | 0.5 | 1.0 | 0.5 | 1.0 | 0.5 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 | 0.5 | 2.0 | 0.8 | 2.0 | 0.5 |
| Curving resistance | 1.0 | 0.3 | 1.0 | 0.4 | 1.0 | 0.5 | 1.0 | 0.5 | 1.0 | 0.5 | 2.0 | 0.5 | 1.0 | 0.4 | 1.0 | 0.5 | 2.0 | 0.4 | 1.0 | 0.4 |
| Vehicle related resistance | 4.0 | 0.5 | 5.0 | 0.5 | 5.0 | 0.5 | 5.0 | 0.6 | 5.0 | 0.6 | 5.0 | 0.8 | 5.0 | 0.6 | 5.0 | 0.7 | 5.0 | 0.8 | 4.0 | 0.3 |
| Driver training influence | 2.0 | 0.7 | 3.0 | 1.0 | 2.0 | 0.7 | 2.0 | 0.6 | 2.0 | 0.7 | 3.0 | 0.5 | 2.0 | 0.7 | 3.0 | 0.7 | 1.0 | 0.4 | 1.0 | 0.6 |
| Congestion influence | 2.0 | 0.6 | 3.0 | 0.8 | 3.0 | 0.5 | 3.0 | 0.6 | 2.0 | 0.5 | 2.0 | 1.1 | 2.0 | 0.6 | 3.0 | 0.7 | 3.0 | 0.3 | 2.0 | 0.5 |

In Figure 2.11, the results also show that factors related to congestion and driver training influences were the second most influential in terms of vehicle fuel consumption, according to the participants. The results show that the participants consider that influences of aerodynamic, rolling, inertial, gradient and curving resistances are generally low, although inertial resistance marginally higher for HGV than car.

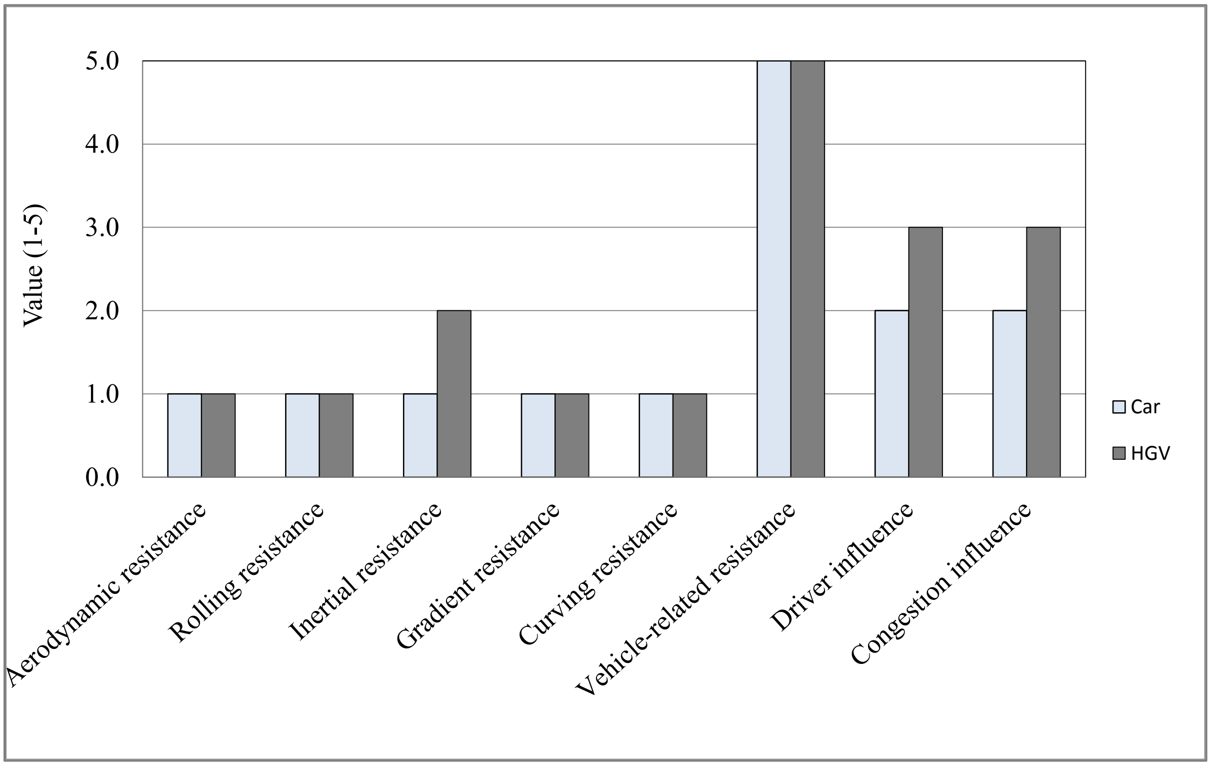



Figure 2.11: Overall (group average) distribution of the measure value related to the forces affecting vehicle fuel consumption for car and HGV

The participants were also asked to provide information to classify the relative potential to improve vehicle fuel consumption efficiency with regards to the 8 categories of resistances, and the associated cost. The results (Figure 2.12) show that the participants think that vehicle-related factors present the highest potential to improve vehicle fuel consumption, followed by congestion and driver influences. Interestingly the participants think that driving training presents the most cost-effective intervention to improve vehicle fuel consumption efficiency, followed by interventions related to congestion and vehicle-related factors.

The factors (level 2 in Table 2-2) associated with each resistance (level 1 in Table 2-2) were also analysed based on a relative scale of 1 to 5. The influence of different factors on the resistances were then classified as follows 1-2 = low, 2-3 = medium, 3-4 = high, 4-5 = very high) as summarised in Table 2-2 and graphically shown in Appendix A-3.

Table 2-2: Categorised and prioritised factors affecting vehicle fuel consumption

| Resistance – Level 1 | Specific Aspect – Level 2 | Influence | |
|---|---|---|---|
| | | Car | HGV |
| Aerodynamic resistance | Vehicle dimensions | Medium | High |
| | Vehicle speed | Medium | High |
| | Wind speed | Medium | Medium |
| | Air density | Low | Low |
| | Aerodynamic aids | Medium | Medium |
| | Temperature | Low | Low |
| | Altitude | Low | Low |
| Rolling resistance | Vehicle weight | Medium | High |
| | Macro-texture | Medium | Medium |
| | Road roughness | Medium | Medium |
| | Road strength (Flexible) | Low | Low |
| | Vehicle speed | Medium | Medium |
| | Tyre and wheel characteristics | High | High |
| | Weather | Low | Low |
| Inertial resistance | Vehicle weight (mass) | Medium | Medium |
| | Engine and drive-train weight (mass) | Medium | Medium |
| | Wheels weight (mass) | Low | Low |
| | Acceleration and deceleration | Medium | Medium |
| Gradient resistance | Vehicle weight | Medium | High |
| | Road gradient | Medium | Medium |
| Curving resistance | Vehicle weight | Medium | High |
| | Curve geometry | Medium | Medium |
| | Tyre and wheel characteristics | Medium | Medium |
| Vehicle-related resistance | Engine drag | Medium | Medium |
| | Accessories, e.g., Regenerative breaking | Medium | Medium |
| | Engine base efficiency | Medium | High |
| | Engine fuel efficiency (fuel types) | High | High |
| | Drive-train efficiency | High | High |
| | Engine idling | Medium | Medium |
| Driving training influence | Driving training | High | High |
| | Fuel consumption monitoring and management | High | High |
| Congestion influence | Congestion influence | High | Very high |

The plots of the modal values indicated a good correlation between the groups of the participants which was confirmed using the Kruskal-Wallis test using the SPSS™ statistical software (IBM, 2010) which suggested that the groups' mean ranks were statistically the same at 95% confident interval (CI) ($p$ > 0.9) for both car and HGV vehicle categories. Independent application of the Spearman's rank correlation technique between the data sets also produced coefficients greater than 0.9 in all cases.

The participants think that vehicle-related factors are the most influential factors affecting vehicle fuel consumption, which is consistent with other literature (Kobayashi et al, 2009; Murrel, 1975; Bennett and Greenwood, 2003; Amann, 1997; Tolouei and Titheridge, 2009). The literature suggests that engine heat losses (engine efficiency) can be as high as 62%. Thus vehicle-related resistance would initially be seen as an area with the greatest potential for improving vehicle fuel consumption efficiency as shown in Figure 2.12.

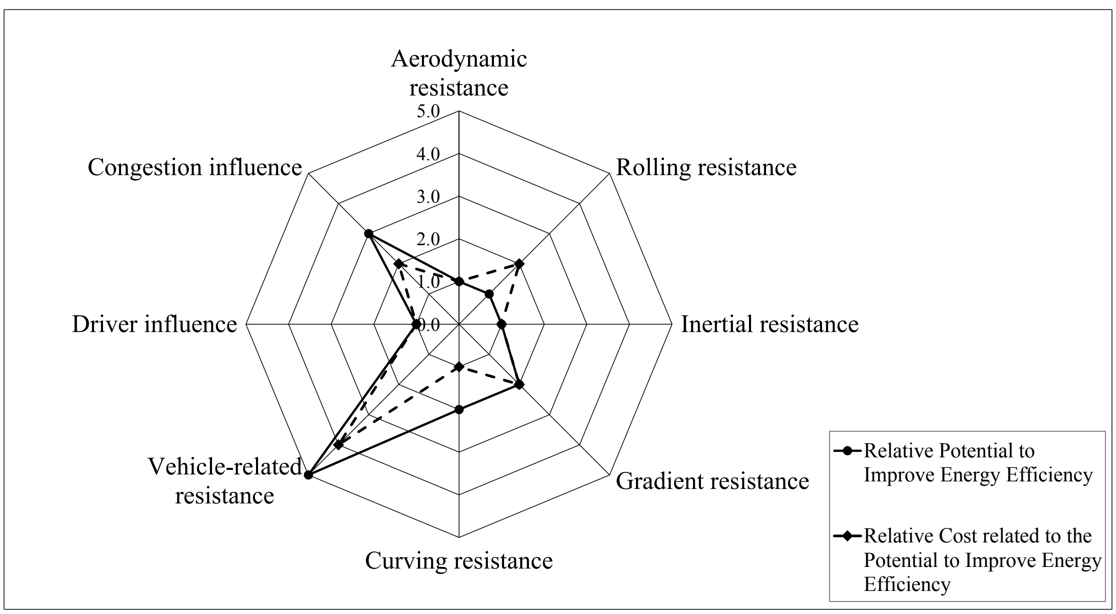



Figure 2.12: Perceived potential and cost of improving fuel economy on a scale of 1 to 5

However, as shown in Figure 2.12 the participants think that interventions aimed at improving engine and transmission efficiencies appear to be much more expensive than other interventions like fuel efficiency focussed driver training (af Wåhlberg, 2006; af Wåhlberg, 2007; Turpin and Scott, 2010), logistical planning (McKinnon et al, 1993), and improving road space to reduce traffic congestion (DfT, 2007). Fuel economy driver training is considered to be the most cost-effective intervention to improve fuel economy by the participants. The findings also show that the participants consider that aerodynamic and rolling forces are higher in heavy goods vehicles (HGV) than in cars. This is also noted in the literature by both Coyle and Brown (2004), and Bennett and Greenwood (2003).

#### *2.4.2.1 Limitations*

This study has some limitations including the following: (i) the size of the sample may not be representative of the population of the knowledge in the UK (England); this could be improved by increasing the number of participants and their technical/academic knowledge with regards to vehicle fuel consumption; (ii) the selected factors affecting vehicle fuel consumption might not be exhaustive; (iii) the influence of the factors are based on subjective views of the participants, and this could be improved by using analytical tools containing well-developed models including the relevant sensitivity analysis. Therefore, the results of this study, especially the prioritisation of the factors affecting vehicle fuel consumption should be used bearing in mind these limitations.

## 2.5 Summary

In this Chapter, the author has shown that vehicle fuel consumption is the biggest component of total road transport energy use. An outline framework was used to structure the factors that affect vehicle fuel consumption. Besides the literature which suggests the importance of the influence of driver action on vehicle fuel consumption, a preliminary investigation, based on a questionnaire, reinforced the suggestion that vehicle-related factors were the most influential factors affecting vehicle fuel consumptions. This is followed by the influence of the driver and, while the vehicle-related factors could be expensive to change in order to improve vehicle fuel economy, driver training could be carried out more quickly and at much lower costs.

To this end the following part of this research focuses only on the influence of driver training on vehicle fuel consumption. In Chapter 3 a literature review is carried out regarding driving style and the use of driver training to improve vehicle fuel efficiency.

# CHAPTER 3 DRIVING STYLE AND FUEL ECONOMY

## 3.1 Introduction

In this Chapter, the author reviews the literature on driving style; its influence on vehicle fuel consumption and the evidence as to where driver training for fuel economy has been used to influence driving style. In Section 3.2, driving style is defined including the reason for its variability among drivers. The review of the literature regarding the use of driver training to influence driving style for vehicle fuel economy is provided in Section 3.3.

## 3.2 Driving Style

### 3.2.1 Definition and Classification

There have been several studies regarding the definition and classification of driving style in relation to road transport performance goals like safety (accidents) (French et al, 1993; West et al, 1993; Elander et al, 1993), fuel consumption and emissions (Doshi and Trivedi, 2010; Murphey et al, 2009; af Wåhlberg, 2007; Turpin and Scott, 2010), and others like time saving and vehicle wear and tear. Elander et al (1993) defined driving style in terms of the way an individual chooses to drive or the driving habits that have become established over a period of years. The habits relate to speed, threshold for overtaking, headway, and the inclination to commit traffic violations.

To facilitate an analysis of the driving styles of individuals or groups French et al (1993) used the following six independent dimensions to classify driving style:

1. Speed: is speed driven by a driver in a particular car and road conditions;
2. Calmness: is associated with staying calm particularly in dangerous situations, where there is little time for thinking;
3. Planning: concerns planning a journey and for example could consist of consulting a map and planning adequate places to stop en route to rest;
4. Focus: is to do with focusing on the task at hand and ignoring distractions;
5. Social resistance – this being made up of dislike for being given advice about driving, and resistance to laws and regulations;

6. Deviance: concerns propensity to break the Highway Code and the law. For example, jumping the lights and overtaking on the inside.

The literature also suggests that driving style relates to the variation in vehicle speeds and/or acceleration (both positive and negative), the time derivative of acceleration (or jerk), acceleration noise (measured by the standard deviation of acceleration in a defined environment) and personality (e.g., anxiety). For example, Murphey et al (2009) defined driving style as a transient (dynamic) behaviour of a driver on the road. They used two parameters to help classify driving style in relation to its effect on vehicle fuel consumption. The first consisted of determining a measure of how fast a driver accelerated which they termed 'jerk analysis'. The second was based on a method of classifying driving style which included the use of the ratio of the standard deviation of the acceleration over time and the average acceleration; and, if the ratio was greater than 100%, the driving style was classified as aggressive, if it was between 50% and 100%, the driving style was classified as normal, and calm if it was less than 50%. They attempted to classify driving style into the following four categories which they related to vehicle fuel consumption:

1. Calm driving: this is where a driver anticipates another road user's movement, traffic lights, speed limits and avoids hard/harsh acceleration. They claimed that calm driving was the most fuel efficient style;
2. Normal driving: this is where a driver uses moderate acceleration and breaking;
3. Aggressive driving: this is where a driver uses sudden acceleration and heavy breaking; they suggested that this was the least fuel efficient style.
4. Stationary.

Taubman-Ben-Ari et al (2004) also suggests four similar driving styles that they found were related to personality variables as follows:

1. Reckless and careless: driving style characterised by deliberate violations of safe driving norms including high speeds and illegal passing;
2. Anxious: driving style relating to feeling of alertness and tension, along with ineffective relation activities when driving;

3. Angry and hostile: driving style characterised by expression of irritation, rage and hostile attitudes, and other similar acts on the road (aggression);
4. Patient and careful: driving style characterised by planning ahead, attention to the road, calmness, and obedience to traffic regulations.

In Section 3.2.2, existing literature explaining the cause of variability in driving style is examined, with the aim of identifying the potential ways of influencing the driving style through methods that improve driving skills (defined by De Groot (2012) as the way in which a person is able to control a car) to improve specific driver-related performances; in this case fuel economy.

### 3.2.2 Variability in Driving Style

Driving style can vary between drivers for a particular driving event, taking into account non-driver related variables such as road, vehicle, and environmental factors. To help explain the reasons behind this variability, research has been carried out by, amongst others, Cacciabue and Carsten (2010), Taubman-Ben-Ari and Yehiel (2010), Elander et al (1993) and French et al (1993). Cacciabue and Carsten (2010) presented a useful summary of the research and suggested that driver behaviour, driver capability and performance are influenced by factors which can be categorised into five major groups as follows:

1. Experience – this defines the accumulation of knowledge or skills that result from the direct participation in the driving activity and is achieved over time;
2. Attitudes or personality – this defines a complex mental state, feelings and values causing the driver to act in certain ways;
3. Task demand – this defines the demands of the process of achieving a specific and measurable goal using a prescribed method to be carried out by the driver;
4. Driver state – this defines the driver's physical and mental ability to drive and is usually associated with fatigue, sleepiness, etc.;
5. Situation awareness or alertness – this defines the driver's perception of the elements in the driving environment within a volume of time and space involving the comprehension of their meaning and the projection of their status to the near future.

In order to measure and monitor these parameters when modelling driver behaviour, Cacciabue and Carsten (2010) related them to observable or measurable variables as shown in Table 3-1.

Table 3-1: Parameters and observable variables affecting driver behaviour (Cacciabue and Carsten, 2010)

| Parameters (Factors) | Measureable Variables |
|---|---|
| Experience | 1 Number of km per year<br>2 Number of years with driving licence |
| Attitudes | 1 Speed choice<br>2 Lane keeping<br>3 Overtaking propensity<br>4 Headway |
| Task demand | 1 Traffic complexity<br>2 Weather<br>3 Light<br>4 Speed<br>5 Driving direction |
| Driver state | 1 Lane keeping; headway control<br>2 Duration of driving; time-on-task<br>3 Weather; road condition<br>4 Traffic complexity<br>5 Speed |
| Situation awareness | 1 Distraction<br>2 Driver state<br>3 Task demand |

Consequently, in order to improve or maximise the potential performance from a driver with respect to achieving certain goals, e.g., fuel efficient driving and safe driving, some of the above factors associated with the five categories need to be changed or influenced to change. Clearly some of the parameters affecting driver behaviour (Table 3-1) will be difficult, if not impossible, to change but some can be influenced through, for example, various individual, community, company, national and international based approaches including (Barkenbus, 2010):

- Public education;
- Driver feedback;
- Regulatory actions;

- Economic (policy and actions);
- Social marketing.

These approaches can be structured at a strategic, tactical and operational level (Robinson et al, 1998; Sivak and Shoettle, 2011) depending on the level of application. The present research focuses on driver training to influence driving style for better fuel economy at an operational level.

Driver training as a method for improving driving skills for fuel economy (af Wåhlberg, 2006, af Wåhlberg, 2007) and the use of intelligent driver support systems (Jamson et al, 2012, Beusen et al, 2009) are considered as approaches that provide driver feedback. Driver feedback includes (Gonder et al, 2011):

- General advice sources to the drivers;
- Driver training for fuel economy;
- Convention dashboards (visual);
- Comprehensive driver-vehicles interface;
- Global Positioning System (GPS), i.e. satellite navigation (satnav);
- Smart phone applications;
- Offline fleet feedback systems.

The present research addresses bullet point number 2 on the list above and involves both theoretical and practical work.

## 3.3 Training Drivers for Fuel Economy

The literature shows that driving styles have a strong influence on vehicle fuel consumption (af Wåhlberg, 2007; Murphey et al, 2009), and that by training drivers to drive differently (by imparting specific driving skills), vehicle fuel consumption economy can be improved (see for example, Evans, 1979; Siero et al, 1989; Nader, 1991; Ericsson, 2001; van der Voort et al, 2001; af Wåhlberg, 2002; Parkes and Reed, 2005; af Wåhlberg, 2006; af Wåhlberg, 2007; Zarkadoula et al, 2007; Beusen et al, 2009; Symmons and Rose, 2009; Manser et al, 2010; Scott et al, 2012; Turpin and Scott, 2010; Luther and Baas, 2011). The initial work regarding the training of drivers in economical driving styles were focussed primarily on reducing the amount of vehicle fuel consumption (Siero et al, 1989; Nader, 1991; Ericsson, 2001; af Wåhlberg, 2002; Parkes and Reed, 2005) but more recent studies also address the optimisation of the training, for example, safety, journey time and comfort performances when the drivers return to their normal driving, (af Wåhlberg, 2006; af Wåhlberg, 2007; Zarkadoula et al, 2007; Symmons and Rose, 2009). Intelligent driver-vehicle interface systems are also emerging as effective and efficient means of influencing driving style for better driving goals (e.g., safety and fuel economy) (Jenness et al, 2009; Manser et al, 2010; Young et al, 2011; ecoDriver, 2012; Fiat, 2010; Lai et al, 2012; Jamson et al, 2012; Cacciabue and Carsten, 2010; Amditis et al, 2010).

### 3.3.1 On-the-Road Training

In this research, on-the-road training is used to refer to training involving both theoretical and practical sessions carried out by the trainers and the drivers on the road.

Siero et al (1989) describe the training of mail-van drivers employed by the Netherlands Postal and Telecommunications Services (PTT) to improve fuel economy, which resulted in an improvement of more than 7%. Both on-road and theoretical methods were combined, using the model summarised in Figure 3.1, to influence the drivers' behaviours related to fuel-saving. Their training was based on three principles as follows:

1. Provision of information to the drivers;
2. Provision of task assignment and control;
3. Provision of feedback regarding fuel consumption to the drivers.

These principles were translated into six phases that are shown in Figure 3.1.

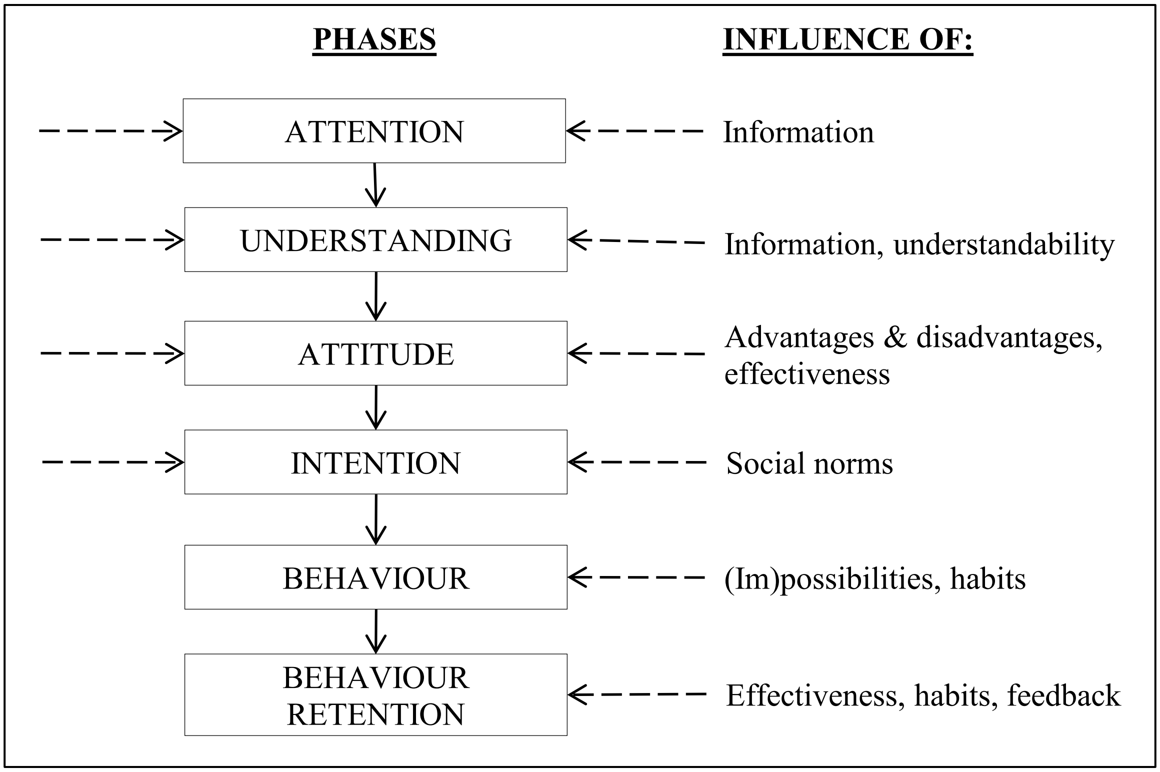



Figure 3.1: A phase model used for influencing behaviour related to fuel consumption (Siero et al, 1989)

In order to design the training and provide the right information to the drivers, Siero et al (1989) conducted a preliminary (pilot) study where they classified the drivers' behaviour against the following four factors:

1. Pressing down the accelerator (gas) pedal when accelerating;
2. Shifting gear;
3. Anticipating; and,
4. Exceeding maximum speed limits.

The idea of classifying driving style or behaviour in order to target drivers' performance improvement or assess the potential has also been used in other related studies. For example French et al (1993) developed and used a driving style questionnaire (DSQ) to classify the drivers' driving styles based on the six dimensions and their associated measures summarised in Section 3.2.1. Although the classification by French et al (1993) was intended to assist the assessment of driving style against factors like age, gender, and accident liability, a modified version of their DSQ can be used for determining specific drivers' pre-training information for assessing the impact of driver training. Siero et al (1989) provided information to counter the drivers' misconceptions and to support their fuel-saving behaviour recognised through the pilot study, forming part of the whole training. The information provided included the use of stickers placed on the dashboards to display advice to the drivers; a tachometer and a fuel flow meter were installed in 30% of the organisations delivery vans, giving the driver opportunities to obtain information on gear shift and acceleration.

Siero et al (1989) report that PTT, as an organisation, committed to saving 5% on fuel use as an organisation. The task assignment and control was based on the organisation structure shown in Figure 3.2. For a period of 6 months, fuel use was included as an item on the agenda of managers/directors' monthly meetings ensuring that the supervisors were consulted to discover the impact of the training on the ground. This component of the principles of training for fuel-efficiency is consistent across many such training schemes including the safe and fuel-efficient driver (SAFED) training scheme in the UK (DfT, 2003a): management commitment is essential to champion fuel-saving initiatives.

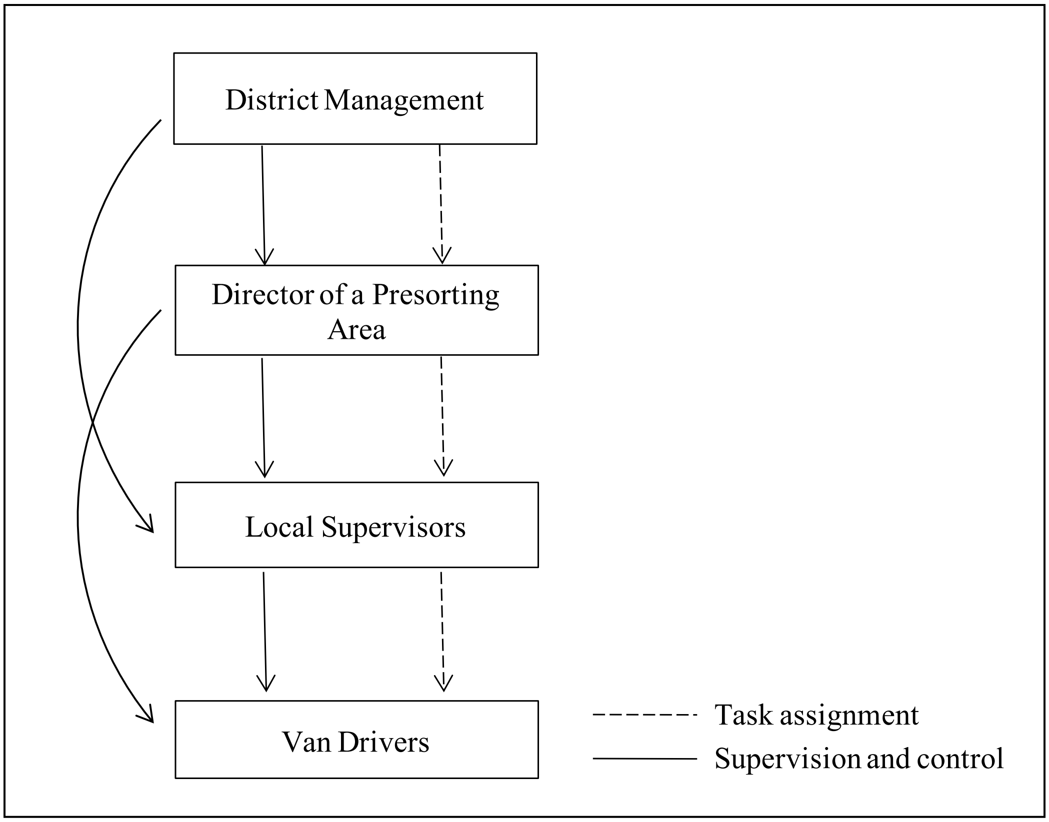



Figure 3.2: Implementation of fuel-saving behaviour in a postal district assignment of tasks, supervision and control (Siero et al, 1989)

According to Siero et al (1989), weekly vehicle (van) fuel consumption data were recorded and expressed as percentages of the measurements before the training in order to provide feedback to the drivers and supervisors. They adjusted the fuel saved to changes in the control group and then provided figures as feedback through bulletins posted at the depots' notice boards. An overall improvement of over 7% in the drivers' fuel economy was achieved. Although they were interested in the impact of the training on fuel saving as the primary outcome, they also observed improvements in attitudes, social norms and behaviours (measured by questionnaires), and suggested that the changes were caused by a combination of factors, that is, information, task assignment and control, and feedback; although it was not possible to determine or pinpoint the particular behavioural elements that were responsible for the observed effects.

Another study by af Wåhlberg (2002), carried out with 35 bus drivers and other personnel from Gamla Uppsalabuss in Uppsala, Sweden, typically an urban environment, tested a method of using acceleration patterns to quantify the effects of training for fuel efficiency. The training involved the use of both on-the-road and theoretical methods. af Wåhlberg (2002) notes in this study that training fuel efficient driving in Europe (mainly Sweden and Finland) were dominated by the brand name 'EcoDriving'. See Luther and Baas (2011) for a comprehensive review of EcoDriving-based training methods which has also been summarised in Section 4.2.4. af Wåhlberg (2002) was cautious about the claimed effects of 'EcoDriving' and similar techniques especially on areas of performance other than fuel consumption. He also noted that previous studies regarding fuel consumption were scarce and, if any, most lacked appropriate scientific analysis, besides being limited to the training environment alone and not on how people drove in actual traffic. The other deficiency highlighted was that no reliable study had covered a period longer than a year after the training.

According to af Wåhlberg (2002) the principles or instructions related to 'EcoDriving' are:

A) General principles

- Do not use more than half-throttle;
- Change gear before 3000 revolutions per minute (RPM);
- Plan ahead, to avoid braking, by adjusting your speed in an early phase by the use of friction;
- Use a uniform throttle when a desirable speed has been achieved, that is, do not compensate when loosing speed at an inclination;
- Drive in the highest possible gear;
- Use engine braking instead of the brake pedal;
- Do not overtake unnecessarily;
- Awareness/theory session where the instructors highlight the environmental problems, pollution by vehicle and different ways of reducing vehicle fuel consumption.

B) Specific instructions used

- Accelerate more strongly;
- Start the acceleration early;
- Release the throttle in descent;
- Plan continuously ahead.

According to af Wåhlberg (2002) instructions used in training programmes like 'EcoDriving' have been related to improving fuel consumption economy as the only measureable variable, but that this variable is not very informative in terms of driver behaviour. The interest was to measure other variables that could explain why training was not working in some cases, and also, if couched in positive terms, exactly what behaviours would be affected. This issue was also noted by Siero et al (1989). To this end, af Wåhlberg suggested the following methods of measuring driver behaviour:

1. The use of vehicle data – these include revolutions per minute (RPM), fuel consumption, speed, etc.
2. The scoring (by an observer) of observable behaviours related to driving attributes (skills) associated with fuel consumption like braking, gear change, acceleration, speed, etc. This method is similar to the self-reporting method used by French et al (1993) to classify driving style/behaviour using the DSQ;
3. The use of acceleration patterns (which have been used to predict traffic accidents) since they have been observed to be stable over time and are easily measured (af Wåhlberg, 2002).

af Wåhlberg (2002) successfully used acceleration patterns (no. 3 above), alongside fuel consumption, to quantify the effect of the training which was carried out on pre-determined bus routes. The results of the study showed that fuel consumption had decreased; accelerations were compressed into shorter bursts of stronger change in speeds, and decelerations decreased.

af Wåhlberg (2006) reports on an extension of the training of drivers at the bus company Gamla Uppsalabuss in Uppsala to investigate passenger comfort and driver acceleration behaviour. The following short-term effects of the training on the following performance areas were investigated:

1. Comfort – this was assessed by means of passenger questionnaires regarding the general level of comfort associated with the bus company compared with the specific ride after the driver training, and the use of the general statistical methods like analysis of variance (ANOVA); and
2. Acceleration – this was assessed by measuring the mean acceleration and deceleration levels of the drivers on the same route before and after the training, and then applying the ANOVA method.

af Wahlberg (2006) found evidence of correlations to suggest that ‘EcoDriving’ affected comfort by analysing the impact of the training on acceleration variables, which indicated a negative impact on comfort.

Another study by af Wåhlberg (2007) regards the long-term (annual) impact of heavy ‘EcoDriving’ on fuel consumption, accident and driver acceleration behaviour as part of the study initiated in 2002 (af Wåhlberg, 2002). The training was carried out in two main phases, the first phase being the traditional heavy ‘EcoDriving’ phase and the second phase involved the use of instantaneous driver technical feedback system (EconenTM) to help the driver achieve even better fuel economy. Although it is noted in the study that the benefit of such training in terms of vehicle fuel consumption rapidly diminishes after the training (also observed by Turpin and Scott, 2010), the performance was reported on an annual basis thereby limiting the assessment of the training say on a monthly basis. An average fuel consumption reduction of about 2% was reported over a period of 12 months; a further 2% reduction was also observed through the use of the driver feedback system. Besides other constraints that were encountered in the study (including problems with fuel types, data logging, vehicle condition and composition), the monthly or weekly fuel consumption (performance) was also not reported; this would be beneficial to understand when to carry out such training renewal or regimes.

A study by Turpin and Scott (2010) for the Department for Transport (DfT) regarding the longevity of the benefits of the safe and fuel-efficient driver (SAFED) training suggests that transport operators with continuous driver management programmes (philosophy) are likely to achieve greater benefits from SAFED driver training, and that the benefits can be sustained over a longer period of time. SAFED training, which is a 1-day off-the-job course, involves both theory and practical (on-the-road) tuition covering fuel efficient driving techniques like early awareness, better use of gears, avoiding harsh braking, planning ahead and fuel economy awareness. The training is usually given to two drivers at a time in their own company vehicle. A more detailed review of SAFED training is provided in Section 4.2.3.

The benefit, mainly in terms of fuel consumption efficiency, was compared among 4 groups of operators divided by means of pre- training questions as follows:

1. Group 1 – Operators with no driver management and with no training in fuel economy (not necessarily SAFED);
2. Group 2 – Operators with no driver management but with training in fuel economy;
3. Group 3 – Operators with driver management but without training in fuel economy;
4. Group 4 – Operators with both driver management and training in fuel economy.

The training involved 33 transport operators and 360 trained drivers and an equivalent number of drivers as a control group. Training questionnaires were used to collect information from the drivers and the operators before and after the training. A summary of the number of the participants used in the study is given in Table 3-2.

Table 3-2: Number of SAFED study participant numbers (Turpin and Scott, 2010)

| Study Group | Study Category | Vans | HGVs | Total |
|---|---|---|---|---|
| 1 | No Management, No Training | 41 | 45 | 86 |
| 2 | No Management, Training | 32 | 43 | 75 |
| 3 | Management, No Training | 43 | 47 | 90 |
| 4 | Management, Training | 65 | 44 | 109 |
| Total | | 181 | 179 | 360 |

Turpin and Scott (2010) note several issues associated with the study as follows:

1. Existence of multiple vehicle drivers as shown in Table 3-3 – this meant that such drivers annual vehicle-km is reduced depending on the types of vehicle driven compared to those of non-multiple vehicle drivers. Turpin and Scott (2010) also note that the issue is inherent in many transport operations, and that attempts were made to ensure accurate data collation in the study;
2. Bad data and required tolerance levels – according to Turpin and Scott (2010) the data collated were statistically assessed for outliers and also through liaison with the participating companies to carry out additional checks.
3. Data completeness – incomplete data submissions for the duration of the study due to driver and company dropouts, and bad data or outliers;
4. Insufficient pre-training period covering only 1 month, therefore providing insufficient baseline data needed to eliminate potential seasonal impacts; these could have been addressed by capturing or using pre-training data for a full calendar year;
5. Varying training times especially the commencement of the training due to delays in the procurement and the weather; these issues also contributed to gaps in the data;
6. Other factors included the variation in the geographical operation areas of the drivers and the vehicles used. Although the geographical area of the study was defined as England, some drivers drove out of this area and the definition of HGV and Vans as the classes of vehicles did not rule out different makes and models being involved. All these factors could have contributed to variability in the MPG data sets of the study.

Table 3-3: Number of SAFED multiple drivers (Turpin and Scott, 2010)

| Study Group | Study Category | Vans | HGVs | Total |
|---|---|---|---|---|
| 1 | No Management, No Training | 12 | 12 | 24 |
| 2 | No Management, Training | 2 | 21 | 23 |
| 3 | Management, No Training | 20 | 0 | 20 |
| 4 | Management, Training | 25 | 9 | 34 |
| Total | | 59 (32%) | 42 (23%) | 101 (28%) |

The data sets were subjected to a series of statistical analyses including regression modelling where low levels of significance ($R^2$ values) were observed for wider population applications. The data sets were also subjected to t-stat tests to evaluate the significance of the SAFED training of the drivers relative to the control group (untrained drivers). Two-sample unpooled t-stat tests were used, assuming that the samples had equal variances.

Turpin and Scott (2010) claim the following results:

1. On the day of the training, the average van driver improvement in MPG was 29% and that of the HGV driver was 13%, as shown in Figure 3.3 and Figure 3.4 respectively; the values, especially for the van drivers, are somewhat higher compared to those reported in other similar types of training, for example Siero et al (1989) report 7%. The HGV improvement value is similar to the one reported by Parkes and Reeds (2005) regarding a simulator-based training;
2. The longevity of the benefits showed an average improvement of 4 to 8% for van drivers over the first 6 months following the training, with higher fluctuations over the remaining period as shown in Figure 3.5. The average benefits for HGV drivers is much lower, and it is 1% to 2% over the first 6 months following the training and it falls to zero after 9 months (Figure 3.5), unlike for the van that suggests that the benefits disappear after 14 months. Given that there was no use of real-time driver feedback system of any form in this study, the HGV result seems comparable with that reported by af Wåhlberg (2007), although, it should be noted that the training environment and the type of the heavy vehicles involved were different;
3. The t-stat tests revealed that group 4 and specifically the van drivers realised the greatest benefit that could be applied to the wider population with the benefits of the training, in terms of improved fuel economy, lasting for about 2 years for the van drivers. The finding suggests that higher improvement in fuel economy could be realised in the less heavy vehicle categories light van and cars as opposed to heavy goods vehicles (HGV). This could be due to the greater responsibility or ownership that is usually attached to the vehicles by the drivers of cars and vans.

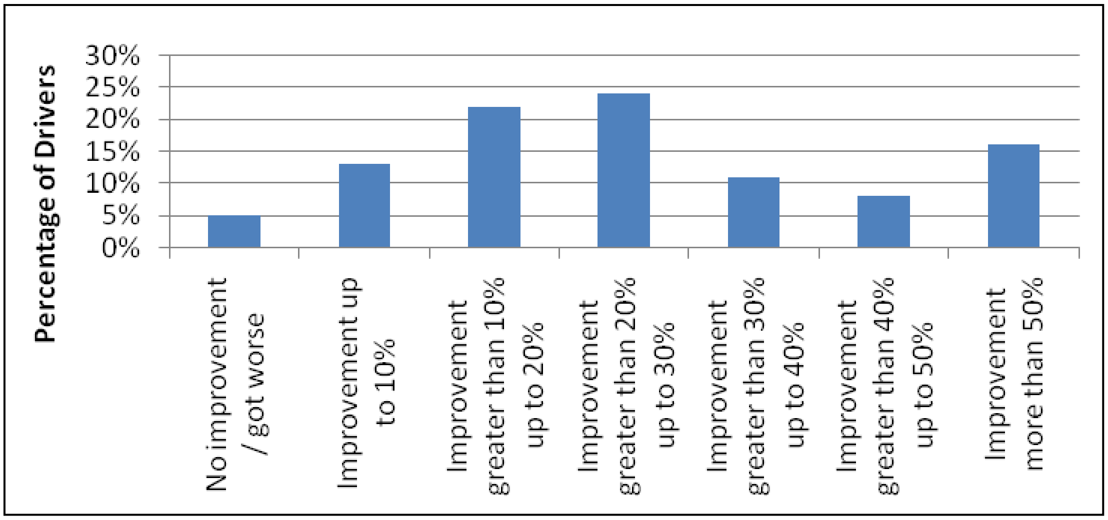



Figure 3.3: Improvement in MPG on the day of the SAFED training for van drivers (Turpin and Scott, 2010)

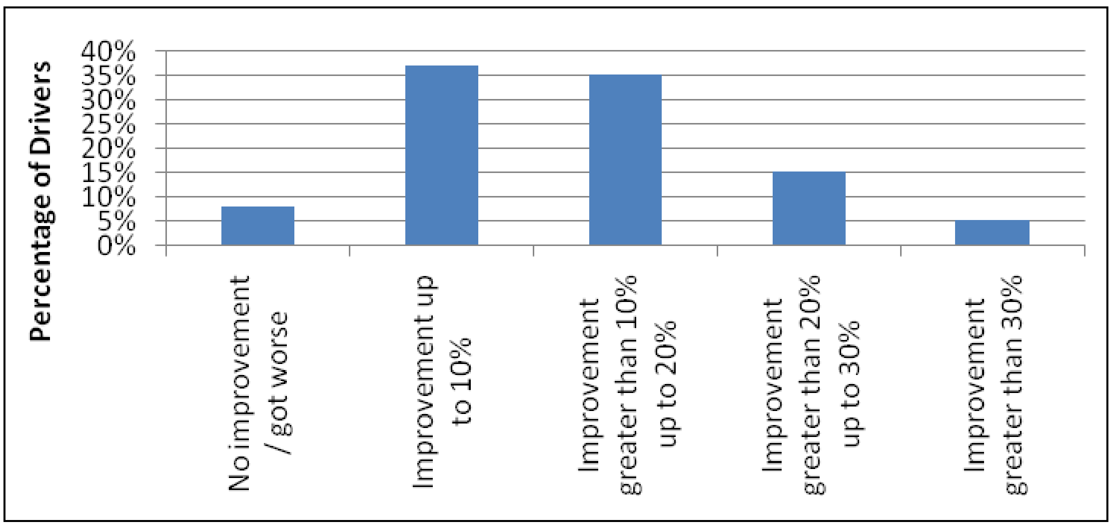



Figure 3.4: Improvement in MPG on the day of the SAFED training for HGV drivers (Turpin and Scott, 2010)

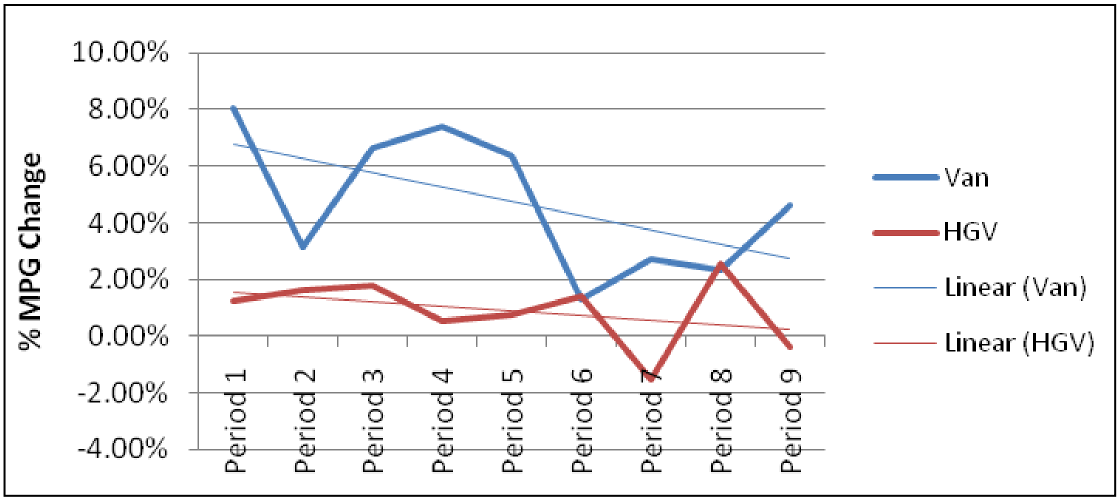



Figure 3.5: Longevity of (percentage improvement in MPG for trained group against control group) SAFED for van and HGV over 9 periods/months (Turpin and Scott, 2010)

Turpin and Scott (2010) do not report longevity benefits for operators classified as Group 1. For Group 2, the results also show insignificant benefits for both HGV and vans, but with higher initial impact for van drivers which disappear after 6 months. Although Group 3 results are insignificant, it indicates, however, that the benefits last for 6 months for HGV and 9 months for van drivers suggesting that driver management alone could have a higher impact than training in isolation.

In the study several hypothesis were also tested with regards to fuel economy including the following aggregation:

1. Industry sector – the operators were divided into 4-sub groups, namely, construction waste, food and drink, general haulage, and services. Turpin and Scott (2010) found that van drivers in the services and food and drink sectors showed much greater and significant improvement in MPG than the other sectors, while HGV in food and drink, and general haulage had much greater improvement; no explanations were provided for these results/findings;
2. Company size – the operators were divided into two groups; Turpin and Scott (2010) found that larger companies (>250 vehicle fleet) showed much greater improvement in MPG than smaller (< 250 vehicle fleet) companies. The report attributes this to a

potentially greater driver management culture within the large operators than the smaller operators;

3. Driver age – the drivers were categorised into 2 age subgroups, under 45 years of age and those over 45. Although insignificant for application to a wider population, Turpin and Scott (2010) suggest that both van and HGV drivers under the age of 45 on average achieved a better improvement in their MPG than those over 45; no reasons were provided or suggested to explain this finding. Although Stothard and Nicholson (2001) found negligible impacts of individual characteristics, like age, on skill acquisition and retention, other studies (for example Belz and Aultman-Hall, 2011 and Gwyther and Holland, 2011) suggest that age could affect vehicle fuel consumption, which can be related to speeds and accelerations;
4. Driver's initial opinions regarding the importance of training for fuel efficiency and driver knowledge of fuel efficiency were also separately tested in the study, where it was found that both van and HGV drivers who did think that fuel consumption was important generally had an overall better improvement in their MPG over the study duration, while van drivers with both good and poor knowledge of fuel efficiency had similar levels of performances and HGV drivers with initially poor knowledge of fuel efficiency had much higher improvement in MPG than those with good knowledge (Turpin and Scott, 2010).

The study by Turpin and Scott (2010) did not, however, assess in detail driver management practices among the operators which could have contributed to the positive impacts of fuel economy training. The study scope also did not cover road network maintenance and operations. As mentioned earlier, the baseline data used in this study was limited to only 1-month of data, implying that there are likely to be inherent seasonal effects not accounted for in the analysis results.

### 3.3.2 Simulator-based Training

Simulators have been used to shape and study driver behaviour for several decades, especially the interaction with the driving environment. A study by Blana (1996) assesses several simulators that are or were available at the time of the study. Simulators are being used to provide cost-effective training for drivers to improve their performance in fuel economy (Dolan et al, 2003; Parkes and Reed, 2005; Manser et al, 2010; Dogan et al, 2011) and road safety (Welles and Holdsworth, 2000; Abou-Zeid et al, 2011; Jamson et al, 2012).

The results of one of the major simulator-based driver training for fuel economy are reported by Parkes and Reed (2005). The study was conducted in the UK and was sponsored by the (DfT) through the Road Haulage Modernisation Fund (RHMF) and was conducted at the Transport Research Laboratory (TRL) headquarters in Berkshire, England. The study partly formed the foundation for the now operating safe and fuel efficient driving (SAFED) training in the UK. The study consisted of three phases, namely:

1. November 2003 to March 2004 – training and validation trials where quantitative data was used to analyse the efficiency and the acceptability of the training; 600 drivers were involved in this phase of the training;
2. May to September 2004 – in this phase, a further 400 drivers were involved, primarily to develop a training courseware for fuel-efficiency;
3. Longitudinal cohort study – this was the final phase of the study to track the patterns of performance over repeated sessions, and also to assess the transfer of the performance to the real world.

According to Parkes and Reed (2005) 36 drivers (excluding the control group) were involved in the third phase although only 17 were able to provide a complete on-the-road data set needed for the assessments of the impact of the training. The drivers were trained using a simulated 40-tonne laden semi-trailer (TRUCKSIM) to achieve maximum differential in fuel usage between drivers who demonstrated good and bad driving techniques for fuel economy. The training involved 3 sessions or visits to the TRUCKSIM facility where the total fuel used and the total distance travelled by each candidate on the road (real world) was recorded for 5-working days after each training session. The training sessions (the first and the second sessions separated by a period of 8 weeks and, the second and third by 6 to 8 weeks) were each completed within a day and involved the following:

1. Pre-training – this involved the use of questionnaires and an initial drive on a set route to benchmark the driver's characteristics; this is also consistent with the pilot

study reported by Siero et al (1989). Another simulation study by Dolan et al (2003) suggests qualification of drivers into quartiles, depending on the variable to be investigated when they investigated the impact of driver company experience, age and change of vehicle on fuel consumption. They did not find any significant impact after the training. In this study, Dolan et al (2003) reported a successful use of simulator-based training to achieve a 6-month average improvement in fuel efficiency of 2.8% and 7% with the poorest drivers;

2. Training – this involved a presentation by a qualified trainer where driving techniques relevant to fuel efficiency were communicated to the drivers, and the application in the simulator drive;
3. Post-training – drivers were provided with immediate feedback on their performance after each session of the training. The feedback was benchmarked to 25% of the most efficient and 25% of the least efficient drivers. The feedback included the red, amber and green (RAG) colour coding including specific and relevant comments where necessary.

Parkes and Reed (2005) used the general linear model repeated procedure involving pair-wise comparisons to assess the 6 levels of driving (3 visits with 2 drives per visit) against the variables summarised Table 3-4. The impacts were noted to be most significant between drives 1 and 2 (first session) and insignificant or marginal between 3 and 4, and 5 and 6, showing that the benefits were retained between the sessions (Figure 3.6).

Table 3-4: Summary of the impacts of TRUCKSIM training on measured attributes reported by Parkes and Reed (2005)

| Variable | Impact of the TRUCKSIM training |
|---|---|
| Fuel use – training day | Improved mean fuel economy |
| RPM – under acceleration | Reduced mean RPM (asymptotic) with improved mean torque |
| RPM – under deceleration | Reduced mean RPM (asymptotic) with improved mean torque |
| Number of gear changes | Reduced number of gear changes |
| Time taken to complete task | Marginally reduced mean time to completed the task, hence improved efficiency |

| | |
|---|---|
| Fuel use – on the road (retention of training) | Improved fuel economy |

The mean reported improvement in miles per gallon (MPG) was 15.7%, taking into account the control group, although the reported 95% confidence interval was wide, with upper and lower bounds of 25.4% and 6.0% respectively (Figure 3.6).

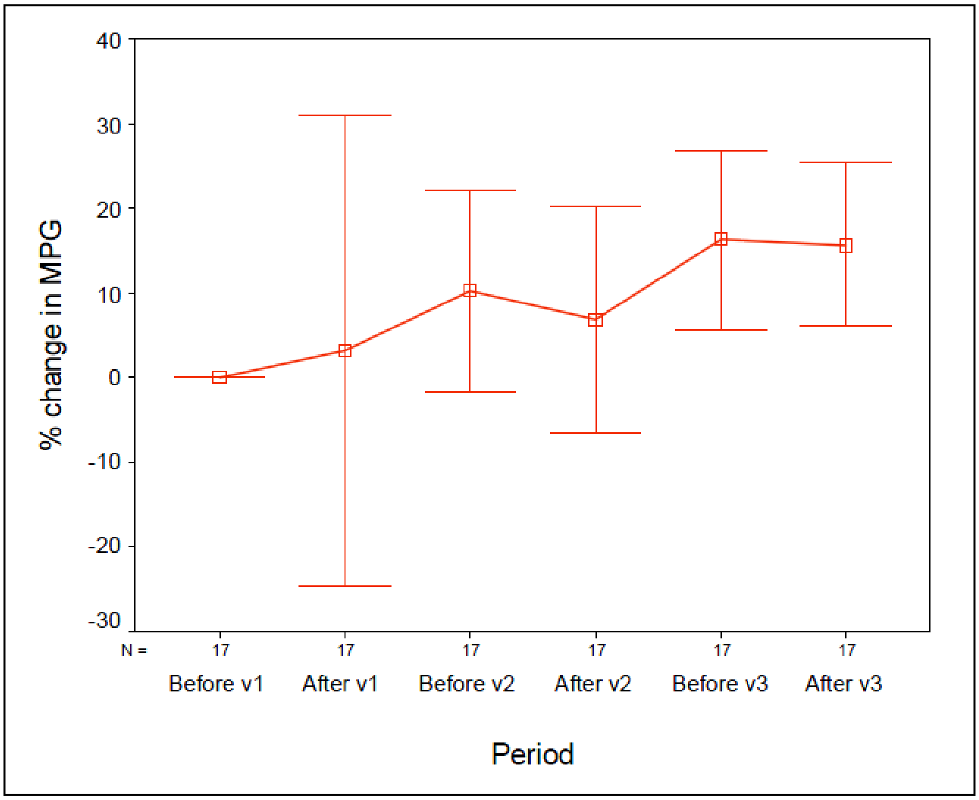



Figure 3.6: The relative change in fuel efficiency of drivers taking into account the performance of the control group (Parkes and Reed, 2005)

Another recent hybrid (on-road and simulator) driver training called 'Eco-driving', and reported by Scott et al (2012), was conducted at the Institute for Automobile and Manufacturing Advanced Practice (AMAP), at the University of Sunderland, UK. The training was delivered by means of a simulator, on-road and theory methods. A significant reduction in vehicle fuel consumption and emissions was observed in the simulator recordings. The training approach investigated in the research, Driver Optimisation for Low

Emissions Transport (DROPLET), is based on a theoretical model of driver training, Goals for Driver Education (GDE) by Hattaka et al (2002). The training involved 30 participants including 15 as a control group. The range of the participants' age was 20-64 and all were members of the general public or staff from the University of Sunderland.

Scott et al's (2012) hybrid training consisted of 3 components which are similar to the cases reported by Seiro et al (1989) and Parkers and Reed (2005):

1. Pre-training – this included a pre-training questionnaire and a 1.23 km drive on the simulator to capture the participants' pre- training baseline measure of Eco-driving performance. Both the control group and the trained group received the pre-training modules; no feedback was given to the participants at this stage;
2. Training – the training was provided in the form of on-road training. This was provided to the trained group only, and it lasted about 90 minutes. The training was based on the DROPLET course content and was delivered by a qualified fleet trainer. Although the type of vehicle used for the on-road is not stated, 'Fleettechnique' training uses the client/customer vehicle to train the client/customer as long as long as the vehicle is roadworthy, insured and the customer has a valid licence. A theory session was conducted upon completion of the drive where the participants were given feedback through video clips and comments on their performance, and were given tips aimed at improving their performance. The participants then had a final drive in the simulator using the same scope as in the first run. The control group was also allowed to have the second run but did not receive any of the training interventions (Scott et al, 2012);
3. Post-training (feedback) – this included the use of post-training questionnaires and leaflets.

Scott et al (2012) observed a significant improvement in the fuel economy measurements for both the control group and the trained group. They accounted for the improvement in the control group to exposure to the simulation and, when corrected, the trained group still had a significant improvement both in terms of fuel and emissions. Whilst they hardly assign any specific percentage values to the observed improvements, they rather stress the significance of the impact of the training aspects. Literature regarding the direct application of simulator-based driver training to assess the fuel consumption improvement for drivers involved in road network maintenance and operations is very limited.

### 3.3.3 Challenges of Influencing Driving Style

The challenges of influencing driving style can be viewed in two ways; first, is it possible to define and measure driving style in a way that can be related to the driving goals (safety, fuel economy, time saving, etc.)? Although interventions like driver training have been known to influence individual's driving style, it is difficult to assign the change to specific parameters accounting for the driver behaviour (or driving style). As shown in Table 3-1 driving style or behaviour is linked to several parameters (experience, attitude, task demand, driver's state and situation awareness) which are responsible for the driver performance. Several studies have investigated the influences of these parameters on single and multiple performance goals, drawing similar conclusions. These include Holland et al (2010), Taubman-Ben-Ari and Yehiel (2012), Gwyther and Holland (2012), Elander et al (1993), French et al (1993) and Dogan et al (2011). In order to understand the influence of interventions like driver training (and other methods of improving fuel economy) on these parameters, driver behaviour models (e.g., Cacciabue and Carsten, 2010; Amditis et al, 2010; McGordon et al, 2011) can be used for the specific driver, vehicle and the driving environment. These models would benefit from fine data captured through vehicle electronic control units (ECU).

The second approach is to examine the effectiveness and efficiency of the methods used to influence the driving style. With regards to the use of driver training to influence the driving style for better fuel economy, several related challenges have been reported including the following:

- Optimisation of training: driver training programmes are not specific enough to meet the needs of specific individuals or groups (Young et al, 2011). Driving style is influenced by several factors (Cacciabue and Carsten, 2010; Amditis et al, 2010; McGordon et al, 2011) that can be related to the driver, vehicle and the driving environment;

- Limited application: literature indicates that driver training has been limited mainly to the haulage or freight and passenger vehicle operations. There is hardly any literature related to the application for such training in the most effective and efficient way to the drivers involved in the road network maintenance and operations;
- The acceptance of driver training for fuel economy is low among drivers and the public (see Treatise, 2005; Young et al, 2011; Gonder et al, 2011; ecoDriver, 2012);
- Retention of the benefits, e.g., fuel economy; there is evidence of poor retention of the benefits from driver training for fuel economy and thus the need for periodic re-training of the drivers. This has not been well researched and developed (Siero et al, 1989; Nader, 1991; Ericsson, 2001; af Wåhlberg, 2002; Parkes and Reed, 2005; af Wåhlberg, 2006; af Wåhlberg, 2007; Zarkadoula et al, 2007; Symmons and Rose, 2009; Turpin and Scott, 2010);
- Cost: there is an indication (Young et al 2011, ecoDriver, 2012; Treatise, 2005) that training might be considered less effective and less efficient than other emerging methods which aim at utilising intelligent transport systems like driver-vehicle interfaces and adaptations. The benefits from the driver training programmes are marginal and maintaining it requires periodic re-training which can be inefficient, therefore, the question of reducing the cost of training while maintaining the benefit is raised;
- Transfer of learning (trainers): the effectiveness of the driver training is dependent on the quality of the trainer and the training facility (environment) (Parkes and Reed, 2005; af Wåhlberg, 2006; DfT, 2003a);
- Lack of incentives: there is usually a lack of incentives for drivers, especially those employed by companies, to produce the best performances since they are usually not the owners/shareholders (Treatise, 2005; Gonder et al, 2011). Indeed it has been suggested that drivers are usually aware of the driving techniques for fuel economy; however, they do not appear to use it successfully on the road (Manser et al, 2010). This could possibly be due to lack of encouragement in the form of training or advice. When drivers are formally advised or trained, their performance improved, see Section 3.3). There are also other potential incentives;

- Policy issues: unlike the safety goal, regulatory measures related to driver training for fuel economy are still few and weak, for example, fuel economy driving is not an mandatory part of the driver certificate of professional competence (CPC) training programme regulated by the European Union (EU) Directive 2003/59/EC (JAUPT, 2010);
- Competing and sometimes conflicting driving goals: there is also evidence that the driving goal of fuel economy is not competitive against other driving goals, like safety and time saving (Dogan et al, 2011; Young et al, 2011).

The challenges above are likely to be reduced by the use of a comprehensive driver-vehicle interface as a method of improving vehicle fuel economy (van der Voort et al, 2001; Larsson and Ericsson, 2009; Jenness et al 2009; Manser et al 2010; ecoDriver, 2012; Young et al, 2011; Lai et al, 2012) based on on-board data logging devices and feedback.

### 3.3.4 Other Driver Feedback Methods

Research into specific and comprehensive Intelligent Transport Systems (ITS) like Intelligent Speed Adaptation (ISA), involving improved driver-vehicle interfaces is emerging as a way of improving driving goals like safety and fuel economy (van der Voort et al, 2001; Larsson and Ericsson, 2009; Jenness et al 2009; Manser et al 2010; Young et al, 2011; ecoDriver, 2012; Fiat, 2010; Lai et al, 2012; Jamson et al, 2012; Cacciabue and Carsten, 2010; Amditis et al, 2010) and many of these studies have demonstrated the potential of the system with regards to these goals. Some of the major research projects involving the use of a driver-vehicle interface to improve the performance of driving goals (safety and fuel economy) include the ecoDriver project (coordinated in the UK) which targets up to 20% reduction in $CO_2$ emissions and fuel consumption in road transport through green driving behaviour where drivers receive eco-driving recommendations and feedback specifically adapted to their vehicle and driving characteristics (ecoDriver, 2012). The principle of the driver-vehicle feedback for the ecoDriver project is shown in Figure 3.7.

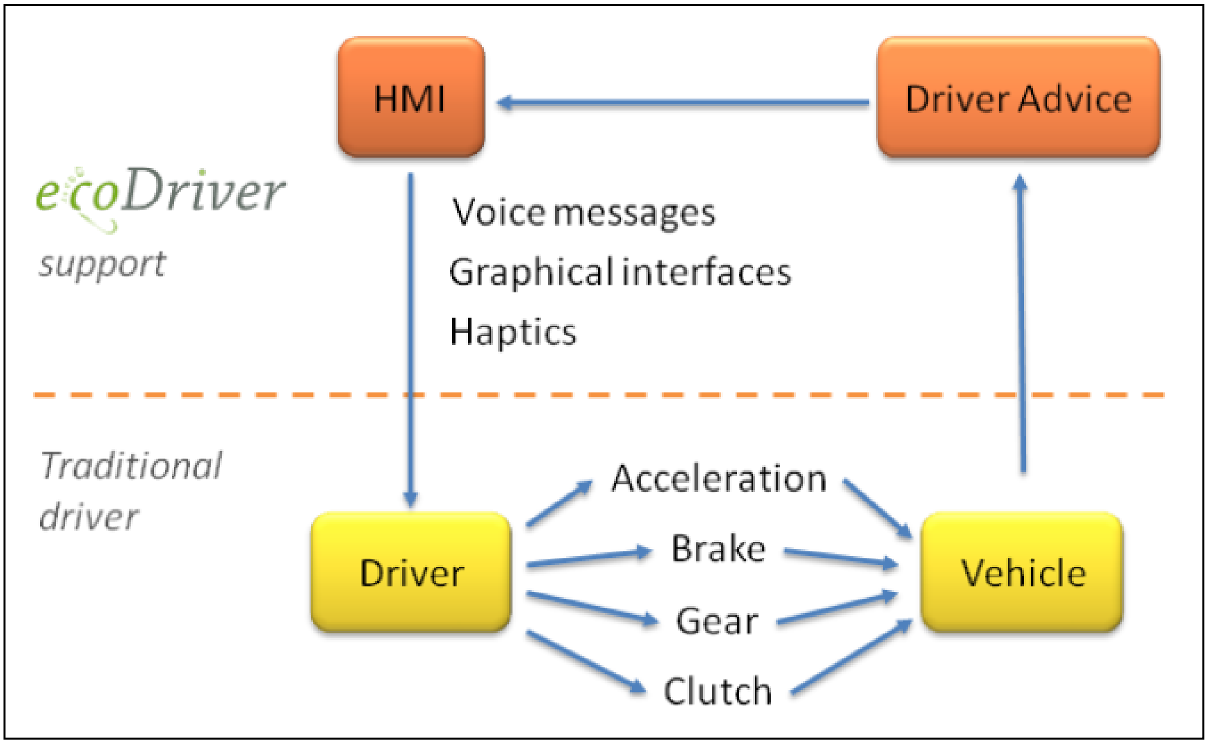



Figure 3.7: ecoDriver enhanced model for eco-driving feedback (ecoDriver, 2012)

Another similar research project, with a much broader scope, is eCoMove which also targets a 20% total reduction in transport energy use (Figure 3.8) from three aspects, namely, driver-vehicle interface for better route choice, driving performance and traffic management and control (eCoMove, 2010). Regarding driving performance, the eCoMove project is focussing on improving pre-trip planning (eco-pre-trip planning), smart driving (eco-smart driving) and post-trip feedback (eco-post trip feedback) using intelligent driver-vehicle interface.

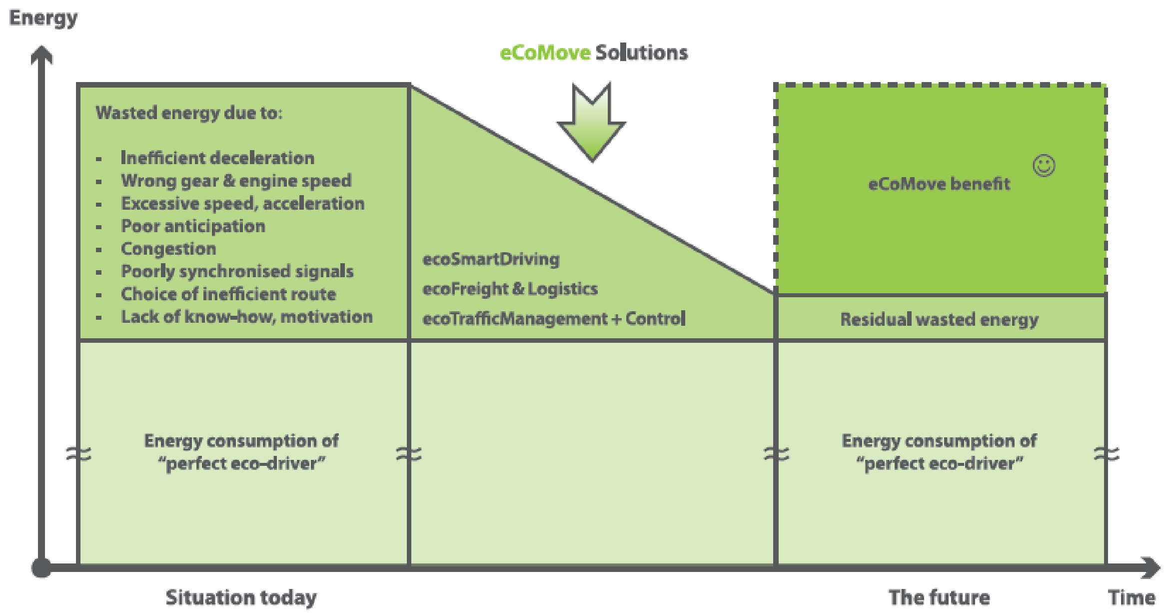



Figure 3.8: The objective of the eCoMove research project (ecoMove, 2010)

Fiat, who have been leading the driving performance objective of the eCoMove, published a report regarding a driver-vehicle feedback system incorporated in some of their vehicles to assist drivers lower their CO2 emissions and fuel consumption (Fiat, 2010). The Fiat system provides drivers with a tool to understand, review and improve their driving performance over time in an eco-friendly way. Drivers can monitor their performances both instantaneously and strategically over a period of time by using a Universal Serial Bus (USB) stick to record the driving data which can then be uploaded and analysed by Fiat's online system providing drivers with dashboards as shown in Figure 3.9.

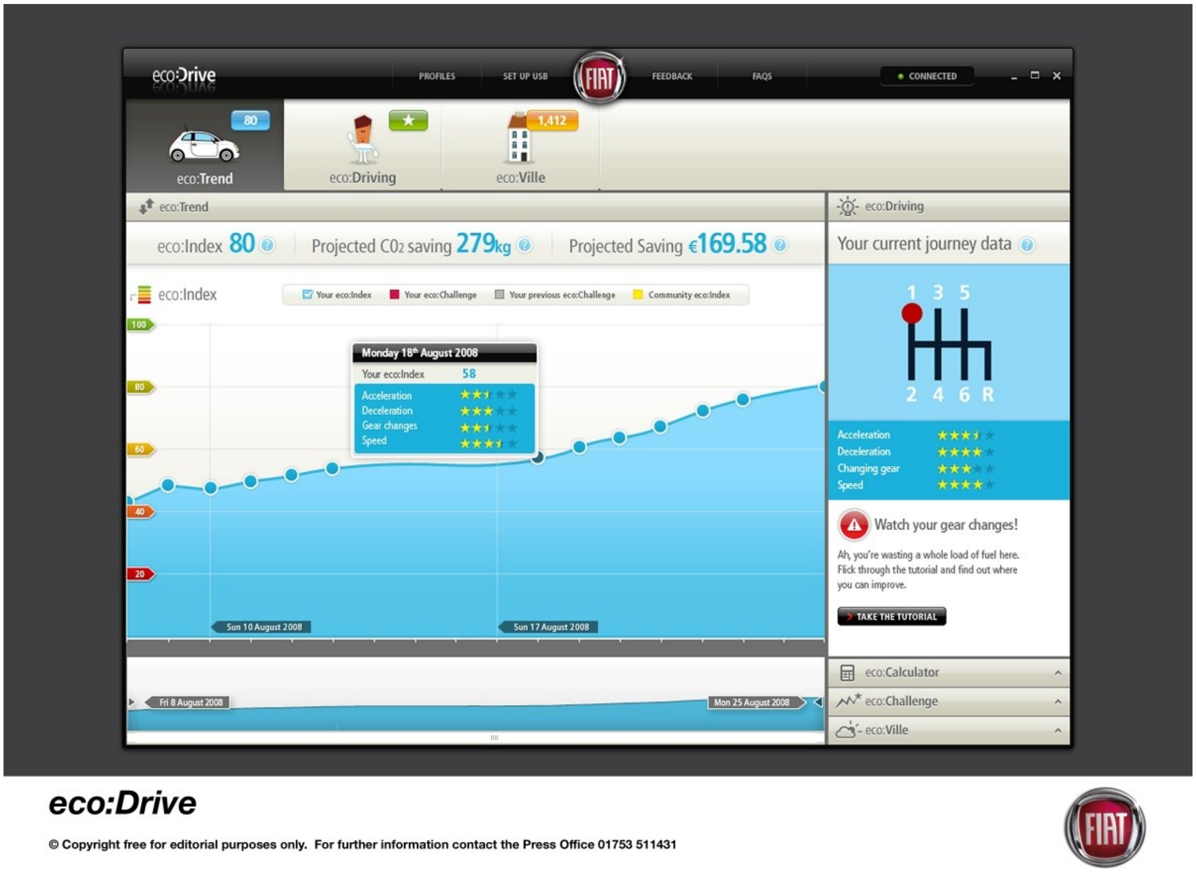



Figure 3.9: eco:Drive dashboard by Fiat (Fiat, 2010)

A report by Manser et al (2010) regarding the use of a fuel economy driver interface concept (FEDIC), a device that drivers can use to change driving behaviours to improve fuel economy, suggests that such interfaces could improve fuel economy by as much as 11%. They investigated how driver behaviour was affected by a FEDIC that displayed information about acceleration behaviour (FEDIC-B) and a FEDIC that displayed instantaneous fuel economy (FEDIC-FE) using the comparisons shown in Figure 3.10.

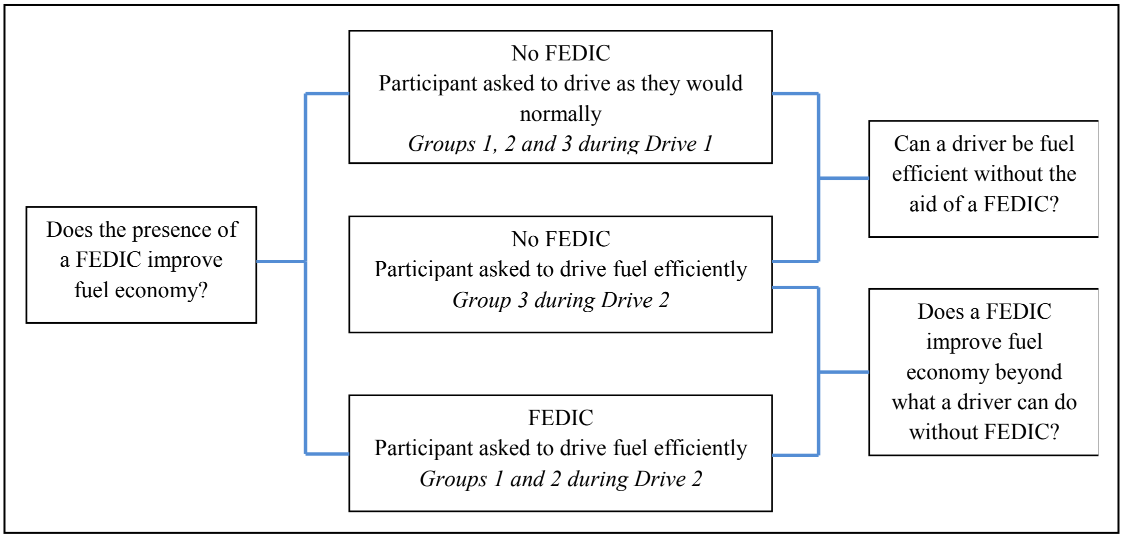



Figure 3.10: Conceptual representation of three group comparisons used to test the research questions (Manser et al, 2010)

Although Manser et al (2010) found that drivers could improve their fuel economy without the aid of FEDIC, they suggested that the use of FEDIC could produce a much greater improvement in fuel economy, especially in an urban-like driving environment. They observed that such an improvement was linked to smoother acceleration driving behaviour. Manser et al (2010) implemented recommendations from earlier work by Jenness et al (2009) regarding the same project.

However, the safety and other adverse performance implications of the use of the emerging driver-vehicle interface systems is also an area of current interest and has been covered by many studies which suggest ways of addressing the concerns (van der Voort et al, 2001; Larsson and Ericsson, 2009; Carsten and Nilsson, 2001; Machau and Walker, 2003; Carsten and Tate, 2005; Young et al, 2011; Lai et al, 2012; Jenness et al, 2009; Manser et al, 2010; Jamson et al, 2012; Amditis et al, 2010). Young et al (2011) also suggest that the codes of practice for the design and the development of such systems are emerging as one of the ways of ensuring that positive benefits gained from the systems are not counteracted by negative issues, e.g., related to driver distraction by the system.

## 3.4 Summary

Although interventions like driver training have been known to influence individuals' driving style, it appears to be difficult to link improvements in fuel economy to specific parameters which account for the driver behaviour (or driving style). Although the benefit of driver training for fuel economy has not been attractive (short-term and long-term) in cases where it has been applied there are indications that the benefits of the training could be greatly improved. Some of the areas that could be used to improve the benefit of driver training in terms of fuel economy are:

- To adapt the training to the local driving conditions of the drivers;
- To engage the drivers so that the objectives of the training are accepted;
- To monitor the performance of the training and provide feedback to the drivers;
- To provide a more cost effective training that can be easily accepted by the vehicle operators;
- To provide in-vehicle devices to provide the drivers with continuous information regarding the driving actions to be carried out safely to improve their fuel economy; this could translate into a sort of continuous driver training;
- To create a clear objective regarding the purpose of the training; say, fuel economy or safety in order to avoid potentially competing and conflicting driving goals.

In this research a specific cost effective driver training was designed and provided to drivers involved in road network maintenance and operations where driving characteristics suggest potential opportunity improving fuel economy. The drivers' performances were monitored and feedback provided to the drivers on a regular basis. No in-vehicle device was used to support the drivers with fuel economy driving.

The next Chapter provides a review of driver training methods that can be used for fuel economy. Driving attributes like speeds and acceleration which affect vehicle fuel consumption will also be covered in the Chapter.

# CHAPTER 4 DRIVER TRAINING FOR FUEL ECONOMY

## 4.1 Introduction

In this Chapter, the writer reviews driver training approaches for vehicle fuel economy including the methods for capturing driver training data and the driving attributes related to fuel economy. The review also covers driving attributes or factors which influence drivers' fuel economy. The review also facilitated the design of a company-based driver training for fuel economy reported in Chapters 6 and 7.

## 4.2 Driver Training Approaches

### 4.2.1 Vocational Driving Licence (UK)

In almost all countries, the possession of a vocational driving licence is a regulatory requirement for driving a vehicle. To obtain a licence in the UK, the prospective driver is required to pass a theory and a practical test (DSA, 2009). The categories of the licences that can be acquired are summarised in Table 4-1.

Table 4-1: Categories of driving licences in the UK (DSA, 2009)

| Category | Vehicle | Weight (Tonne) |
|---|---|---|
| A | Motorcycles and light three or four wheel vehicles | < 0.55 |
| B | Cars and light vans | < 3.5 |
| C1 | Medium size vehicles | 3.5 to 7.5 |
| C | Large vehicles | > 7.5 |
| D | Buses | - |

Without a formal training for fuel economy, it is usually assumed that the driver holding a vocational driving licence has baseline (taken as zero) skills with regard to fuel economy (consumption) (see for example, Evans, 1979; Siero et al, 1989; Nader, 1991; Ericsson, 2001; van der Voort et al, 2001; af Wåhlberg, 2002; Parkes and Reed, 2005; af Wåhlberg, 2006; af Wåhlberg, 2007; Zarkadoula et al, 2007; Beusen et al, 2009; Symmons and Rose, 2009;

Manser et al, 2010; Scott et al, 2012; Turpin and Scott, 2010; Luther and Baas, 2011). Across a range of drivers, however, the baseline fuel economy performance (without any form of training for fuel economy) could vary because of the potential difference in their driving styles (Section 3.2.2) and the driving conditions. Although some elements of fuel economy have been added to the assessment or training for the vocational licence for categories A, B and C1 vehicles in the UK (Sivak and Schoettle, 2011), it is still very limited and the impact has not been fully evaluated. Fuel economy also forms part of the driver certificate of professional competence (CPC) training programme regulated by the European Union (EU) Directive 2003/59/EC (JAUPT, 2010), although it is not a mandatory requirement.

### 4.2.2 Certificate of Professional Competence (CPC)

The Driver Certificate of Professional Competence (Driver CPC) training approach is a continuous professional development which carries on throughout a professional bus, coach or lorry drivers' career (JAUPT, 2010). The implementation of EU Directive 2003/59 requires all professional bus, coach and lorry drivers to hold a Driver CPC, in addition to their vocational driving licence listed above (EU, 2003). However, training for fuel economy is not a mandatory part of the driver CPC (JAUPT, 2010). In the UK, Safe and Fuel Efficient Driving (SAFED), described below, forms an approved training for fuel economy for the driver CPC (JAUPT, 2010).

### 4.2.3 Safe and Fuel Efficient Driving (SAFED)

#### *4.2.3.1 Overview of SAFED*

Safe and Fuel Efficient Driving (SAFED) is a high quality driver development training with proven and significant fuel saving benefits (see Section 3.3.1). The training is a one-day course for heavy goods vehicles (HGV) or large vehicles (LV) (including buses) and vans. The training involves a mix of classroom and on-the-road tuition which teaches the use of driving techniques including better use of gears, keeping correct distances to avoid harsh braking, and an overall awareness of fuel economy and the road layout.

The UK Government initiated SAFED in 2003 (after a feasibility study by Transport Research Laboratory (TRL)) with funding to develop the training material, the trainer pool and to demonstrate the safety and fuel saving benefits to the freight industry. Over 12,000 truck drivers and 7,500 van drivers have been trained under the scheme in England (DfT, 2010a). SAFED is not a legal requirement but it forms an optional part of the approved training for fuel economy for the driver CPC (JAUPT, 2010).

According to DfT (2010a) the use of efficient driving techniques by drivers trained under the SAFED programme could result in fuel saving of up to 20% in the short-term (days to weeks) and over 5% in the long-term (months to years) for medium-to-large vehicles (vans and large vehicles). However, a recent study regarding the longevity of SAFED by Turpin and Scott (2010) found an average improvement of 4 to 8% for van drivers over the first 6 months following the training and 1% to 2% over the same period for HGV drivers, with the benefits disappearing after 14 and 9 respectively of the training.

Although the sponsorship of the SAFED training programmes for LV and vans by the UK Government has ended, the training is commercially available from private providers throughout the UK. The trainers are accredited through the Joint Approvals Unit for Periodic Training (JAUPT) following a successful training for trainers.

#### *4.2.3.2 Contents of SAFED*

SAFED driver training programmes have been developed for large/heavy and light commercial vehicles (HGV and buses, and vans). SAFED consists of one full day of off-the-job training on a candidate-to-instructor ratio of 1-to-1 or 2-to-1. The programme consists of practical and theory assessments based on safety (accident prevention and reduction) and fuel efficient driving (DfT, 2006d; DfT, 2009c). The SAFED training day programme is outlined in Table 4-2. The detailed SAFED training programmes for HGV and van are provided in Appendix B-1 and Appendix B-2 respectively.

Table 4-2: Outline of the SAFED training day

| Item | Training Session | LV (HGV) | LCV (Van) |
|---|---|---|---|
| 1 | Introduction or preliminary session (training objectives, driver/vehicle checks) | 1 hour, general | 2 hours, general |
| 2 | First drive | 1 hour per candidate | 30 minutes per candidate |
| 3 | Instructors feedback regarding first drive, vehicle/road craft instructions (some elements might be delivered after the demonstration drive by the instructor) | 1 hour 30 minutes per candidate | 1 hour 15 minutes per candidate |
| 4 | Demonstration drive by the instructor | 30 minutes | 30 minutes |
| 5 | Second drive | 1 hour per candidate | 30 minutes per candidate |
| 6 | Underpinning knowledge exercise consisting of two theory tests | 30 minutes | 30 minutes |
| 7 | Final feedback and discussion | 45 minutes | 30 minutes |

Note: LV = Large Vehicle, LCV = Light Commercial Vehicle

The fundamental areas covered by the SAFED training programme are classified as follows (DfT, 2006d; DfT, 2009c):

1. Driver factors;
2. Operating the vehicle;
3. Vehicle dynamics;
4. Awareness.

The importance of each of the driving attributes provided in Table 4-3 in terms of vehicle fuel consumption is discussed under Section 4.5.

Table 4-3: Categorisation of driving attributes linked to SAFED

| Item | Category | Driving Attribute |
|---|---|---|
| 1 | Driver factors | Hazard awareness |
| | | Driver attitude |
| | | Driver fatigue |
| 2 | Operating the vehicle | Initial checks |
| | | Acceleration and speed |
| | | Braking |
| | | Gear changes /selection |
| | | Clutch control |
| | | Forward planning |
| | | Vehicle idling |
| 3 | Vehicle dynamics | Route planning |
| | | Loads and loading pattern |
| | | Adjustable aerodynamics and windows |
| 4 | Awareness | Culture change |
| | | Management commitment |

### 4.2.4 EcoDriving

#### *4.2.4.1 Overview of EcoDriving*

According to Sivak and Schoettle (2011) EcoDriving has been well-established in Europe for many years and it consists of programmes or schemes developed by both individual countries (e.g., the Netherlands and Sweden) and the European Union (EU) as a regional group. Barkenbus (2010) notes that EcoDriving efforts across Europe have been targeted at existing drivers (occasionally novice drivers) and vary in their programmatic offerings, usually involving high-visibility public relations campaigns, sessions devoted to driver training and collaboration with commercial sponsors.

Sivak and Schoettle (2011), Barkenbus (2010) and afWåhlberg (2007) generally characterise and define EcoDriving using driving techniques linked to reducing vehicle fuel consumption and $CO_2$ emissions, reducing accidents and related risks, reducing other vehicle part consumption by: accelerating moderately, anticipating traffic flow and signals, thereby avoiding sudden and frequent starts and stops; maintaining an even driving pace, driving at or safely below the speed limit; and eliminating excessive idling.

#### *4.2.4.2 Contents of EcoDriving*

According to af Wåhlberg (2002) the principles or instructions related to EcoDriving are related to the following driving attributes:

- Acceleration;
- Gear change;
- Forward planning;
- Braking;
- Speeding and overtaking;
- Awareness.

Specific instructions given to the drivers are provided in Section 3.3.1 and they are related to the following primary (golden) rules for EcoDriving (Sivak and Schoettle, 2011):

1. Anticipate traffic flow;
2. Maintain a steady speed at low revolutions per minute (RPM);
3. Shift up early;
4. Check tyre pressures frequently, at least once a month and before driving at high speed;
5. Consider that any extra energy required costs fuel and money.

EcoDriving training practices also consist of theory and practical sessions similar to those of SAFED (afWåhlberg, 2002; afWåhlberg, 2007); indeed in some literature (Sivak and Schoettle, 2011) it is claimed that SAFED originated as a results of early EcoDriving practices in mainland Europe.

#### *4.2.4.3 EcoDriving in and outside Europe*

EcoDriving in Europe has been developed and practiced under several national (Netherlands, Sweden, Finland, Germany, Switzerland, UK) and international (TREATISE, FLEAT, ECODRIVEN, ECOWILL, ecoMove and ecoDriver), and Sivak and Schoettle (2011) provide detailed descriptions and reviews of these schemes. Sivak and Schoettle (2011) also provide reviews of EcoDriving programmes in the USA, Canada, Australia, Japan and New Zealand.

## 4.3 Successful Driver Training for Fuel Economy

### 4.3.1 Challenges

The objectives of driver training for licence holders have mainly been for fuel economy and safety reasons and as reviewed in Section 3.3. Driving style has an influence on vehicle fuel economy and safety. There are challenges regarding definition and measurement of driving style in a way that can be related to the driving goals (safety, fuel economy, time saving, etc.), and the effectiveness and efficiency of the methods that can be used for it. With regards to driver training, the challenges include issues like the driver training programmes not being specific enough to meet the needs of individuals or groups; limited evidence of successful application of the training, low acceptance of the training, poor retention of the benefits from the training, inadequate knowledge about the drivers, cost of training, quality of the trainers and the training facilities (environment), lack of incentives, policy issues, and the issues related to the competing driving goals.

The quality of the traditional driver training for fuel economy (both for novice and existing drivers) could be improved if the quality elements related to the following stages of the training were improved:

1. Pre-training;
2. Training;
3. Post-training.

The three stages of driver training are illustrated in Figure 4.1 for the traditional driver training with and without driver management practices and also for the emerging method of using continuous driver feedback through a vehicle-driver interface, which is outside the scope of this research (it is provided here for illustration purposes only).

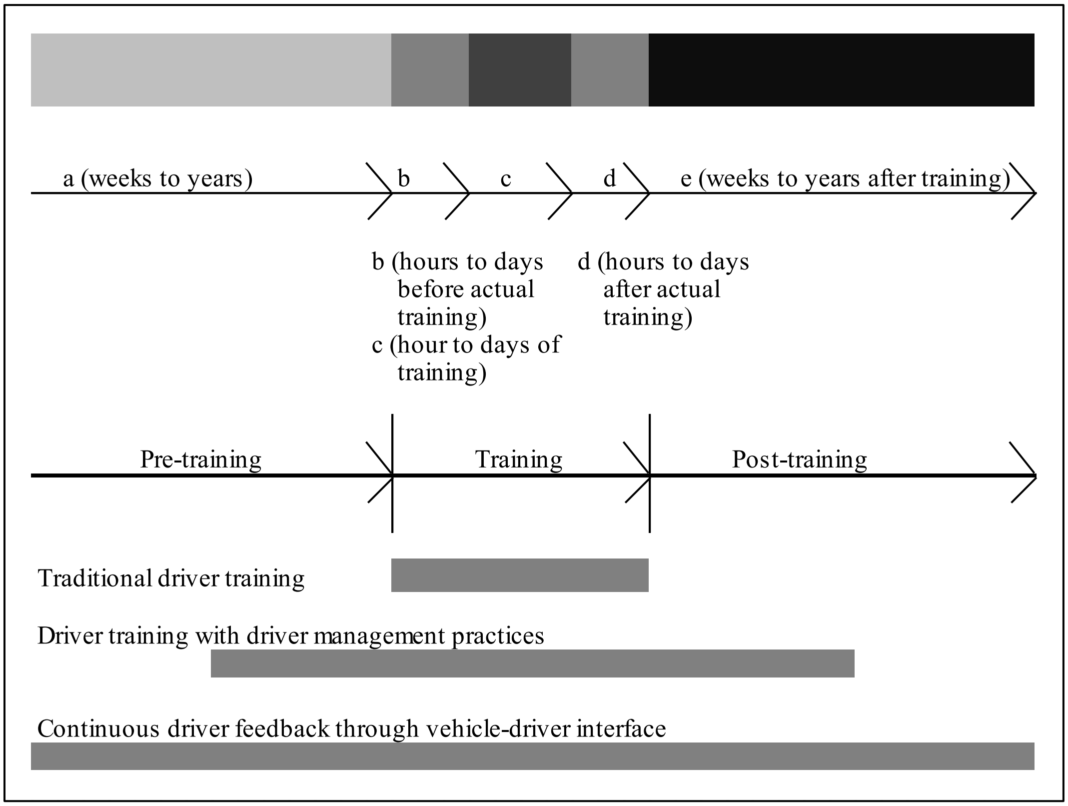



Figure 4.1: Three stages of driver training for fuel economy

There are several factors that influence the quality of training. The revised Human Resource Development (HRD) model by Holton (2005) (Figure 4.2) can generally be used to determine and consequently address the factors. In summary, these factors can be categorised into two dimensions: the first dimension consists of the learning, the individual and the organisational aspects. The second dimension, which influences the first, consists of motivation, environment (e.g., learning environment for the drivers) and ability; these factors influences the outcomes of the training.

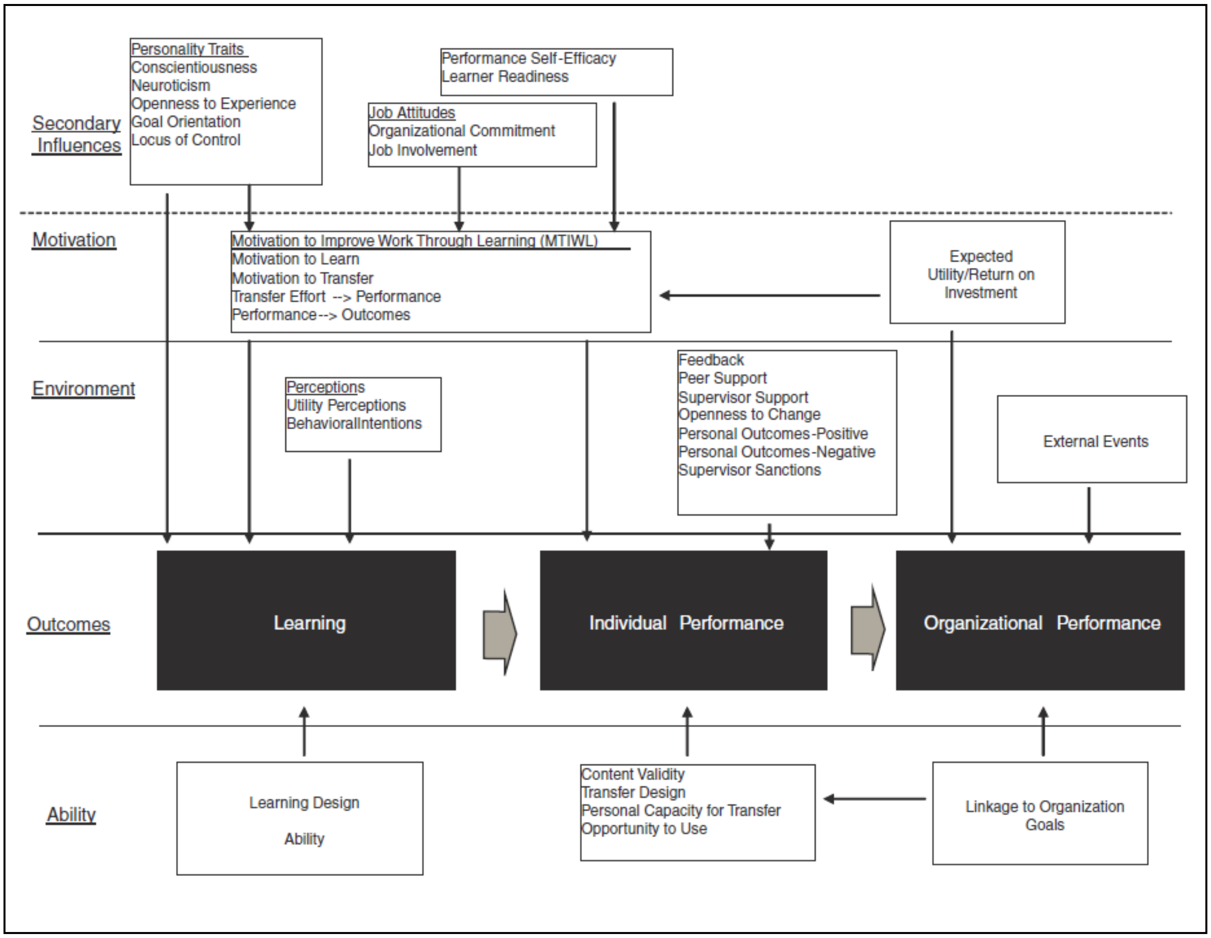



Figure 4.2: Human Resource Development (HRD) evaluation and research model (revised by Holton, 2005)

### 4.3.2 Intelligence and Design (Pre-Training)

Pre-training generally refers to the period before the actual training. This is necessary to collect the relevant data related to the candidate (e.g., behaviour, task, etc.) and other influencing factors in order to design the training that would meet the needs of the candidate. The aim is to establish as much knowledge about the driver and the related conditions as possible; but the effort needs to be balanced against the cost of obtaining and processing the data. The following methods have been used to collect pre-training data (French et al, 1993; Siero et al, 1989; DfT, 2003a):

- Desk study (review of existing literature and environment);
- Questionnaires;
- Pilot training;

- Driver management.

Questionnaires can be used to collect the information necessary to benchmark the drivers and the design of training for better fuel economy (Ackroyd and Hughes, 1981) and this approach has been adopted in the past (see French et al; 1993; Turpin and Scott; 2010; af Wåhlberg, 2006). Pilot training can also be used and it involves part of the population being trained to inform the full rollout of training. Pilot training provides more realistic data regarding the training (Bryman, 2001) and can be used in conjunction with questionnaires (Siero et al, 1989).

Driver management is a comprehensive and continuous programme that is championed to engage drivers and employees to save fuel. Information is provided to the drivers and employees regarding the benefits of saving fuel, the actions required to save fuel, the systems and technology to be used to save fuel, and the drivers' performances through record keeping (DfT, 2006c). Through driver management there is usually drivers' performance data that can be used for planning purposes (training needs, design, monitoring and evaluation) by the fleet managers or fuel champions. In a study regarding the longevity of the benefits of driver training for fuel economy, Turpin and Scott (2010) found that drivers under driver management performed better than those without it, when trained under similar conditions.

### 4.3.3 Training (Intervention)

The actual training (or transfer of knowledge) is affected by several factors, as highlighted in Figure 4.2 relating to the following:

- Training material and its validity;
- Trainer;
- Trainees;
- Training environment.

The quality of the training can be enhanced by improving the parameters that are associated with the factors outlined above, as outlined in Figure 4.2.

### 4.3.4 Monitoring and Adaptation (Post-Training)

Assessment of the performance of the drivers through fuel use monitoring is an essential part of fuel management because it provides management and feedback information to both the drivers and their managers (DfT, 2008). The drivers should be informed of their performance and achievements to keep them well motivated. Unfortunately, with the traditional training this is often dependent on the drivers' managers (DfT, 2008; Turpin and Scott, 2010) and the systems that are used to capture and report the data as described in Section 4.4. Such data provides information that can be used to schedule renewal of the training, the vehicle or related systems and processes.

## 4.4 Capturing Fuel Economy Data

The influence of driver training on fuel economy which was reviewed in Chapter 3, involving various data capture methods. In this section the methods that can be used to capture data in order to evaluate the influence of drive training are reviewed to inform the training that is described in Chapter 6. Using the knowledge from the literature review carried out in Chapter 3 the data capture methods have been categorised under the following data groups:

1. Fuel consumption;
2. Distance travelled;
3. Driver behaviour.

### 4.4.1 Fuel Consumption

#### *4.4.1.1 Fuel Cards*

Fuel cards are electronic cards that companies provide to their drivers to enable them to purchase mainly fuels for their vehicles from private fuelling stations within their business operation areas. Fuel cards can be uniquely issued to a driver or to a vehicle or to a driver/vehicle. Most fuel card services are provided by dedicated companies who generate reports on fuel use and associated cost to the vehicle operating companies.

However, it has also been noted that many businesses in the UK, especially smaller ones, still carry out their fuel transactions by the use of cash or card payments (Powley, 2011), which do not offer detailed data use. Powley (2011) and Virtos (2010), who also cites related literature by Cole (2008), de Kock (2009) and Anon (2009), discuss the advantages and disadvantages of fuel cards. According to the literature, the advantages of fuel cards include the use of less paper work, high flexibility to use where and when, reduced the need for fuel storage at depots, benefits from dedicated service by fuel card companies. Fuel cards offer and provide full control to fleet managers to manage fuel use. On the disadvantages of fuel cards, the literature highlights that not all fuel stations accept fuel cards, there is usually need to plan when and where to re-fuel, drivers need to be aware of the benefits associated with fuel cards, otherwise other potential benefits like improving fuel economy might not be achieved, moreover some information (vehicle registration and odometer reading) during transaction still need to be entered manually, thereby creating room for errors.

##### *4.4.1.2 Company Storage*

While fuel cards are suitable for company vehicles which cover wide geographical areas for their operation and which often operate off-station for several hours or days at a time (e.g., haulage and distribution companies), in-house fuel storage is usually preferred for vehicle operations which involve localized driving, central vehicle storage, specialist vehicles and limited availability of fuel stations within the operation areas (e.g., construction, waste and maintenance companies). Modern pump systems (Merridale™, 2012) allow drivers to be identified through the use of fuel keys (pump keys) where drivers can enter odometer readings each time they fill the vehicle (DfT, 2008), for example the Merridale™ fuel pumps (Merridale, 2012). Such information can then be analysed to provide management information through related fuel pump software, for example the Merridale FuelFX™ (Merridale, 2012).

### 4.4.2 Distance Travelled

##### *4.4.2.1 Odometer*

The vehicle dashboard odometer is still one of the main ways of recording distance travelled by vehicles for the purpose of estimating the driver miles per gallon (MPG) (Virtos, 2010; Turpin and Scott, 2010). Although pre-selected routes with known distances have been used during driver training and monitoring (af Wåhlberg, 2006; af Wåhlberg, 2007) the odometer reading provides a means of checking the actual distance travelled. The use of odometer requires that the driver accurately record the odometer every time the vehicle is fuelled and this has been noted as the main drawback in the use of odometer readings (Beusen et al, 2009; Virtos, 2010; Turpin and Scott, 2010). Due to these problems, Global Positioning System (GPS) based systems have proved more successful, see Sections 4.4.2.2 and 4.4.4.

#### *4.4.2.2 GPS and GPRS Systems*

Global Positioning by Satellite can be used to record the distance travelled by a vehicle and also provide the real-time locations of the vehicle (or GPS tracking) (Beusen et al, 2009; Masternaut, 2012). Real-time data from the vehicle on-board logging devices are relayed to a central database by means of the General Packet Radio Service (GPRS) (Beusen et al, 2009; Masternaut, 2012) usually provided by mobile telephone service providers. Although this method initially appears to be more expensive than the use of odometers, it is becoming the choice for many fleet operators (Vivaldini et al, 2012) because of the associated benefits which include real-time fleet management, monitoring and data capture.

### 4.4.3 Driver Behaviour

The use of self-reporting or driver questionnaires has been the main method of collecting data to study the behaviour of drivers with regards to difference performance requirements, such as safety and fuel economy. A detailed literature review of self-reporting studies involving the use of driver questionnaires for self-reporting, as summarised in Table 4-4, can be found in Toledo et al (2008) and Jensen et al (2011).

Table 4-4: Summary of key driver behaviour questionnaires

| Self-report Questionnaire | Purpose | Reference |
|---|---|---|
| Driver behaviour Inventory (DBI) | Measured driver stress based on the variability of the DBI. | Gulian et al, 1989 |
| Driver Behaviour Questionnaire (DBQ) | Measured driver behaviour based on 3 dimensions, namely, driver violations, errors and lapses. | Reason et al, 1990 |
| Driving Style Questionnaire (DSQ) | Measured driving style based on six independent dimensions, namely, speed, calmness, planning, focus, social resistance and deviance as discussed in | French et al, 1993; West et al, 1993 |

| | | |
|---|---|---|
| | Section 3.2.1. | |
| Driving Vengeance Questionnaire (DVQ) | Measured attributes to investigate the use of vengeance among drivers. | Wiesenthal et al, 2000 |
| Multidimensional Driving Style Inventory questionnaire (MDSI) | Measured a wider range of driver's behaviours attributes and classified behaviours as reckless and careless, anxious, angry and hostile, and patient and careful as described in Section 3.2.1. | Taubman Ben-Ari et al, 2004 |

The DSQ has been of particular interest to this study because of the similarity of the driving style attributes being associated with vehicle fuel consumption. However, the questionnaire that has been used in this study was a modified version of the DSQ by French et al (1993) as described in Section 6.4.1. LeBlanc et al (2006) also used a modified DSQ to investigate safety-related changes in driver behaviour and levels of driver acceptance as a result of introducing intelligent vehicle initiative road departure crash warning systems. The modifications of the original forms of the driver questionnaires have mainly been carried out to meet the specific needs of the investigations being carried out. The main advantage of using self-reports is they can be used to collect a large amount of data over a short period of time at relatively low cost. However, as suggested by Rabbitt and Abson (1990), the collection of data by means of self-reporting is regarded as subjective in nature and can also be affected by individual characteristics including memory efficiency. Another issues with self-reports are social desirability and social approval biases as discussed by Adams et al (2005).

The continued advances in technology, however, mean that improvements in the collection of driver behaviour data by means of in-vehicle data recorders (IVDR) are being made as described below.

### 4.4.4 Vehicle Electronic Data

Toledo et al (2008) notes the lack of reliable tools to collect detailed information about individuals as one of the main obstacles in understanding the relationship between drivers' characteristics and their driving behaviour, to facilitate good monitoring and interpretation of the drivers' behaviour as indicated by, among other attributes, fuel consumption, acceleration and speed profiles. IVDR enhanced by GPS and GPRS Systems as described above are emerging as the way forward as such information can then be used for driver-vehicle interaction and monitoring systems (van der Voort et al, 2001; Larsson and Ericsson, 2009; Jenness et al 2009; Manser et al 2010; ecoDriver, 2012; Beusen et al, 2009; Young et al, 2011; ecoDriver, 2012; Fiat, 2010; Lai et al, 2012; Jamson et al, 2012; Cacciabue and Carsten, 2010; Amditis et al, 2010; McGordon et al, 2011).

IVDR systems normally include the Controller Area Network bus (CANbus) system which is fitted into the vehicles in order to record the driving data. Bosch (1991) provides the description and specifications of CANbus. CANbus is widely used due to its robustness and affordability, compared to other methods like Local Interconnect Network (LIN), FlexRayTM and similar others, as a mean of transferring such driver behaviour information from different vehicle electronic control units (ECU) (Virtos, 2010).

Systems such as CANbus can provide data regarding vehicle use including fuel consumption, distance travelled, speed, engine use, revolutions per minute (RPM), pedal position, throttle, braking and miscellaneous related information regarding vehicle handing.

### 4.4.5 Miles per Gallon (MPG)

In vehicle operation or fleet management, Miles per Gallon (MPG) and distance travelled are the main measurement to indicate vehicle or driver fuel economy as reported in many literature including Siero et al (1989), Turpin and Scott (2010), Gonder et al (20120 and Parkes and Reed (2005).

## 4.5 Fuel Economy Driving Attributes

### 4.5.1 Rationale

The consumption of fuel by the vehicle allows it to overcome resisting forces against motion and other influencing factors, as shown in Figure 2.10. The factors which affect vehicle fuel consumption are related to these forces and several literature sources (Redsell et al, 1993; Bennett and Greenwood, 2003; Odoki and Akena, 2008) discuss the influence of the factors.

In order to provide an understanding of the factors that affect vehicle fuel consumption, so that they can be addressed during training, mechanistic equations for estimating the tractive forces, consisting of aerodynamic drag, rolling, gradient, curvature and inertial resistances can be used to show mathematically the contribution of the factors. These factors are considered when teaching drivers skills regarding fuel economy during driving. The ARFCOM model (Figure 2.10) can essentially be related to the Vehicle-Specific Power (VSP) modelling approach which is defined as the vehicle engine power output per unit vehicle mass; it is expressed as a function of vehicle speed, road gradient and acceleration. VSP is related to the resisting forces to motion including aerodynamic drag, rolling resistance and road gradient (Jiménez-Palacios, 1999; Zahi et al, 2008; Song et al, 2012). These models are increasingly being used to estimates vehicle fuel consumption and emissions (Bennett and Greenwood, 2003; Zahi et al, 2008; Song et al, 2012).

Empirical models (see Parajuli et al, 2003; Bennett and Greenwood, 2003) could also be used but because of the inability of the empirical models to explicitly show how the factors linked to vehicle, road, environment and drivers are combined mathematically to influence vehicle fuel consumption; they are less adequate for the purpose of teaching driving for fuel economy.

The mathematical representations of the components of the ARFCOM model (tractive forces) are summarised hereafter and include aerodynamic drag and rolling resistances, the gradient and curving resistances as well as inertial effect.

#### *4.5.1.1 Aerodynamic Drag Resistance*

The aerodynamic force represents the force required to push an object through the air and it is calculated using Equation 4.1 (Bennett and Greenwood, 2003):

Equation 4.1 $$F_a = 0.5 \times \rho \times CD \times AFa \times v_r{}^2$$

Where: $F_a$ is the aerodynamic force opposing motion in N

$\rho$ is the mass density of air in kg/m$^3$

$CD$ is the aerodynamic drag coefficient

$AFa$ is the projected frontal area of the vehicle in m$^2$

$v_r$ is the speed of the vehicle relative to the wind in m/s

At elevated speeds, the aerodynamic drag force is dominant especially for the heavy or large vehicles.

#### *4.5.1.2 Rolling Resistance*

According to Bennett and Greenwood (2003), Biggs (1988) described rolling resistance as:

> *"... the total of all forces, apart from aerodynamic drag, acting on a free-wheeling vehicle (i.e., with the clutch disengaged). Thus, it includes all frictional forces from the output of the gear box to the wheels and tyre resistance forces."*

In its simplest form the rolling resistance is calculated using Equation 4.2:

Equation 4.2 $$F_r = M \times g \times CR$$

Where:

$F_r$ is the rolling resistance in N

$M$ is the vehicle mass in kg

$g$ is the acceleration due to gravity in m/s$^2$

$CR$ is the coefficient of rolling resistance

The impact of rolling or frictional resistance on a vehicle's motion has attracted many studies over the past two decades. The most recent documentation of the formulation for estimating rolling resistance by Bennett and Greenwood (2003) is given by Equation 4.3:

Equation 4.3 $$F_r = CR_2 \times FCLIM \times \left(b_{11} \times N_w + CR_1(b_{12} \times M + b_{13} \times v^2)\right)$$

Where:

$CR_1$ is the rolling resistance tyre factor

$CR_2$ is the rolling resistance surface factor

| | |
|---|---|
| $FCLIM$ | is a climatic factor related to the percentage of driving done in snow and rain |
| $b_{11}$, $b_{12}$, $b_{13}$ | are rolling resistance parameters |
| $N_w$ | is the number of wheels |

$F_r$ is a significant component at low speed but also absorbs energy at high speed due to the internal friction in the rubber tyres.

#### *4.5.1.3 Gradient Resistance*

The gradient resistance is the force component in the direction of travel necessary to propel a vehicle up a grade (positive resistance) or down a grade (negative resistance). Literature suggests that quite large fuel savings can be obtained by anticipating gradient and choosing appropriate gears and speeds (DfT, 2009c) Figure 4.3 shows a force resolution diagram for a vehicle on a gradient. The weight of the vehicle can be resolved into both a parallel and perpendicular component with respect to the direction of travel. Therefore, the gradient resistance is given by Equation 4.4 (Bennett and Greenwood, 2003):

Equation 4.4 $$F_g = M \times g \times Sin(\theta)$$

Where: $F_g$ is the gradient force in N

$\theta$ is the angle of incline in radians

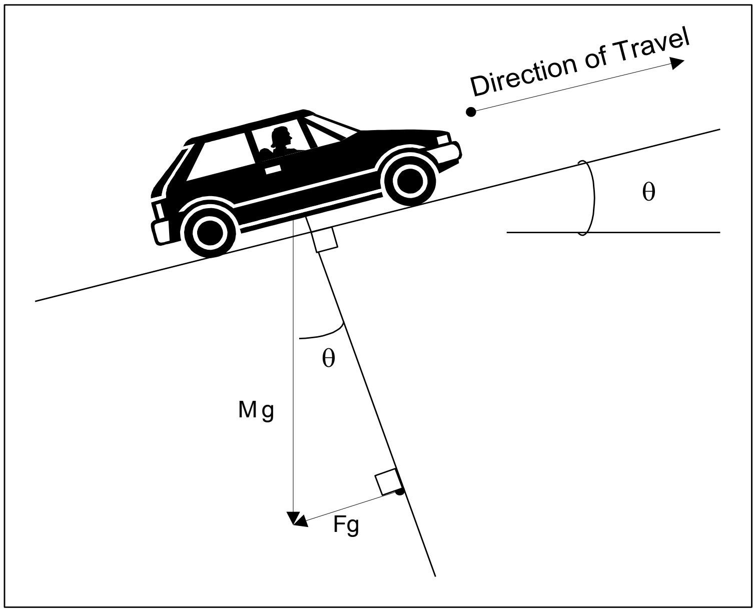



Figure 4.3: Resolving forces on a gradient (Bennett and Greenwood, 2003)

Since $\theta$ is small, $\theta \approx sin(\theta) \approx tan(\theta)$, and $tan(\theta) = GR$, where $GR$ is the gradient as a decimal. Using this approximation $F_g$ can be written using Equation 4.5:

Equation 4.5 $$F_g = M \times GR \times g$$

The approximation that $\theta \approx \sin(\theta) \approx \tan(\theta)$ introduces a 1.1% error on a gradient of 15%.

#### *4.5.1.4 Curvature Resistance*

When a vehicle traverses a curve, the tyres deform by a finite amount, resulting in a small angle (slip angle) occurring between the direction of travel of the car and the direction of travel of the wheels. Due to the slip angle created, an additional force against motion (the curvature resistance) is placed on the vehicle. The curvature resistance has been found to be proportional to the side force applied to the wheels and the slip angle (Equation 4.6) (Bennett and Greenwood, 2003):

Equation 4.6 $$F_{cr} = F_f \times \tan(\emptyset)$$

Where: $F_{cr}$ is the curvature force in N

| | | |
|---|---|---|
| | $F_f$ | is the side friction force in N |
| | $\emptyset$ | is the slip angle in radians |

The slip angle $\emptyset$ is a measure of the amount of roll (or deformation) in the tyres. The slip angle is dependent upon the magnitude of the side force applied to each wheel and inversely to the stiffness of the tyre. Since $\emptyset$ is small, $tan(\emptyset) \approx \emptyset$. Hence, the curvature resistance can be written using Equation 4.7:

Equation 4.7 $$F_{cr} = F_f \times \emptyset$$

The basic method for estimating the balance of forces as a vehicle traverses a curve is given by Equation 4.8:

Equation 4.8 $$\frac{M \times v^2}{Ra} = (M \times g \times e) + (M \times g \times f)$$

| | | |
|---|---|---|
| Where: | $Ra$ | is the radius of the curve in m |
| | $e$ | is the super-elevation in m/m |
| | $f$ | is the side friction factor |

Thus the curvature resistance $F_{cr}$ can be given by Equation 4.9:

Equation 4.9 $$F_{cr} = max\left[0, \frac{\left(\frac{M \times v^2}{Ra} - M \times g \times e\right)^2}{N_w \times C_s}\right]$$

| | | |
|---|---|---|
| Where: | $N_w$ | is the number of wheels |
| | $C_s$ | is the tyre stiffness in kN/rad |

#### *4.5.1.5 Inertial Resistance*

When a vehicle accelerates it needs to overcome inertial resistance. The inertial effects of the various vehicle rotating parts, that is, the engine, the wheels and the drivetrain, serves to increase the vehicle dynamic mass over its static mass. The increased mass is termed the effective mass and it is given by Equation 4.10 (Bennett and Greenwood, 2003):

Equation 4.10 $$F_i = M' \times a$$

Where: $F_i$ is the inertial resistance in N

$M'$ is the effective mass in kg

$a$ is the acceleration in m/s$^2$

The effective mass is defined by Equation 4.11:

Equation 4.11 $$M' = M + M_w + M_e$$

Where: $M_w$ is the inertial mass of the wheels in kg

$M_e$ is the inertial mass of the engine and drivetrain in kg

And, further substitutions of the masses above produces Equation 4.12 or Equation 4.13:

Equation 4.12 $$F_i = M \times \left(a0 + a1 \times a\tan\left(\frac{a2}{v^2}\right)\right) \times a$$

Or

Equation 4.13 $$F_i = M \times (EMRAT) \times a$$

Where: $F_i$ is the inertial resistance in N

$a$tan is the arc tan in radians

$v$ is the vehicle velocity in m/s

*a0 to a2* are regression coefficients

*EMRAT* is the ratio of effective mass to mass

Generally, the consumption of the traditional fossil fuel vehicle (petrol or diesel) tends to follow a u-shaped (Figure 4.4) as the vehicle speed increases from a very low to a very high value (Redsell et al, 1993; Bennett and Greenwood, 2003; Odoki and Akena, 2008).

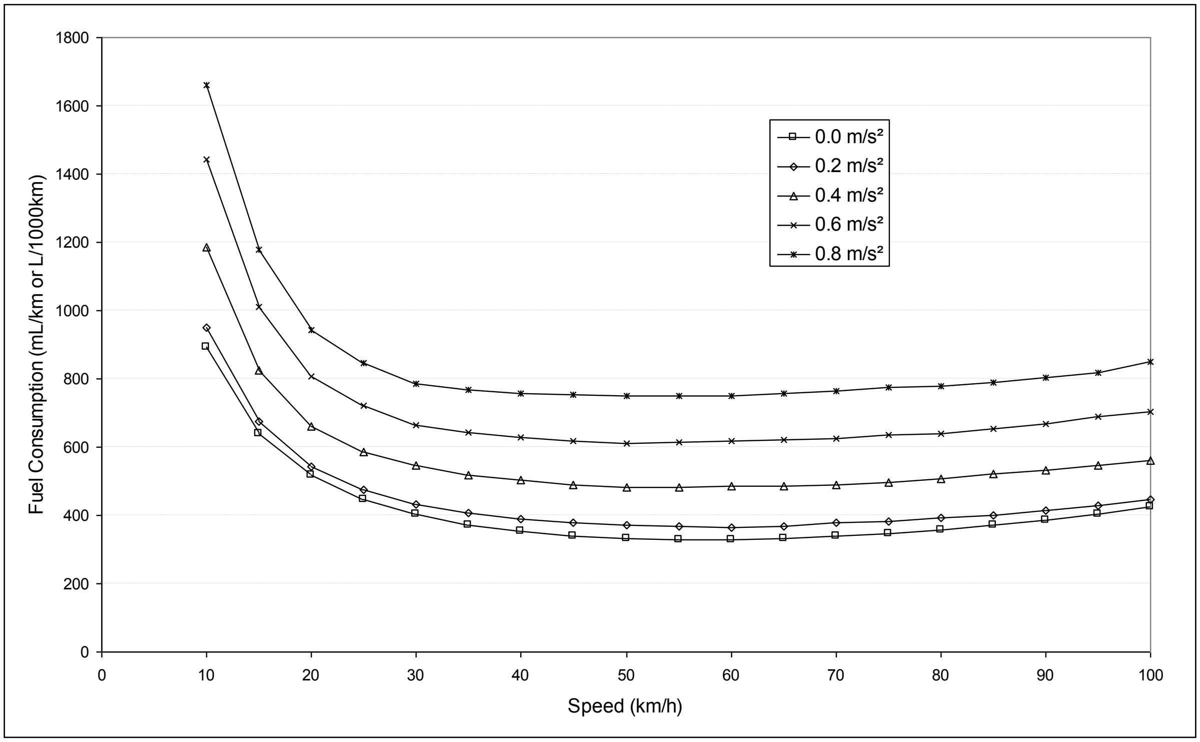



Figure 4.4: The effect of speed and acceleration rate on vehicle fuel consumption (Bennett and Greenwood, 2003)

The first part of the curve is dominated by the rolling or friction resistances, and the second part of the curve (high speeds) is dominated by aerodynamic drag. Thus by maintaining uniform speeds around the optimum part of the curve (usually 40-60 km/hr) vehicle fuel consumption can be reduced. Furthermore, by maintaining uniform speeds or using smooth acceleration and braking, inertial resistance can also be minimised (Redsell et al, 1993; Bennett and Greenwood, 2003; Odoki and Akena, 2008). The results from several studies regarding the influence of driver behaviour on vehicle fuel consumption, including (Siero et al, 1989; Nader, 1991; Ericsson, 2001; van der Voort et al, 2001; afWåhlberg, 2002; Parkes and Reed, 2005; afWåhlberg, 2006; afWåhlberg, 2007; Zarkadoula et al, 2007; Symmons and Rose, 2009; Scott et al, 2012; Turpin and Scott, 2010; Luther and Baas, 2011), highlight the influence on fuel economy of driving attributes like gear shifting, speed, accelerations and driver management.

The rationale summarised above, including the influences of the accessories, engine friction, drive train and engine efficiency, can be used to explain the influence of the driving attributes on vehicle fuel consumption as discussed hereafter.

In the following sections, the influences of the driving factors which are linked to the SAFED training (see Section 4.2.3.2) on fuel economy are described. As described in Section 4.2.3, the factors or attributes are those that are covered in the SAFED training programme.

### 4.5.2 Driver Factors

The driving environment refers to non-vehicular factors, as described in the following paragraphs. Teaching the driver how to manage these factors has the potential to improve the economy of driving.

#### *4.5.2.1 Hazard*

According to DfT (DfT, 2006d; DfT, 2009c) there are three types of hazards, namely: permanent, temporary and environmental. Permanent hazards include junctions, bends and street furniture. Use of information gained through earlier observation of these hazards gives the driver more time to plan ahead and systematically manage the position of the vehicle, thereby reducing, for example, unnecessary accelerations and gear changes. Temporary hazards include the positions and movements of other road users. Environmental hazards include the nature of the road surfaces and weather conditions (DfT, 2006d; DfT, 2009c). Therefore, continuous monitoring of these changes, can the result in steady state speeds that lead to a reduction in fuel consumption.

#### *4.5.2.2 Driver Behaviour*

The task of driving requires a great deal of vigilance due to the constant interactions with other drivers, some of whom will not necessarily drive in the style and manner that matches those of others, and such situations can lead to frustration, and possibly anger, to levels that result in road rage incidents (DfT, 2006d; DfT, 2009c). The resulting behaviours can increase fuel consumption due to the increases in harsh accelerations and decelerations, and high speeds.

#### *4.5.2.3 Driver Fatigue*

By the very nature of the driving task, fatigue will be a problem with some drivers; this could be mental fatigue caused by the degree of concentration needed to drive safely, or physical fatigue caused by the effort exerted when driving (DfT, 2006d; DfT, 2009c). Keeping the body hydrated and taking a break from driving every two hours can combat the effects of fatigue. Furthermore, the DfT (2006d; 2009c) recommends a good night's sleep of at least six hours before setting off, to ensure that the risk of falling asleep at the wheel is minimised which would otherwise result in unsteady driving thereby increased accelerations, decelerations, poor gear changes and excessive speeds among other elements which increase vehicle fuel consumption.

### 4.5.3 Operating the Vehicle

#### *4.5.3.1 Initial Checks*

i) *Fuel levels* – First, the more fuel carried by a vehicle, the greater is its weight and the higher is the fuel consumption since more motive force is required to overcome the increase in some of the resisting forces. Secondly, fuel expands when it is hot and it could be heated by both the sun and by the vehicle systems; consequently, fuel could leak if the vehicle's tank is filled to the brim.

ii) *Tyre checks* – According to DfT (DfT, 2006d; DfT, 2009c) correctly inflated tyres offer less resistance on the road, increase fuel economy, give greater stability and reduce the risk of accidents. DfT (DfT, 2006d; DfT, 2009c) also writes that under inflated (less pressure) tyres reduce fuel efficiency and increase wear, thereby reducing tyre life and increasing the related running costs, and that over inflated (more pressure) tyres offer less stability, produce less grip on the road, increase braking distances and increase road damage.

iii) *Comfort and familiarisation* – according to DfT (DfT, 2006d; DfT, 2009c) it is necessary for a driver to be comfortable when driving; that the drivers should check their seat belt, driving positions, head restraints, mirrors and should also make themselves familiar with in-car technology, such as cruise control, in order to avoid disruptions which cause instability in the moving mass, unsteady vehicle speeds, increase in accelerations, and consequently an increase in vehicle fuel consumption.

iv) *Mobile phones and personal accessories* – DfT (DfT, 2006d; DfT, 2009c) reports that disruptions resulting from the use of mobile phones or other personal items, such as foods/drinks, result in poor vehicle control during driving leading to reduced fuel use efficiency and increased safety concerns. This is due to poor acceleration control and speed management, poor control of clutch and gear, harsh braking and lack of forward planning when driving as discussed hereafter.

#### *4.5.3.2 Acceleration Events and Speed*

Excessive speeds and high acceleration rates have negative effects on fuel economy and increase the safe braking distance, as discussed in Section 4.5.1. In addition, excessive accelerations can also put extra stress on the engine and the transmission system, resulting in shorter component lives and increased maintenance costs and fuel consumption. Parkes and Reed (2005), for example, showed that by contrast, effective use of acceleration and deceleration transformed into useful torque with appropriate gear selections.

#### *4.5.3.3 Braking*

Smooth and tapered braking will not only save fuel but can reduce stress on the driver, the vehicle and the load, and harsh braking uses more fuel by increasing acceleration and deceleration or speed variations, increasing the number of gear changes and other secondary effects(DfT, 2006d; DfT, 2009c; af Wåhlberg, 2007).

#### *4.5.3.4 Gear Changes (Selection)*

The correct selection of gear at the appropriate time means that power is delivered more effectively, with better engine performance (DfT, 2006d; DfT, 2009c; af Wåhlberg, 2007). It is not always necessary to use every gear because the brakes on modern vehicles are so much more efficient. Every time a gear is correctly changed up, there is an improvement in fuel consumption and, therefore, keeping the engine from over revving reduces fuel use. Reducing the number of gear changes also creates a safer and cleaner environment and reduces engine wear. Parkes and Reed (2005) found that trained drivers used up to 30% fewer gear changes to complete a task compared to untrained drivers, which resulted in better vehicle handling and reduced fuel consumption.

#### *4.5.3.5 Clutch Control*

Clutch pedals in larger vehicles are heavier to operate and, therefore, their excessive use may cause driver fatigue and unnecessary wear on the vehicle (DfT, 2006d; DfT, 2009c). DfT (2006d) and DfT (2009c) recommends the use of handbrakes when stationary on a gradient, to prevent wear and to reduce fuel use due to the accelerators not being needed to balance the clutch when trying to prevent the vehicle from rolling backwards.

#### *4.5.3.6 Forward Planning*

Driver training programmes for fuel economy (DfT, 2006d; DfT, 2009c; af Wåhlberg, 2007) recommend drivers to plan well ahead and to keep the vehicle moving to reduce journey time and fuel consumption; that is "plan to stop but look to go" when approaching a hazard. Thus, by keeping the vehicle moving, the running cost is reduced as the brakes and the accelerator are used less because the speeds gathered under power can be used to descend hills on undulating roads. This is supported by the fact that the modern engine will cease to inject fuel into the combustion chambers once the accelerator pressure is removed, consequently saving fuel.

#### *4.5.3.7 Engine Idling*

Idling uses fuel yet without any useful work output (DfT, 2006d; DfT, 2009c; af Wåhlberg, 2007). By avoiding excess idling fuel can be saved.

### 4.5.4 Vehicle Dynamics

#### *4.5.4.1 Route Planning*

According to DfT (2006d; DfT, 2009c) about 20% of driving time on unfamiliar roads is spent getting lost, thus increasing fuel consumption. By planning the travel route in advance, drivers can avoid congestion, getting lost, higher fuel prices at petrol stations on certain routes and plan rest points which all result in improved efficiency.

#### *4.5.4.2 Loads and Loading Pattern*

The equations for estimating the resisting forces to motion indicates that loading would influence fuel consumption, first, by increasing the vehicle operating weight, and secondly, depending on the loads and loading patterns, by increasing aerodynamic resistance. By contrast, utilising the full loading space available, the number of trips per vehicle can be reduced to save fuel (McKinnon et al, 1993).

#### *4.5.4.3 Adjustable Aerodynamics and Windows*

The use of adjustable aerodynamics, especially for large vehicles and the closing of vehicle windows at high speeds reduces the vehicle aerodynamic resistance and consequently fuel consumption (Good Year, 2008). Modern cars are aerodynamically designed to cut resistance and boost efficiency (DfT, 2006d; DfT, 2009c). Open windows increase fuel consumption and the DfT (2006d, 2009c) argues that, in most cases, it is better to use the air conditioning (a/c) as opposed to leaving the windows opened because at relatively high speeds the energy used by the a/c is lower than the energy used to overcome the aerodynamic resistance related to the open windows.

### 4.5.5 Awareness

#### *4.5.5.1 Culture Change*

According to DfT (2008) the majority of driver development is about changing driver attitudes and behaviour which, in many instances, cannot be achieved by compulsion. The benefits of the driver development interventions have to be ‘sold’ to the drivers (van der Voort et al, 2001).

#### *4.5.5.2 Management*

In terms of improving fuel use economy, driver management could be examined under two themes, namely, commitment and monitoring. According to DfT (2008) the commitment of senior management:

1. Allows budget allocations for training activities;
2. Secures staff time for work concerned with developing initiatives;
3. Supports the idea of leading by example;
4. Supports measures that may require changes in policy;
5. Engages those responsible for environment, health and safety policies because driver development initiatives support these policies. Driver development activities may be part of wider business initiatives, such as a health and safety policy, and where this is the case, the training activities could be promoted in such a way that they are embedded within the wider business initiatives.

Fuel use monitoring forms an essential part of fuel and driver management because it provides management and feedback information. It is also important to publicise successes to let the drivers know about their achievements thus giving them the motivation needed, for example, by publishing a regular newsletter (DfT, 2006d; DfT, 2009c; af Wåhlberg, 2007) or providing information on a company intranet.

## 4.6 Summary

Driver training for vehicle fuel economy has been reviewed, including the considerations needed to improve the benefits of such training starting from the pre-training period through the post-training monitoring. Although fuel cards and keys, odometers and self-reporting questionnaires are currently the main methods of capturing the data regarding driver training, the use of in-vehicle data recorders (IVDR) is emerging as a preferred method.

The conventional driver training focus on teaching driving skills which relate driving attributes like speed, gear change and acceleration to fuel economy. It has been shown that the influence of some of the driving attributes on vehicle fuel consumption could be deduced by examining mechanistic equations for estimating the vehicle fuel consumptions. In Chapter

5, the driving factors or attributes identified in this chapter are prioritised in terms of fuel economy.

# CHAPTER 5 PRIORITISING DRIVING ATTRIBUTES FOR FUEL ECONOMY

## 5.1 Introduction

A number of driving factors or attributes which affect vehicle fuel consumption were identified in Section 4.5. In order to ensure that the appropriate focus was given to the most influential factors during the driver training, the attributes had to be prioritised in terms of fuel economy. To achieve this, a rationale method was used, known as Analytical Hierarchy Process (AHP). This involved the pair-wise comparison of the attributes in terms of their influence on vehicle fuel consumption.

## 5.2 Attributes

### 5.2.1 Mathematical Definition of the Attributes

The influence of the driving attributes, identified in Chapter 4, on vehicle fuel consumption for a particular driving environment can be defined using Equation 5.1.

Equation 5.1 $$T_0 = \sum_{i=1}^{n} (A \times TS)_i$$

Where:

$T_0$ is the overall influence of the driving attributes on vehicle fuel economy, can be assumed to be equal to the maximum possible influence of that driver training can have on vehicle fuel consumption

$A_i$ is the weight assigned to the training attribute $i$ based on the influence of the attribute $i$ on vehicle fuel consumption

$TS_i$ is an importance factor that can be assigned to an attribute $i$ due to the traffic system or driving environment.

### 5.2.2 Prioritising Attributes

The driving attributes related to fuel economy were identified in Section 4.5 in terms of the driver factors, vehicle operation, vehicle dynamics and driver awareness. The influence of each of the driving attributes on vehicle fuel consumption is likely to vary by driver, vehicle, road type and the general driving environment. Even under similar driving conditions the influence of the attributes on fuel consumption can vary, therefore, by quantifying the relative influence of the attributes, driver training can be better informed so that appropriate focus can be given to the most influential factors. Prioritisation of the attributes required setting ranks or ratings of importance in terms of fuel consumption. Prioritisation exercises are usually challenging when there are conflicting and competing objectives and when there is lack of a consistent framework to measure the performance of the alternatives (or attributes) against the objectives (Odoki et al, 2013). In this case, the performance of the attributes in terms of fuel consumption was measured with the help of expert knowledge.

Multi-Criteria Analysis (MCA) provides a mean of assessing project alternative and ranking situations involving competing and conflicting demands (Cafiso et al, 2002; Voogd, 1983; Odoki et al, 2013; Chai et al, 2013). According to Cafiso et al (2002) two possible ways of analysis, summarised in Table 5-1 (after Voogd, 1983), can be used to distinguish between the types of MCA methods, depending on the domain of alternatives as follows:

1. Multiple Attribute Decision Making (MADM) – usually involving a number of discrete, limited and pre-specified alternatives. This requires both inter- and intra-attribute comparisons, involving implicit or explicit tradeoffs;
2. Multiple Objective Decision Making (MODM) – usually with decision variables to be determined in a continuous domain, or with infinite or large number of choices, to best satisfy the decision making constraints, preferences or priorities.

Table 5-1: Multi-Criteria Analysis (MCA) methodologies (Hwang and Masud, 1979)

| Stage at which Information is Needed | Major Classes of MODM | Major Classes of MADM |
|---|---|---|
| No articulation of preference | ○ Global criterion method | ○ Dominance<br>○ Maximin<br>○ Maximax |
| Priori articulation of preference | ○ Utility function (UF)<br>○ Bounded objectives method (BOM)<br>○ Lexicographic method<br>○ Goal programming (GP)<br>○ Goal attainment method (GAM) | ○ Conjunctive method<br>○ Disjunctive method<br>○ Lexicographic method<br>○ Elimination by aspects (EA)<br>○ Permutation method<br>○ Linear assignment method (LAM)<br>○ Simple additive weighting (SAW)<br>○ Hierarchical additive method |

| Stage at which Information is Needed | Major Classes of MODM | Major Classes of MADM |
|---|---|---|
| | | o ELECTRE (Elimination and choice expressing reality)<br>o PROMETHEE (Preference ranking organization method for enrichment evaluation)<br>o TOPSIS (Technique for order preference by similarity to the ideal solution)<br>o Analytical hierarchy process (AHP)<br>o SMART (Simple multi-attribute rating technique) |
| Progressive articulation of preference | o Method of Geoffrion<br>o Surrogate worth trade off<br>o Method of satisfactory goals<br>o Method of Zionts-Wallenius<br>o Step method (STEM)<br>o Sequential multi-objective problem solving (SEMOPS) and Sequential information generator for multi-objective problems (SIGMOP) methods<br>o Method of displaced ideal<br>o Goal programming STEM (GPSTEM) method<br>o Method of Steuer | |
| Posterior articulation of preference | | |

Most of the studies carried out to analyse the performance of different MCA methods arrived at the conclusion that it is extremely difficult to categorically state which method is more appropriate for a given data problem, or to identify the advantages and disadvantages of using one method instead of another (Voogd, 1983). According to Cafiso et al (2002) the choice of methods to be used in an application of multi-criteria evaluation can be based on the nature of the problem and the purpose of the evaluation. In the present case the only objective regards the influence of the attributes on vehicle fuel consumption, thus the MADM method would be appropriate. The Analytical Hierarchy Process (AHP), one of the MADM methods was chosen to carry out the ranking task. AHP was chosen because it involves simple pair-wise comparisons between the constituent elements related to the objective. AHP allows the decision makers to understand how the weightings influence the outcomes, as described in Section 5.3. Recently, in an extensive review of the methods and applications of MCA, Chai et al (2013) found that AHP was the most frequently used method in multi-attribute problems.

## 5.3 Method

### 5.3.1 Analytical Hierarchy Process (AHP)

AHP is a multi-criteria decision technique that can combine qualitative and quantitative factors for prioritising, ranking and evaluating alternatives (see Hwang and Masud, 1979; Diakoulaki and Grafakos, 2002; Karni et al, 1990; Lootsma and Schuijt, 1997; Stewart, 1992; Zanakis et al, 1998). AHP systematically transforms competing objectives in a series of simple "pairwise" comparisons of alternatives (in this case driving attributes) and uses these to generate the rankings (Saaty, 1990).

Compared to similar MCA methods (Table 5-1), AHP does not require an explicit definition of the trade-offs between the possible values of each attribute (that is, it is not necessary to build utility functions), and it allows users to understand the way in which outcomes are reached and how the weightings influence the outcomes. AHP provides an effective and efficient methodology to determine the relative importance of the driving attributes using fundamental mathematical principles. AHP provides a framework for both qualitative and quantitative analysis which allows for the differences between attributes to be assessed. AHP uses a methodology that is easy to understand and to use by most decision makers. A certain degree of inconsistency is allowed in AHP, meaning that AHP does not completely rely on the decision maker's preference (Diakoulaki and Grafakos, 2002; Karni et al, 1990; Lootsma and Schuijt, 1997; Stewart, 1992; Zanakis et al, 1998). The AHP methodology assumes that the influence of the factors with respect to one another can be evaluated, and on the same scale. AHP methodology assumes that mutually independent criteria are used to assess the performance of the factors or attributes (Odoki et al, 2013).

### 5.3.2 Principles of AHP

The principles of AHP are decomposition, comparative judgments, and hierarchic composition or the synthesis of priorities (Saaty, 1994). The decomposition principle is applied to structure a complex problem into a hierarchy of clusters, sub clusters, sub-sub clusters and so on (Forman and Gass 2001). The principle of comparative judgments is applied to construct pair-wise comparisons of all combinations of elements in a cluster with respect to the parent of the cluster. These pair-wise comparisons are used to derive 'local' priorities of the elements in a cluster with respect to their parent (Forman and Gass 2001). In this case the attributes have only been related to vehicle fuel consumption.

AHP is based on the following three axioms (Forman and Gass, 2001):

1. The reciprocal axiom which requires that, if $P_C(E_A,E_B)$ is a paired comparison of elements *A* (say attribute 1) and *B* (say attribute 2) with respect to their parent, element *C* (fuel consumption), representing how many times more the element *A* possesses a property than does element *B*, then the condition given by Equation 5.2 applies;

Equation 5.2 $$P_C(E_B, E_A) = \frac{1}{P_C(E_A,E_B)}$$

Where: $P_C$ is pair-wise comparison of the elements *A* and *B*

$E_A$ is an element A of the defined attributes

$E_B$ is an element B of the defined attributes

2. The homogeneity axiom which states that the elements being compared should not differ by too much; else there will tend to be larger errors in judgment;
3. The third axiom states that judgments about, or the priorities of the elements in a hierarchy do not depend on lower level elements. This axiom is required for the principle of hierarchic composition to apply.

The following sections provide procedures of AHP that were carried out in the modelling of the relative importance of the driving factors with regard to drivers' fuel economy.

### 5.3.3 Selection of Experts

In order to carry out the pair-wise comparisons information was solicited from driver trainers or instructors of the Safe and Fuel Efficient Driving (SAFED) programme in England by means of a questionnaire. The experts were identified through consultation with the Transport Research Laboratory (TRL) where the SAFED programme was developed (from 2003) and where the initial training of trainers had been carried out. By 2009, several certified private training businesses were already established across England although many were facing economic difficulties due to the recession because several transportation businesses were shrinking and/or closing down. A total of 54 questionnaires (Appendix C-1) were sent out to be completed by instructors working in 9 driver training offices identified in England in 2009. 36 completed questionnaires were received from the respondents, as summarised in Appendix C-2.

### 5.3.4 Material Design

The questionnaire (Appendix C-1) was developed using the principles of pair-wise comparisons (Saaty, 1980). The pair-wise comparisons were carried out for all the attributes using the Saaty (1980) rating scale (1980) shown in Table 5-2.

Table 5-2: Saaty (1980) rating scale

| Intensity of Importance | Definition | Explanation |
|---|---|---|
| 1 | Equal importance | Two factors contribute equally to the objective |
| 3 | Somewhat more important | Experience and judgement slightly favour one over the other |
| 5 | Much more important | Experience and judgement strongly favour one over the other |
| 7 | Very much more important | Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice |
| 9 | Absolutely more important | The evidence favouring one over the other is of the highest possible validity |
| 2, 4, 6, 8 | Intermediate values | When compromise is needed |

Table 5-2 shows a typical pair-wise comparison using an optimised Saaty rating scale. This would mean that driving attribute 1 (braking) is much more important than attribute 2 (clutch control) in terms of fuel consumption.

Table 5.2: Pair-wise comparison of attributes 1 and 2 (Saaty, 1980)

| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Attribute 1 (e.g., braking ) | | | X | | | | | | | Attribute 2 (e.g., clutch control) |

### 5.3.5 Procedure

The completed questionnaires data is provided in Appendix C-2 as a frequency table of pair-wise comparisons. The table was built from individual comparison of the attributes by each trainer or instructor, based on the methodology described in Section 5.3.4.

## 5.4 Analysis and Results

### 5.4.1 Matrix of Comparison

The rating value represented by the mode (or median where appropriate) for each of the attributes pair-wise comparisons of the attributes given in Appendix C-2 represented the relative importance of the factors in each pair in terms of vehicle fuel consumption. A triangular matrix, illustrated in Figure 5.1, was generated using the following rules:

- If the representative rating value was on the left side of the diagonal of the matrix containing 1s in Figure 5.1, the actual rating value was used; and,
- If the representative rating value was on the right side of the diagonal of the matrix containing 1s in Figure 5.1, the reciprocal of the rating value was used.

$$
\begin{array}{cc}
 & \begin{array}{ccccc} \text{Hazard} & \text{Driver Behaviour} & \text{Driver Fatigue} & \text{Initial Checks} & \ldots \end{array} \\
\begin{array}{c} \text{Hazard} \\ \text{Driver Behaviour} \\ \text{Driver Fatigue} \\ \text{Initial Checks} \\ \ldots \end{array} & \begin{pmatrix} 1 & 1/3 & 3 & 1/2 & \ldots \\ & 1 & 5 & 3 & \ldots \\ & & 1 & 1/3 & \ldots \\ & & & 1 & \ldots \\ \ldots & \ldots & \ldots & \ldots & 1 \end{pmatrix}
\end{array}
$$

Figure 5.1: Triangular matrix of comparison

The lower triangular matrix of comparison was completed using the reciprocal values of the upper diagonal, that is, if $a_{ij}$ is the element of row $i$ column $j$ of the matrix, then the lower diagonal is completed using Equation 5.3.

Equation 5.3 $$a_{ji} = \frac{1}{a_{ij}}$$

The completed matrix of comparison is shown in Table 5-3 while the matrix with the values normalised to generate the priority vectors as shown in Table 5-4 and described in the following paragraphs.

Table 5-3: Generated matrix of comparison

| Matrix of Comparison ($MC_{ij}$) | | Item | 1 | | | 2 | | | | | | | 3 | | | 4 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Category | Driver Factor | | | Operating the Vehicle | | | | | | | Vehicle Dynamics | | | Awareness | |
| Item | Category | Attribute | Hazard | Driver Behaviour | Driver Fatigue | Initial Checks | Acceleration and Speed | Braking | Gear Changes /Selection | Clutch Control | Forward Planning | Vehicle Idling | Route Planning | Loads and Loading Pattern | Adjustable Aerodynamics and windows | Culture Change | Management |
| 1 | Driver Factor | Hazard | 1.00 | 0.33 | 3.00 | 0.50 | 0.20 | 5.00 | 0.20 | 0.50 | 0.33 | 0.25 | 0.33 | 0.20 | 0.20 | 0.20 | 0.20 |
| | | Driver Behaviour | 3.03 | 1.00 | 5.00 | 3.00 | 1.00 | 0.33 | 0.20 | 1.00 | 0.33 | 0.33 | 1.00 | 3.00 | 1.00 | 0.20 | 0.33 |
| | | Driver Fatigue | 0.33 | 0.20 | 1.00 | 0.33 | 0.14 | 0.20 | 0.14 | 0.33 | 0.20 | 0.20 | 0.20 | 0.33 | 1.00 | 0.20 | 0.20 |
| 2 | Operating the Vehicle | Initial Checks | 2.00 | 0.33 | 3.03 | 1.00 | 0.33 | 0.33 | 0.33 | 1.00 | 0.33 | 3.00 | 1.00 | 5.00 | 3.00 | 0.50 | 0.33 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Acceleration and Speed | 5.00 | 1.00 | 7.14 | 3.03 | 1.00 | 4.00 | 3.00 | 5.00 | 5.00 | 5.00 | 7.00 | 5.00 | 7.00 | 1.00 | 1.00 |
| | | Braking | 0.20 | 3.03 | 5.00 | 3.03 | 0.25 | 1.00 | 3.00 | 5.00 | 3.00 | 3.00 | 1.00 | 3.00 | 1.00 | 1.00 | 0.33 |
| | | Gear Changes /Selection | 5.00 | 5.00 | 7.14 | 3.03 | 0.33 | 0.33 | 1.00 | 5.00 | 3.00 | 5.00 | 3.00 | 5.00 | 7.00 | 0.33 | 0.33 |
| | | Clutch Control | 2.00 | 1.00 | 3.03 | 1.00 | 0.20 | 0.20 | 0.20 | 1.00 | 0.50 | 0.33 | 0.33 | 2.00 | 3.00 | 0.20 | 0.14 |
| | | Forward Planning | 3.03 | 3.03 | 5.00 | 3.03 | 0.20 | 0.33 | 0.33 | 2.00 | 1.00 | 0.50 | 0.25 | 0.50 | 1.00 | 0.20 | 0.33 |
| | | Vehicle Idling | 4.00 | 3.03 | 5.00 | 0.33 | 0.20 | 0.33 | 0.20 | 3.03 | 2.00 | 1.00 | 3.00 | 0.25 | 3.00 | 0.20 | 0.33 |
| 3 | Vehicle Dynamics | Route Planning | 3.03 | 1.00 | 5.00 | 1.00 | 0.14 | 1.00 | 0.33 | 3.03 | 4.00 | 0.33 | 1.00 | 3.00 | 3.00 | 0.20 | 0.20 |
| | | Loads and Loading Pattern | 5.00 | 0.33 | 3.03 | 0.20 | 0.20 | 0.33 | 0.20 | 0.50 | 2.00 | 4.00 | 0.33 | 1.00 | 3.00 | 0.20 | 0.20 |
| | | Adjustable Aerodynamics and windows | 5.00 | 1.00 | 1.00 | 0.33 | 0.14 | 1.00 | 0.14 | 0.33 | 1.00 | 0.33 | 0.33 | 0.33 | 1.00 | 0.20 | 0.20 |
| 4 | Awareness | Culture Change | 5.00 | 5.00 | 5.00 | 2.00 | 1.00 | 1.00 | 3.03 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 1.00 | 1.00 |
| | | Management | 5.00 | 3.03 | 5.00 | 3.03 | 1.00 | 3.03 | 3.03 | 7.14 | 3.03 | 3.03 | 5.00 | 5.00 | 5.00 | 1.00 | 1.00 |

Table 5-4: Normalised matrix

| Normalised Hierarchy Matrix | | Item | 1 | | | 2 | | | | | | | 3 | | | 4 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Category | Driver Factor | | | Operating the Vehicle | | | | | | | Vehicle Dynamics | | | Awareness | |
| Item | Category | Attribute | Hazard | Driver Behaviour | Driver Fatigue | Initial Checks | Acceleration and Speed | Braking | Gear Changes /Selection | Clutch Control | Forward Planning | Vehicle Idling | Route Planning | Loads and Loading Pattern | Adjustable Aerodynamics and windows | Culture Change | Management |
| 1 | Driver Factor | Hazard | 0.02 | 0.01 | 0.05 | 0.02 | 0.03 | 0.27 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.03 | 0.03 |
| | | Driver Behaviour | 0.06 | 0.04 | 0.08 | 0.12 | 0.16 | 0.02 | 0.01 | 0.03 | 0.01 | 0.01 | 0.03 | 0.08 | 0.02 | 0.03 | 0.05 |
| | | Driver Fatigue | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.03 | 0.03 |
| 2 | Operating the Vehicle | Initial Checks | 0.04 | 0.01 | 0.05 | 0.04 | 0.05 | 0.02 | 0.02 | 0.03 | 0.01 | 0.10 | 0.03 | 0.13 | 0.07 | 0.08 | 0.05 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Acceleration and Speed | 0.10 | 0.04 | 0.11 | 0.12 | 0.16 | 0.22 | 0.20 | 0.13 | 0.16 | 0.16 | 0.24 | 0.13 | 0.16 | 0.15 | 0.16 |
| | | Braking | 0.00 | 0.11 | 0.08 | 0.12 | 0.04 | 0.05 | 0.20 | 0.13 | 0.10 | 0.10 | 0.03 | 0.08 | 0.02 | 0.15 | 0.05 |
| | | Gear Changes /Selection | 0.10 | 0.18 | 0.11 | 0.12 | 0.05 | 0.02 | 0.07 | 0.13 | 0.10 | 0.16 | 0.10 | 0.13 | 0.16 | 0.05 | 0.05 |
| | | Clutch Control | 0.04 | 0.04 | 0.05 | 0.04 | 0.03 | 0.01 | 0.01 | 0.03 | 0.02 | 0.01 | 0.01 | 0.05 | 0.07 | 0.03 | 0.02 |
| | | Forward Planning | 0.06 | 0.11 | 0.08 | 0.12 | 0.03 | 0.02 | 0.02 | 0.05 | 0.03 | 0.02 | 0.01 | 0.01 | 0.02 | 0.03 | 0.05 |
| | | Vehicle Idling | 0.08 | 0.11 | 0.08 | 0.01 | 0.03 | 0.02 | 0.01 | 0.08 | 0.07 | 0.03 | 0.10 | 0.01 | 0.07 | 0.03 | 0.05 |
| 3 | Vehicle Dynamics | Route Planning | 0.06 | 0.04 | 0.08 | 0.04 | 0.02 | 0.05 | 0.02 | 0.08 | 0.13 | 0.01 | 0.03 | 0.08 | 0.07 | 0.03 | 0.03 |
| | | Loads and Loading Pattern | 0.10 | 0.01 | 0.05 | 0.01 | 0.03 | 0.02 | 0.01 | 0.01 | 0.07 | 0.13 | 0.01 | 0.03 | 0.07 | 0.03 | 0.03 |
| | | Adjustable Aerodynamics and windows | 0.10 | 0.04 | 0.02 | 0.01 | 0.02 | 0.05 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 0.01 | 0.02 | 0.03 | 0.03 |
| 4 | Awareness | Culture Change | 0.10 | 0.18 | 0.08 | 0.08 | 0.16 | 0.05 | 0.20 | 0.13 | 0.16 | 0.16 | 0.17 | 0.13 | 0.11 | 0.15 | 0.16 |
| | | Management | 0.10 | 0.11 | 0.08 | 0.12 | 0.16 | 0.16 | 0.20 | 0.18 | 0.10 | 0.10 | 0.17 | 0.13 | 0.11 | 0.15 | 0.16 |

The comparison matrix was then used to model the relative influence of the driving attributes (parameters) which influence vehicle fuel consumption as discussed hereafter.

### 5.4.2 Priority Matrix

The matrix of comparison shown as Table 5-3 was used to produce the priority matrix (or vector of priorities). The priority vector was obtained by applying Equation 5.4 and Equation 5.5 (Saaty, 1990) which is an approximation of an Eigen vector (and Eigen value) of a reciprocal matrix. Equation (5.4) was used to determine each element $NM_{ij}$ of the normalised hierarchy matrix (NHM) shown in Table 5-4:

Equation 5.4 $$NM_{ij} = \frac{RW_{ij}}{\sum_{i=1}^{N}(RW)_{ij}}$$

Where: $NM_{ij}$ is the normalised value of a matrix cell described by row $i$, and column $j$

$RW_{ij}$ is the value of the hierarchy (or comparison) matrix cell described by row $i$, and column $j$

$N$ is the number of elements of each row of the hierarchy (comparison) matrix NHM, that is, the number of selected criteria (attributes)

Equation (5.5) was then used to determine each element $W_i$ of the vector of priorities (VP), which is a column matrix, as shown in Table 5-5:

Equation 5.5 $$W_i = \frac{\sum_{j=1}^{N}(NM)_{ij}}{N}$$

Where: $W_i$ is the value of the column matrix cell described by row $i$

$NM_{ij}$ is the normalised value of matrix cell described by row $i$, column $j$

Table 5-5: Vector of priorities or the relative importance of the attributes

| Vector of Priorities | | Attribute | Vector of Priorities | Relative Importance (%) |
|---|---|---|---|---|
| Item | Category | | | |
| 1 | Driver Factor | Hazard | 0.035 | 3.5 |
| | | Driver Behaviour | 0.050 | 5.0 |
| | | Driver Fatigue | 0.014 | 1.4 |
| 2 | Operating the Vehicle | Initial Checks | 0.048 | 4.8 |
| | | Acceleration and Speed | 0.149 | 14.9 |
| | | Braking | 0.084 | 8.4 |
| | | Gear Changes /Selection | 0.102 | 10.2 |
| | | Clutch Control | 0.030 | 3.0 |
| | | Forward Planning | 0.045 | 4.5 |
| | | Vehicle Idling | 0.052 | 5.2 |
| 3 | Vehicle Dynamics | Route Planning | 0.052 | 5.2 |
| | | Loads and Loading Pattern | 0.040 | 4.0 |
| | | Adjustable Aerodynamics and windows | 0.027 | 2.7 |
| 4 | Awareness | Culture Change | 0.135 | 13.5 |
| | | Management | 0.136 | 13.6 |
| Total | | | 1.00 | 100.0 |

The vectors of priorities represent the relative importance of the driving attributes in terms of their influence on vehicle fuel consumption, that is, $A_i$, given in Equation 5.1. Therefore, the results show that acceleration (and speed) is judged by the experts consulted to have the highest influence on vehicle fuel consumption and this is followed by culture change and management aspects while driver fatigue has been deemed to have the least influence. These qualifications of the driving attributes were emphasised during the design and administration of the training (by informing the participants about the results), described in Section 6.5.

### 5.4.3 Model Consistency

According to Coyle (2004) if $N$ elements are considered for comparison, $C_1$ ... $C_N$ and the relative 'weight' (or priority or significance) of $C_i$ with respect to $C_j$ is denoted by $a_{ij}$ and form a square matrix $A = (a_{ij})$ of order n with the constraints that $a_{ij} = 1/a_{ji}$, for $i \neq j$, and $a_{ii} = 1$, for all $i$; such a matrix is said to be a reciprocal matrix. Although many authors (Saaty, 1980; Coyle, 2004) recommend $N$, the number of elements considered for comparison to be 7±2 for better consistency regarding the expert pair-wise choice, studies have been documented (Shiraishi *et al*, 1998), where the values of $N$ exceeded 10. In this research the number of elements used was 15.

When computed, the related eigenvector of the resulting matrix of comparison yields a measure for inconsistency. According to Shiraishi *et al* (1998) the degree of inconsistency is measured by the principal Eigen value, $\lambda_{max}$, of the matrix. Furthermore, if $C$ is a pair-wise comparison matrix of size $N$, it is known that $\lambda_{max} \geq N$ and C is consistent if and only if $\lambda_{max} = N$. The quantity ($\lambda_{max}$ - $N$) gives the consistency. Normalizing by the size of the matrix, the consistency index ($CIx$) is defined by Equation 5.6.

Equation 5.6 $$CIx = \frac{\lambda_{max}-N}{N-1}$$

Saaty (1980) showed that if the respondent or expert is consistent then $CIx = 0$, however, if the referee is not absolutely consistent then $\lambda_{max} > N$, and thus the need to measure the related level of inconsistency. For this purpose, Saaty (1980) defined the consistency ratio ($CRa$) shown by Equation 5.7.

Equation 5.7 $$CRa = \frac{CIx}{RIx}$$

Where: $RIx$ is the random consistency index (RI) average value of $CIx$ random matrices using the Saaty scale (1980) obtained by Forman (1990) (Table 5-6)

Table 5-6: Random consistency index (*RIx*) (Forman, 1990)

| *N* | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| *RIx* | 0 | 0 | 0.58 | 0.9 | 1.12 |
| *N* | 6 | 7 | 8 | 9 | 10 |
| *RIx* | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

Alonso and Lamata (2006) discuss the problem of accepting and rejecting matrices and, in particular, the relationship between the consistency and the scale used to represent the decision maker's judgements to which they developed an adaptable and simpler criterion of matrix acceptance. Their criterion is shown as a Boolean function (*F*) given by Equation 5.8.

Equation 5.8 $$F = (\lambda_{max}, \phi)$$

Where: $\lambda_{max}$ is the measure of CI

$\phi$ is the level of consistency needed, $0 < \phi \leq 1$. This level provides adaptability to different scopes (applications), as shown in Table 5-7, where $\phi = 0.10$ would represent Saaty's limit for acceptance

Table 5-7: AHP model consistency parameter, $\lambda_{max}$ (Alonso and Lamata, 2006)

| $\phi$ \ *N* | 3 | 5 | 10 | 15 | 20 | 50 | 100 | 500 |
|---|---|---|---|---|---|---|---|---|
| 0.01 | 3.0096 | 5.0450 | 10.1335 | 15.2220 | 20.3104 | 50.8414 | 101.7264 | 508.8060 |
| 0.05 | 3.0478 | 5.2248 | 10.6673 | 16.1098 | 21.5523 | 54.2071 | 108.6319 | 544.0299 |
| 0.08 | 3.0765 | 5.3597 | 11.0677 | 16.7756 | 22.4836 | 56.7314 | 113.8110 | 570.4478 |
| 0.10 | 3.0957 | 5.4497 | 11.3346 | 17.2196 | 23.1045 | 58.4142 | 117.2637 | 588.0597 |
| 0.20 | 3.1913 | 5.8993 | 12.6692 | 19.4391 | 26.2090 | 66.8284 | 134.5274 | 676.1194 |
| 0.50 | 3.4784 | 7.2483 | 16.6730 | 26.0978 | 35.5225 | 92.0710 | 186.3185 | 940.2985 |

For the present study, $\lambda_{max}$ was computed as 19.41 and, by using Table 5-7, with $N = 15$, the level of consistency of the model was evaluated as 0.20. Saaty (1980) recommends the revision of the hierarchy matrix (or matrices) used to compute the *CIx* of the model if the consistency is greater than 0.1, which would be the case in this analysis, say by possibly repeating the survey. However, Alonso and Lamata (2006) argue that the responses are usually taken from a wide range of persons (characteristics and knowledge) and, therefore, the specification of the level of the consistency needed to support various applications of the model is more important (see Equation 5.8 and Table 5-7). The latter view was taken for the model utilisation presented here, for two main reasons: first, much literature regarding driver training for fuel economy shows that it is still difficult to clearly assign the influence or change in fuel consumption to a specific element or parameter related to driver behaviour (see for example, Evans, 1979; Siero et al, 1989; Nader, 1991; Ericsson, 2001; van der Voort et al, 2001; af Wåhlberg, 2002; Parkes and Reed, 2005; af Wåhlberg, 2006; af Wåhlberg, 2007; Zarkadoula et al, 2007; Beusen et al, 2009; Jenness et al, 2009; Symmons and Rose, 2009; Manser et al, 2010; Scott et al, 2012; Turpin and Scott, 2010; Luther and Baas, 2011). Therefore, some level of variability should still be accommodated until when robust data and models that can predict these occurrences are available. Secondly, resources, for example time and money needed to produce high quality results, are usually limited.

### 5.4.4 Limitations

The prioritisation study reported in this Chapter may have limitations as follows: first, the size of the sample or participants is relatively small; this could be improved by increasing number of the participants. Secondly, the results of the prioritisation need to be validated. The validation could be carried out using driving simulators or vehicles equipped with robust models regarding driving or traffic environment, or by training drivers to concentrate on particular factors or attributes when driving.

## 5.5 Summary

A number of driving attributes which affect vehicle fuel consumption, identified in Chapter 4, were prioritised using a Multi-Criteria Analysis method called Analytical Hierarchy Process (AHP). It was found that acceleration (and speed) was judged by the consulted experts (fuel economy driver trainers) to have the highest influence on vehicle fuel consumption. These are followed by culture change and management aspects while driver fatigue has the least influence. The findings were used to inform a driver training design and actual training (by emphasising findings to the trainees) that are reported in Chapter 6.

# CHAPTER 6 COMPANY DRIVER TRAINING FOR FUEL ECONOMY

## 6.1 Introduction

This Chapter concerns the training for fuel economy of drivers working for Amey in the management and the operation of the motorway and trunk road networks in the West Midlands in the United Kingdom. The methodology used is presented in this Chapter and the results are given in Chapter 7. The study commenced in July 2009 and ended in March 2013. The study involved 94 drivers of heavy, medium and light vehicles. The influence of the training on the performances of the drivers in terms of miles travelled per gallon of fuel consumed was monitored over the study period. Additional information concerning demography and driver behaviour related to the training was collected by means of a driving style questionnaire (DSQ) before and after the training. The data from the DSQ was used to assess the influence of the training. The study methodology is summarised in Figure 6.1.

The methods used are outlined below and described further in the subsequent sections of this Chapter. The study methods were as follows:

1. Literature review, desktop study and liaison with the fleet managers at Amey to define the objectives and the scope of the study ;
2. Selection of the participants based on their locations and work characteristics;
3. Training based on a modified Safe and Fuel Efficient Driver (SAFED) training programme, including a pilot trial. The training covered drivers of heavy, medium and light vehicles;
4. Monitoring of the driver performance using:
   i) DSQ;
   ii) A fuel management system which provided records for fuel consumption and distance travelled, and;
5. Use of statistical methods to analyse the data and provide results (Chapter 7) for interpretation and subsequent discussions (in Chapter 8).

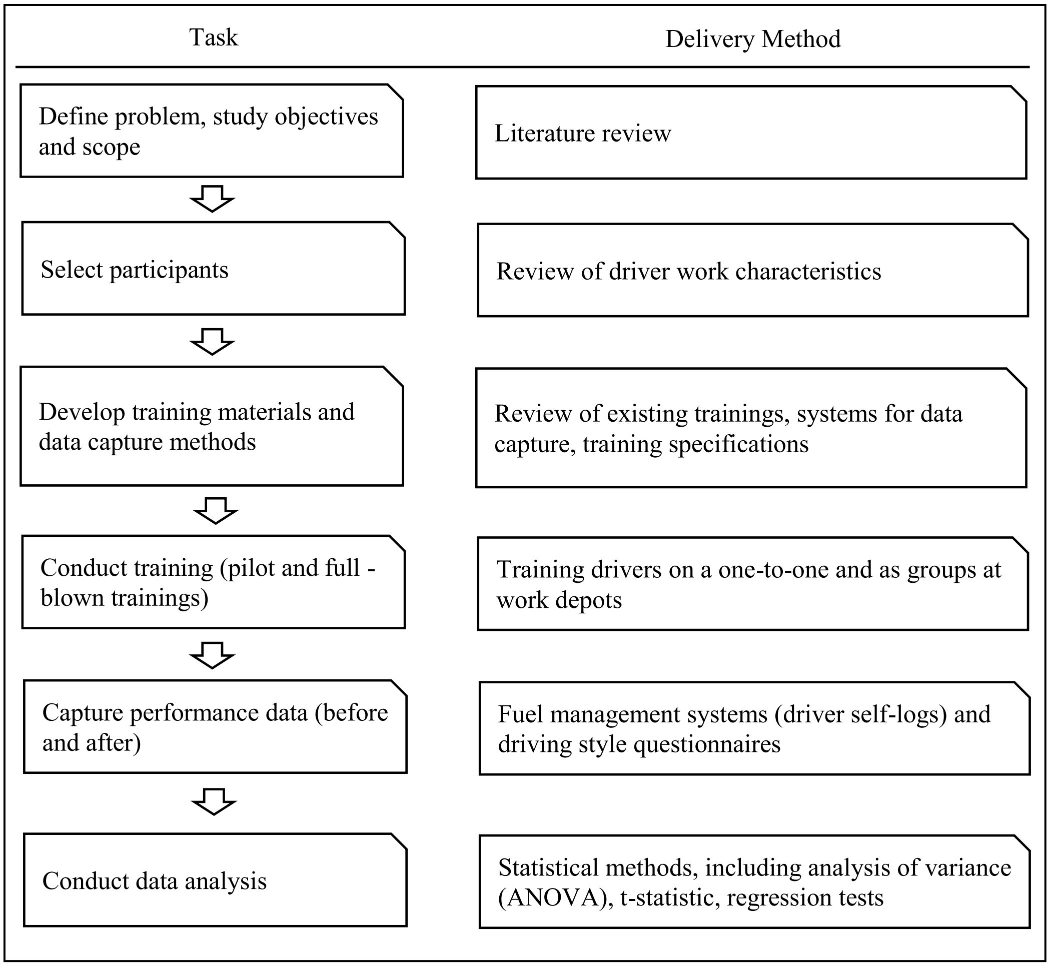



Figure 6.1: Summary of the methodology used to study the impact of fuel efficiency training provided to the road operation drivers

## 6.2 Scope

### 6.2.1 Company (Amey)

Amey is the sole provider of road network maintenance and operations on the UK Highways Agency (HA) Area 9 contract. Area 9 consists of 1,500 carriageway km of motorway and major trunk road network covering the West Midlands in England. The services provided by Amey under the contract include road network monitoring, road maintenance and improvement, traffic operations and planning as described in Section 6.2.3. The road asset types covered by the contract include carriageway and pavement, footways, structures, safety fences, vehicle safety/restraint systems, drainage, earthworks, traffic signs, lighting and traffic signals. Amey also provides management and operations services to over 13,000 pieces of roadside technology including closed circuit television (CCTV) cameras, variable message signs (VMS) and emergency telephones, as part of the West Midlands TechMAC contract. Table 6-1 provides a summary of the contracts.

Table 6-1: Highways Agency (HA) Area 9 and West Midlands Technology Managing Agent Contract (TechMAC) contracts (Amey, 2011)

| Item | Highways Agency (HA) Area 9 | West Midlands TechMAC |
|---|---|---|
| Client | HA | HA |
| Start | July, 2009 | July, 2009 |
| Duration | 3 to 5 years | 3 to 5 years |
| Total value | £440 million | £36 million |
| Total number of employees (both contracts) | 800 | |
| Total number of operational drivers (both contracts) | 220 | |

### 6.2.2 Road Network and Work Depots

The road network and the work depots covered by the HA Area 9 and the West Midlands TechMAC contracts are shown in Figure 6.2. The training was provided to the drivers from Strensham depot, while the drivers from Stafford Park and Doxey depots were used for control purposes. Strensham depot was chosen because Amey's personnel using the depot are required to drive on both the motorway and trunk road network. The depot is also located some distance away from the other depots (Figure 6.2) which meant that the control drivers were potentially less likely to find out about the training. However, drivers operating from Stafford Park and Doxey depots are required to drive on a similar road network and working characteristics as those from the Strensham depot. Strensham depot also provided drivers of small, medium and heavy vehicles; these vehicles categories are defined in Section 6.2.4.

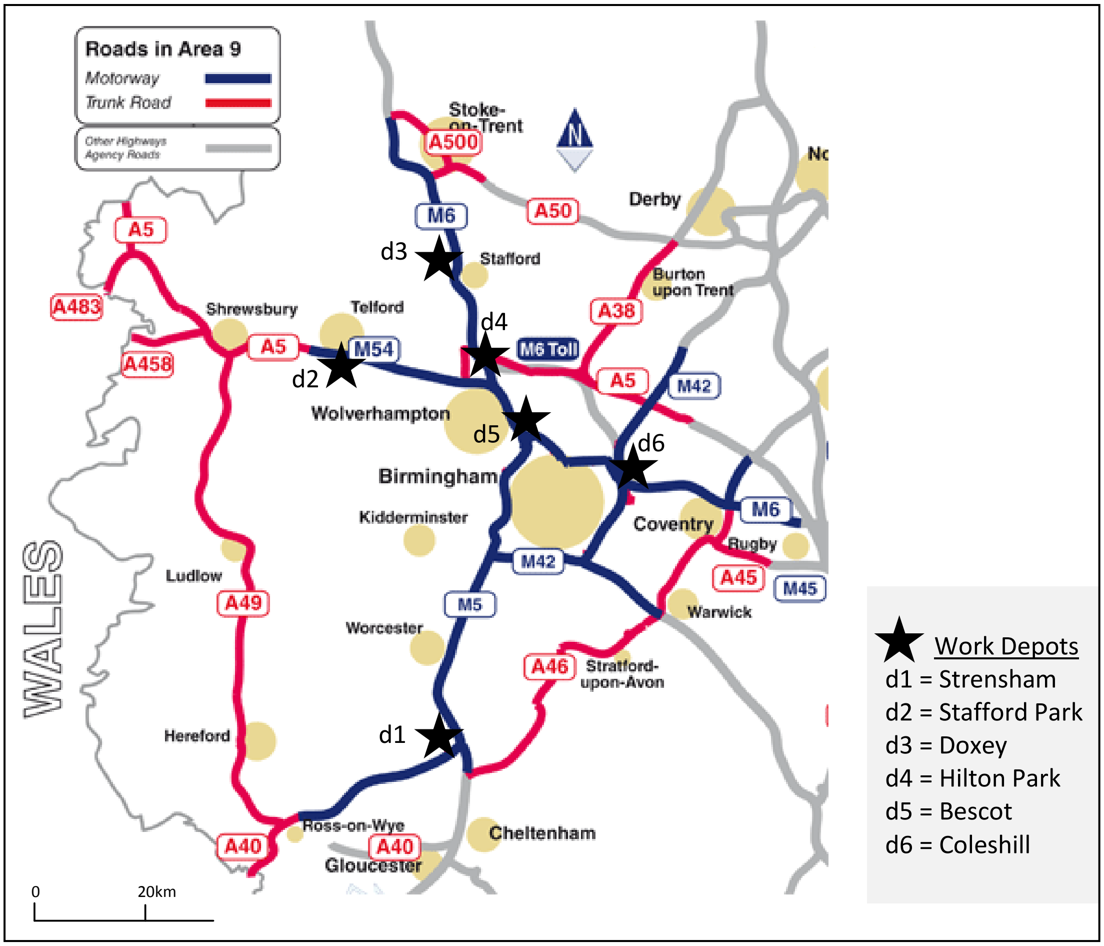



Figure 6.2: The Highways Agency Area 9 road network and work depots

### 6.2.3 Road Network Activities

#### *6.2.3.1 Roads Work Classification*

Road network maintenance and operations includes all traffic management and user support activities intended to permit, to improve, or to facilitate the use of an existing road network, whatever its conditions of use (PIARC, 2003; Amey, 2011). Road network driving tasks can be associated to the following three categories of road network initiatives (Robinson et al, 1998; PIARC, 2003):

1. Road network monitoring;
2. Road maintenance planning;
3. Traffic planning and operations.

In Area 9, road network monitoring is one of the main components of road operations that involve the collection of qualitative and quantitative information and data on the roadways to facilitate real-time and non-real-time applications. The primary means of collecting the road data is by use specially equipped vehicles travelling at normal traffic speeds which also mean minimal disruption to traffic (Amey, 2011). The inspection frequency and the speeds of the vehicles, when collecting the data, usually depend on the purpose of the information or data being collected.

Road maintenance works are mainly localised in nature. However, road maintenance works involve a significant amount of driving activities or tasks within the work zones and, to and from the work zones by different trades. Road works can be classified under the following categories (Robinson et al, 1998; Amey 2011):

1. Emergency;
2. Planned;
3. Enforcement.

Traffic planning mainly involves desk studies using the information and data collected on the road network to ensure smooth traffic movement on the road network over short-to-long-term periods. Traffic operations on the other hand involve keeping the traffic moving on a day-to-day basis on the road network. Driving forms a core part of traffic operations (PIARC, 2003).

*6.2.3.2 Driving Tasks*

As opposed to the traditional road haulage or freight industry, driving tasks linked to road network maintenance and operations are characterised by certain unique attributes that have been suggested to bear greater influence on vehicle fuel consumption. The most significant of these attributes include:

- Frequent stop-start (stop and go) actions that can also be linked to numerous and long idling during working (Rakha and Ding, 2003; Amey, 2011). Manser et al, 2010 suggests that such driving situations like 'stop and go' could benefit significantly from driver training for fuel economy, especially where driver-interface assistance is used;

- Variable loads – there is usually significant variability in the vehicle loads associated with road operations, which affects the different resisting forces to motion and thereby fuel consumption;
- Multiple vehicle driving – many drivers in road operations are not dedicated to a particular type or category of vehicle during their working period or shift. Typically, a driver would usually drive both heavy and medium duty vehicle categories in the course of a week as opposed to the drivers in the haulage industry where they are most likely to drive different vehicle makes but not different categories (Turpin and Scott, 2010);
- Higher variability of the travelling speeds due to the nature or demand of the tasks associated with road network maintenance and operations (Greenwood and Bennett, 2003);
- More significant interactions with other traffic both at work zones and on normal routes (Greenwood and Bennett, 2003; ecoMove, 2010);
- Driver training – based on the review in Chapter 3, there is limited literature regarding specific driver training for fuel efficiency which targets drivers involved in road network maintenance and operations is still lacking (see Section 3.3.3).

### 6.2.4 Vehicles

The main types of vehicles that are used in the road network maintenance and operations in Area 9 contracts are summarised in Table 6-2. In Table 6-3 the vehicles have been classified into heavy, medium and light vehicles, in accordance with the classification system suggested by other researchers investigating driver training for fuel economy (see Siero et al, 1989; af Wåhlberg, 2006; af Wåhlberg, 2007 and Turpin and Scott, 2010).

Table 6-2: Highways Agency (HA) Area 9 primary vehicles and classification

| Vehicle Description | Vehicle Use | Category |
|---|---|---|
| 26 Tonne Traffic Management | Traffic management | Heavy |
| 18 Tonne (T) MAN Gritter | Salt spreading on road surfaces | Heavy |
| 18 Tonne Impact Protection Vehicle | Traffic management | Heavy |

| Vehicle Description | Vehicle Use | Category |
|---|---|---|
| 18 Tonne Incident Support Unit with Crash Cushion | Incident response and clearance | Heavy |
| 18 Tonne ORTECO Barrier Rig | Barrier repair | Heavy |
| 18 Tonne Traffic Management | Traffic management | Heavy |
| 18 Tonne Traffic Management with Crash Cushion | Traffic management | Heavy |
| 3.5 Tonne Panel Van | Delivery of materials | Medium |
| 3.5 Tonne Single Cab Tipper | Crew and material carrier | Medium |
| 5 Tonne Incident Support Unit | Incident response and clearance | Medium |
| 7.5 Tonne Tipper | Delivery of materials | Medium |
| 7.5 Tonne Toolpod with Crane | Delivery of materials | Medium |
| 7.5 Tonne Traffic Management | Traffic management | Medium |
| ASTRA Combi Van | Inspection and small delivery | Light |
| ASTRA Estate Car | Inspection | Light |

The average number of operational vehicles on the contracts was estimated at 220 at the time of the training and it included 42 light vehicle drivers. It should be noted that drivers of vehicles which use non-diesel fuels such as petrol, gas and electric hybrid were not included in the study mainly because of their very limited number. For most engineering and haulage operations, the vehicles are usually medium to heavy and are operate on diesel engines. Even for light vehicles diesel engines are cheaper to operate due the higher MPG and lower tax (due to lower emissions) compared to the main competitor, petrol engines.

Table 6-3: Typical vehicles for heavy, medium and light categories at Strensham depot

| Vehicle Category | Vehicle |
|---|---|
| Heavy (>7.5 tonne, diesel fuel) |  |
| Medium (3.5 – 7.5 tonne, diesel fuel) |  |
| Light (<3.5 tonne, diesel fuel) |  |

### 6.2.5 Training Periods

The pre-training, training and post-training evaluation were carried out in four separate periods between August 2009 and April 2013, as shown in Table 6-4.

Table 6-4: Training periods and data capture

| Period | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Date | Aug 2009 to July 2010 | Aug 2010 to July 2011 | Aug 2011 to July 2012 | Aug 2012 to March 2013 |
| Description | Pre-training period to the pilot training | Post training monitoring period for the pilot training | Pre-training period to the large-scale training | Post training monitoring period for the large-scale training |
| Training | - | Pilot | - | Large-scale |
| Training Date | - | July 2010 | - | July 2012 |
| Data Collection Method | • *Merridale™* fuel management system | • *Merridale™* fuel management system | • *Merridale™* fuel management system<br>• Driving style questionnaire (DSQ) | • *Merridale™* fuel management system<br>• Driving style questionnaire |

The duration of each period of evaluation was designed to cover a full year (where possible) for the following reasons:

- To account for the possible variation in fuel consumption due to factors other than the training which are dictated by the time of the year, for example seasons and variation in work activity;
- Existing literature (for example, Turpin and Scott, 2010 and af Wåhlberg, 2007) has suggested that the benefits in terms of the improvement in miles per gallon (MPG) of such training were most noticeable within a year of the training;
- The overall project duration was also constrained by the research resource which needed a final report in 2013.

The MPG performance of the drivers was reported on a monthly basis to provide a similar time scale for comparison with other studies related to training drivers for fuel economy (see Turpin and Scott, 2010). The monthly reporting also reduced the occurrence of significant data gaps due to the drivers' work pattern (4 days on/off shift). A shorter reporting time scale, e.g. weekly, would have meant significant data gaps and consequently increased data variability.

## 6.3 Participants

### 6.3.1 Management Commitment

It was observed from the results of the prioritisation of the driving attributes using the analytical hierarchy process (AHP), described in Section 5.4.2, that managers might have a significant role in reducing company fuel consumption. This was based on the subjective views of the SAFED trainers. Although there is limited literature to confirm this view, it can be realised that managers can support the success of company fuel saving initiatives. For example, in a study reported by Turpin and Scott (2010) it was found that drivers from companies where managers were committed to driver management produced the best fuel economy results.

At Amey no fuel efficiency training had been provided to the drivers prior to this study, though there was some monitoring of performance in terms of MPG, with the intention of providing feedback to the drivers. During this study Amey fleet managers and supervisors in each depot supported the training by providing advice and resources (time, drivers, data capture and consultation).

### 6.3.2 Selection of Participants

Over the study duration, a total of 94 drivers were involved in the study in Area 9; 47 drivers from the Strensham depot formed the training group while 47 drivers from Stafford Park and Doxey depots were used as the control group. An overview of the drivers' demography is given in Table 6-6. The notable absence of female drivers is characteristic for the population of drivers within Amey and similar organisations.

A total of 13 drivers constituted the pilot group that involved road operational drivers from the Strensham depot in July 2010. The drivers volunteered to participate in the training. The pilot group consisted of 9 multi-vehicle drivers of heavy and medium vehicles, and 4 light vehicle drivers.

In the subsequent large-scale training carried out in July 2012, 47 drivers (including the original pilot group) were trained from the same depot (Strensham) as summarised in

Table 6-5. It was decided that the pilot training be extended to all multi-vehicle drivers of medium and heavy vehicles, and all light vehicles (pool cars) that worked from the depot. The training was extended to the other drivers for the following reasons:

1. The results from the pilot training had indicated improved MPG for the trained drivers which could be extended to similar drivers;
2. Driver training for fuel economy did not form part of the initial driver Certificate of Professional Competency (CPC) that drivers from Amey were receiving. Driver CPC became mandatory in 2009 under the EU Directive 2003/59 but training for fuel economy is not a mandatory requirement (EU, 2003). Therefore, the results of the larger scale training could be used to demonstrate the presumed benefit of improved fuel economy (or otherwise);
3. To increase the size of the trained drivers population in order to provide a representative sample within the contracts so that the results could be more representative of (or extended to) the drivers. The total number of participants was limited by the number of drivers that were associated with the contract. Strensham depot had the greatest number of drivers that could be trained out of all the depots or suitable combinations of depots that could be used for the actual training exercise.

A summary of the number of the participants is provided in Table 6-5 below.

Table 6-5: Number of participants

| Trained Drivers | | Control Drivers | Number | Depot |
|---|---|---|---|---|
| Initial/Pilot Training in July 2010 | Large-scale Training in July 2012 | | | |
| Yes | Yes | No | 13 | Strensham |
| No | Yes | No | 34 | Strensham |
| No | No | Yes | 1 (drop out) | Doxey |
| No | No | Yes | 46 | Stafford Park and Doxey |

The pilot group were retrained during the large-scale training together with the new drivers (Table 6-5) because the pilot results had shown that the benefit of the pilot training in terms of improved MPG had completely disappeared. It was therefore acceptable to assume that the retrained pilot group would not contaminate the large-scale training but would instead increase the study sample size.

### 6.3.3 Demography

As suggested and described by many authors, including Cacciabue and Carsten (2010), af Wåhlberg (2006), af Wåhlberg (2007) and French et al (1993), the success of driver training to improve driving style is related to a number of important characteristics of the drivers. Consequently, the driver age, experience, gender, annual vehicle-km driven (business), other driver training received by the study groups (e.g., driver Certificate of Professional Competency (CPC)), work depot and category of vehicle driven were recorded to support the analysis of the training. While the importance of these demographic factors in influencing vehicle fuel consumption have been highlighted by the above authors, the subsequent analysis of the factors in this study was limited due to the nature of the work carried out and the selected depot. Table 6-6 provides a summary of the driver characteristics while the characteristics of the individual drivers are given in Appendix D-1. Due to the sensitivity of some of the driver data, driver experience and age information has been normalised but still in a way that is comparable to those used in similar studies (Turpin and Scott, 2010 and French et al, 1993).

Table 6-6: Driver characteristics and composition

| Characteristic | Category | Training Group | | Control Group | |
|---|---|---|---|---|---|
| | | Heavy/Medium | Light | Heavy/Medium | Light |
| Gender | Male | 100% | 92.3% | 100% | 92.3% |
| | Female | 0 | 7.7% (1 driver) | 0 | 7.7% (1 driver) |
| Experience | Over 10 years | 91.2% | 69.2% | 87.2% | 84.6% |
| | Under 10 years | 8.8% | 30.8% | 12.8% | 15.4% |
| Age | Over 45 | 79.4% | 38.5% | 73.5% | 46.2% |

| Characteristic | Category | Training Group | | Control Group | |
|---|---|---|---|---|---|
| | | Heavy/Medium | Light | Heavy/Medium | Light |
| | Under 45 | 20.6% | 61.5% | 26.5% | 53.8% |
| Work pattern | Day/night shift | 100% | 15.4% | 100% | 15.4% |
| | Day | 0 | 84.6% | 0 | 84.6% |

## 6.4 Data Collection Methods

The training data was mainly collected by two main methods, the use of a self-reporting driving style questionnaire and by a fuel management system that is described below.

### 6.4.1 Driving Style Questionnaire (DSQ)

In order to assess the influence of the training on driver style or behaviour, a self-reporting study in the form of the driving style questionnaire (DSQ) (French et al, 1993) was used to collect information from the drivers. The data was collected from the training group within 1 month before their training and within 1 month after the training in the large-scale training. The DSQ was also completed by the control drivers in the last month of the monitored period of the large scale training (i.e., March 2013). This was to ensure that control drivers were not affected by the training questionnaire (DSQ). The DSQ used is provided in Appendix D-2. The questionnaire sought to address the influence of the training on the driving attributes or factors that have been known to impact on vehicle fuel consumption. The driving attributes included were those whose influences on vehicle fuel consumption were prioritised in Section 5.4.2 using the analytical hierarchy process (AHP).

### 6.4.2 Fuel Consumption and Distance Travelled

The Merridale$^{TM}$ fuel management system (FMS), which is installed in all fuel pumps at the works depots, was used to collect fuel consumption and distance travelled data for each vehicle (and driver) (see Figure 6.3). The system works as follows: Each driver is provided with a unique key that has to be used to enable the driver to fuel a vehicle from a Merridale$^{TM}$ equipped fuel pump. At the time of fuelling the driver is also required to enter the vehicle odometer reading into the fuel station (pump). A summary of the key user interfaces of the Merridale™ software is provided in Appendix D-3.

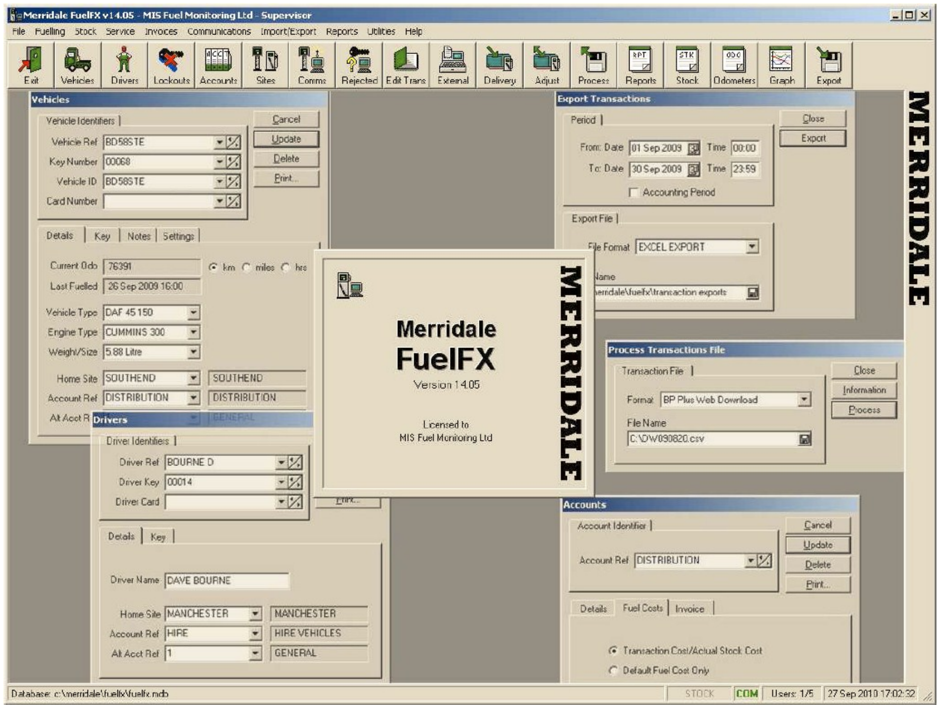



Figure 6.3: Merridale™ fuel management software (Merridale, 2012: Accessed 2/8/2012 at http://www.merridale.co.uk/datasheets/fuelfx.pdf)

The drivers were also instructed to fill (full tank) the vehicle before the start of their work shifts to ensure that they continuously provided reliable data and had sufficient fuel for the work shifts. The collected data containing attributes including fuel consumed, distance travelled, date, driver identity and vehicle identity was then exported to Microsoft Excel for analysis.

## 6.5 Training

The main training components were as follows:

- Training material – the training material provided a list of things which the drivers were asked to do in order to improve their fuel economy. The list was based on the attributes which were known to affect vehicles fuel consumption as identified and prioritised in Section 5.4.2;

- Pilot training – this was the first training involving a small number of the drivers (26 drivers including control groups) which provided information to improve the major (large-scale) training. It involved one to one sessions with the drivers;
- Questionnaires – driving style questionnaires were used to collect data from the drivers before and after the training in order to assess the influence of the training on their driving style;
- Large-scale training – this was the main training that was carried out and it involved training the drivers in groups (94 drivers, including control groups, were involved);
- Post training – this was the period after the training when the performances of the drivers were monitored and feedback given to the drivers.

The training is described in detail in the following paragraphs.

### 6.5.1 Training Material

The training material was designed based on the theory of the SAFED training programme described in Section 4.2.3. The material included a list of the things that the drivers were asked to do in order to improve their fuel consumption efficiency. The list was based on the prioritisation of driving attributes obtained from the AHP analysis of the data obtained from the SAFED trainers. The list was printed on cards (Figure 6.4) which were handed to each of the trained drivers at the end of each training session.

DRIVER TRAINING INTERVENTIONS TO REDUCE FUEL CONSUMPTION

amey

**A List of Things to Do to Minimise Fuel Consumption**

1. Be vigilant when driving
2. Be calm and understanding to other drivers when driving
3. Have sufficient night sleep and necessary breaks during work
4. Regularly check tyre pressure and maintain it at recommended pressure values
5. Make sure you are comfortable and familiar with all the vehicle controls and car support technologies before driving-off
6. Do not use mobile phones or other personal accessories when driving
7. Accelerate uniformly and gently. Avoid high and fluctuating speeds unless dictated by the road signs
8. Use smooth and tapered braking
9. Used block gear change e.g. 1-3-5 or 2-4-6
10. Avoid use of clutch control to balance the car whilst stationary
11. Plan to stop but look to go when approaching hazards
12. Turn the engine off when it is not needed
13. Plan your route prior to leaving home or depot
14. Avoid overloading and adopt proper loading pattern
15. Make aerodynamic adjustments if available. Drive with windows closed especially at high speeds using air conditioning instead if needed

Thank You for Supporting Research Activities within Amey – One Amey

Figure 6.4: Training hand-outs

In order to assess the influence of the training on driving style the trained drivers completed a DSQ (Appendix D-2) before (within the month to the training) and after (within 1 month after the training) the large-scale training that was carried out in July 2012. The DSQ was also completed by the control drivers in the last month of the monitored period of the large scale training (i.e. March 2013) to determine whether the training had influenced driver behaviour. The DSQ was designed in such a way that higher scores (e.g., 5 and 4) meant less fuel efficient driving while low scores (e.g., 0 and 1) indicated better fuel efficient driving with regard to each of the attribute related question.

### 6.5.2 First (Pilot) Training

#### *6.5.2.1 Training Environment*

The pilot training was carried out at Strensham work depot on a one-to-one basis, that is, the driver and the trainer. The training was carried out prior to each driver's work shift. The overall training covered a period of 2 weeks in July 2010.

#### *6.5.2.2 Training Delivery*

The training was carried out by the author and it consisted of theoretical discussion regarding each of the 15 items in Figure 6.4. Each training session with the drivers lasted for up to 30 minutes. At the end of the training each driver was provided with a card-printout of the leaflet (Figure 6.4) for later reference. In the pilot training, neither pre-training nor post-training questionnaires were completed by the drivers.

### 6.5.3 Large-scale Training

#### *6.5.3.1 Modifications after Pilot*

The following modifications regarding the pre-training, participants, training environment, training delivery and post-training were carried out after assessing the pilot training sessions:

- The DSQ was used to collect information from the training drivers within 1 month prior to the training and within 1 month after the training in order to provide data to assess the immediate impact of the training on driver behaviour or attitude. Data from the control group was also collected;
- As stated in Section 6.3.2 the number of drivers participating in the training was increased to cover all the drivers from Strensham work depot who met the requirements of the participants described in Section 6.3;
- The training was carried out in groups of between 10 to 20 drivers at the same time with each session lasting for about 30 to 60 minutes as opposed to the one-to-one sessions during the pilot. Medium and heavy vehicle (multi-vehicle) drivers were trained separately from the light vehicle drivers. The training was carried out over a period of 2 weeks in 2012. The training was delivered by the author using the same training materials as in the pilot study. The drivers were trained in groups not only to reduce the time needed for the training but it also encouraged positive discussions among the trainees, and between the trainees and the trainer. The drivers were also encouraged to consult or report to the trainer and their supervisors after the training on any issue that related to the training or their performance (see report logs in Section 7.7.4);
- Post-training feedback sessions were incorporated in the training as outlined below.

#### *6.5.3.2 Post-Training Feedback*

The MPG of each driver were scrutinised by the author and, subsequently, the information obtained was used to update and discuss the performance of the drivers via monthly telephone conversations. Monthly performance summaries (in terms of average MPG for all the trained drivers by vehicle category) were posted on the notice board in the training depot to foster competition and discussions. The trained drivers were also at liberty and encouraged to arrange ad-hoc meetings with the trainer and their supervisors to discuss issues pertinent to the training, as summarised in Section 7.7.4.

## 6.6 Analysis

### 6.6.1 Data Capture Constraints and Uncertainties

#### *6.6.1.1 Driving Style Questionnaire (DSQ)*

Self-reporting is a simple and straightforward method of gathering data from participants, however, in most cases such data (like in this case) are classified as ordinal data and therefore there are a limited number of appropriate statistical methods for its analysis. Two major studies on the advantages and disadvantages of collection of data by self-reporting methods were carried out by Rabbitt and Abson (1990) and McDonald (2008). Their findings suggest that the collection of data by means of self-reporting is regarded as subjective in nature and can also be affected by individual characteristics, including memory efficiency. This meant that the collected data was used cautiously.

#### *6.6.1.2 Fuel Consumption and Distance Travelled*

As mentioned previously, the Merridale™ fuel management system (FMS) was used to collect data regarding fuel consumption and distance travelled for each vehicle and driver. The data so obtained depends on the records provided by the driver and as a result it could be prone to the following issues:

- Inaccurate records;
- Missing records;
- Issues with multi-vehicle drivers.

The data issues outlined above have been known to influence the quality of data related to MPG obtained from drivers registering odometer readings against fuel consumption (see Siero et al, 1989; af Wåhlberg, 2006; af Wåhlberg, 2007 and Turpin and Scott, 2010). The first key data capture issue was the presence of inaccurate records of vehicle odometer readings resulting in unrealistically high and low MPG values.

The second key data issue regarded missing records which occurred mainly due to drivers not entering the odometer readings and the drivers not being available at work due to several reasons including sickness leave and work termination (there was one case of work termination that affected the control group of the light vehicle category). Other missing records were due to some drivers failing to fuel the vehicle at the start of their shifts. However, where odometer readings were not provided, the data could be obtained from the vehicle use sheet (a daily record provided by each driver) that includes odometer records.

The third key data issues were related to the selected participants who were not only multi-vehicle drivers in terms of vehicle category (for heavy and medium vehicles) but they were also multi-vehicle drivers in terms of vehicle type (for all the vehicle categories). Multi-vehicle drivers in terms of vehicle category meant that the driver drove medium and heavy vehicles (this is usually the case with Amey drivers). Multi-vehicle drivers in terms of vehicle type meant that the driver drove different vehicles within a particular category. The use of unique driver and vehicle identification ensured that the fuel related data was mapped to specific vehicles. Nonetheless, the influence of varying vehicle weight, tyre type and vehicle age still meant that the MPG data varied within each vehicle category. Virtos (2010) identified these issues and modelled for their impact on MPG to generate a 'smoothened MPG'; however, the methodology has not been used in this research because the study duration was long enough for these variations to even out.

As a result, the following assumptions were made:

- Fuel has not been lost other than through the normal working routine, and that it has been used primarily for the normal working routine. However, it should be noted that fuel theft and significant undetected fuel leaks have been known to occur in vehicle fuel use and can have a significant impact on MPG (Virtos, 2010).

- The drivers filled the vehicle to the maximum capacity before the work shifts as instructed;
- The variability caused by fuel spanning two measuring periods (months) was insignificant and that, even if it were, the cases would even out over the longer term (e.g., a year);
- That there was no vehicle sharing between drivers before refuelling;
- The multi-vehicle drivers spent about the same time driving the heavy vehicle as the medium ones.

The data sets were analysed for poor quality data as described in Section 6.6.2.

### 6.6.2 Assessment of Bad Data

#### *6.6.2.1 Raw Data*

The raw data sets were prepared using Microsoft Excel into times series formats which were classified by training periods, vehicle category, training/control groups and driver. In order to determine erroneous or inconsistent data, the data were subjected to the following analysis of extreme observations (outliers).

#### *6.6.2.2 Data Exploration (Outliers)*

Mason et al (2003) note that the presence of outliers which occur through data entry errors or rare events in a data set ‘may obscure characteristics about the phenomena being studied that are present in the bulk of the other data values’, and also that ‘outliers may provide unique information about the phenomenon of interest that is not contained in the other observations’. Consequently, to address this, the following steps suggested by Manson et al (2003) were undertaken to deal with outliers:

1. The MPG data sets were plotted in Microsoft Excel for visual inspections;
2. The SPSS™ statistical software (IBM, 2010) was used to carry out the analysis of outliers at 95% confidence interval (CI) (i.e., at 0.05 significance level) as illustrated in Figure 6.5. The data sets for each sub-period (month) for the training and control

drivers for each vehicle category was assumed to be normally distributed; this was tested using the Shapiro-Wilk test instead of the Kolmogorov-Smirnov test since the datasets were less than 2000 (Steinskog et al, 2007). The range of the $p$ values for the tests and provided in Appendix D-4. It was generally concluded that the observations tended to a normal distribution;

3. MPG observations such as 67 shown in Figure 6.5 were considered significant outliers while observations such as 56 and 64 (Figure 6.5) were considered as moderate outliers. While moderate outliers were retained in the subsequent analysis and use of the data, significant outliers were excluded. Figure 6.6 shows an example of the data histograms.


Figure 6.5: Box plot of MPG observations showing significant (*) and moderate (o) outliers for Month2 of Period1 of the driver training for heavy vehicle.

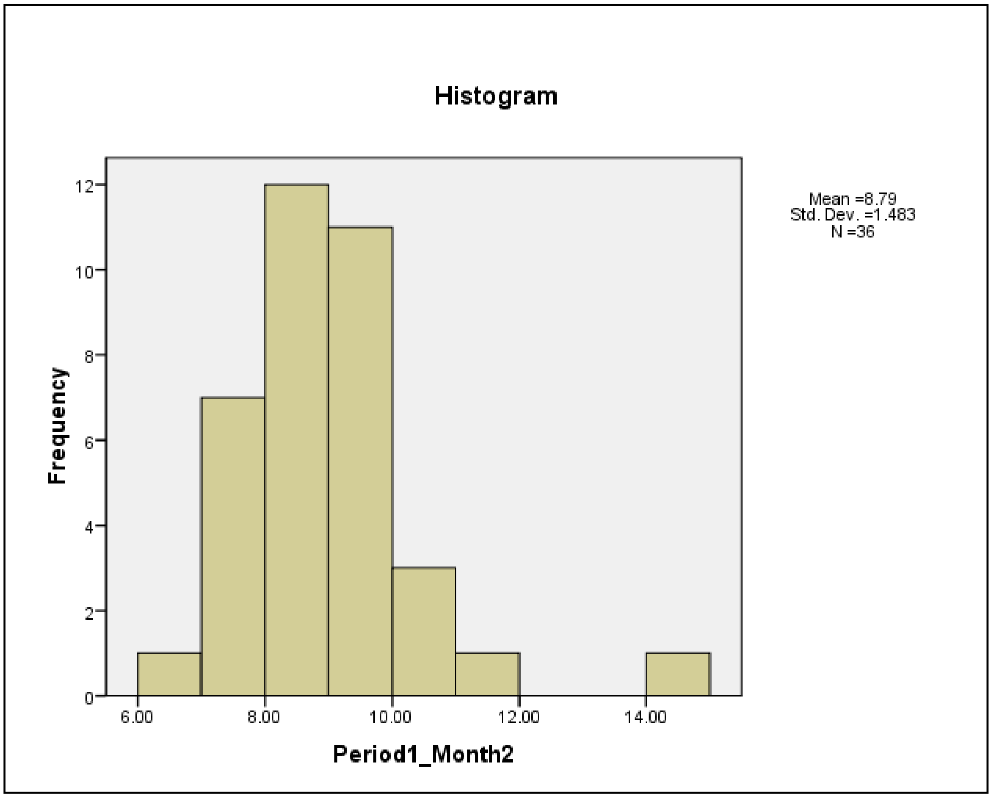



Figure 6.6: Histogram for the MPG observation for the Month2 of Period1 of the driver training.

The MPG data is provided in Appendix D-5.

### 6.6.3 Change in MPG

The percentage change in MPG for each vehicle category was calculated by comparing the corresponding average monthly MPG after the training to that before the training, as expressed by Equation 6.1.

Equation 6.1

$$\Delta MPG_{efffective} = \left(\frac{Avergae\ MPG\ after\ training - Average\ MPG\ before\ training}{Average\ MPG\ before\ training}\right)_{Training} - \left(\frac{Avergae\ MPG\ after\ training - Average\ MPG\ before\ training}{Average\ MPG\ before\ training}\right)_{Control}$$

Where $\Delta MPG_{effective}$ is the effective change in MPG for the training group and it takes into account inherent influences in the results that are not known to the study by applying the results for the control group. In this case a positive change in the MPG for the control group would mean a reduction in the corresponding change in the MPG for the treated group while a reduction in the MPG for the control group would mean an increase in the MPG for the treated group.

### 6.6.4 Trend Lines and Regression Analysis

It has been suggested that the retention of the benefits resulting from training is analogous to retention in human memory. Rubin and Wenzel (1996) analysed human memory retention in detail by comparing the application of different retention functions for short-term (seconds) and long-term (years) scenarios. They suggest that the long-term retention of information is most accurately modelled as a logarithmic function of time, although they also suggest that other forms of mathematical models including power, hyperbolic, and exponential functions could also be adopted. Turpin and Scott (2010) unsuccessfully tried to model the retention of the benefit of driver training for fuel economy (improved MPG) after suggesting a multiple linear regression model for their data sets.

In this study, however, two generalised model forms were initially assumed to predict the performance of the drivers in terms of the change in MPG after driver training in fuel economy. These were the polynomial regression model (Equation 6.2) and the logarithmic model specifications (Equation 6.3).

Equation 6.2 $$Y(x) = \beta_o + \beta_1 x + \beta_2 x^2 \ldots + \beta_n x^n$$

Equation 6.3 $$Y(x) = \beta_o + \beta_1 \ln x$$

| | | |
|---|---|---|
| Where: | $Y$ | is the response (dependent) variable; |
| | $x$ | is the independent variable; |
| | $\beta_o$ to $\beta_n$ | are the model constants. |

Microsoft Excel was used to carry out the trend and regression analysis. The analysis was conducted on both the pilot and the large scale training data sets. The polynomial model was initially modelled to an order of 2, however, for the large-scale training the model constants $\beta_2$ were found to be statistically insignificant (as described in Section 7.6). Subsequently, a linear model of the form shown by Equation 6.4 was used and the results compared with the results based on the logarithmic model.

Equation 6.4 $$Y(x) = \beta_o + \beta_1 x$$

The parameters that were observed and monitored during the trend and regression analysis are summarised in Table 6-7.

Table 6-7: Summary of the key parameters of the regression analysis using the Microsoft Excel™

| Parameter | Meaning |
|---|---|
| *R* squared, $R^2$ | Regression coefficient, *R* squared |
| Standard error, *S* | Standard error of the estimate |
| Significance, *p* | Significance of the estimated parameter |
| Residual (error) plots | An adequate model fit is expected to produce random residuals, thus a plot of the residual of a model fit is not expected to generate any useful pattern or shape (Walpole et al, 2012) otherwise the data, the model specification or the modelling could be deficient. |

### 6.6.5 Statistical Tests

In order to test the significance of the training in terms of the difference between the pre-training and post-training MPG, the Student T-Statistic (Walpole et al, 2012) was used. In order to assess the impact of the training on driver behaviour the Wilcoxon Signed Ranks and the Mann-Whitney (sometimes also called Wilcoxon Rank Sums) tests for non-parametric data sets (Siegel, 1957; Norman, 1993; Bellera et al, 2010) were used.

The statistical methods mentioned above were used because they were most appropriate, given the objective of the experiments and the types of data generated. A 2-tailed test was used in order to provide consistency for comparison with similar studies which have been reported by Turpin and Scott, (2010), addressing the training of drivers to improve their MPG. It is important to note that the application of 2-tailed tests for these types of training trials would be a conservative approach as the drivers would be expected to improve their performance. Therefore, 1-tailed tests would have been more appropriate. Nonetheless, the results that have been reported in this study (*p* values) can be divided by 2 to get the approximate statistics (*p* values) for the 1-tailed tests. As seen in Chapter 7, this would still have a negligible impact on the absolute significance of the results. The applications of the tests are described in the following paragraphs.

#### *6.6.5.1 Student t-Test for MPG Data*

The two test hypotheses were as follows: the null hypothesis, $H_o$, tested that there was no difference between the means of the data sets, and $H_o$ was rejected at a significance level ($\alpha$) when the significance value $(p) \leq (\alpha=0.05)$, that is 95% confidence interval (CI), and the alternative hypothesis, $H_a$, was accepted, that there were statistically significant differences between the means of the data sets.

The following forms of t-Statistic tests were applied, as shown in Figure 6.7, to investigate the influence of the large scale training on the MPG data sets:

1. To test the change in MPG between the training group and the control group – in this case the unpaired (independent) t-Statistic was used to investigate the differences at each corresponding pre-training and post-training month or sub-period, and;
2. Using the assumption that there was no control group, the paired t-Statistic was used to investigate the changes within only the training group at each corresponding pre-training and post-training month or sub-period.

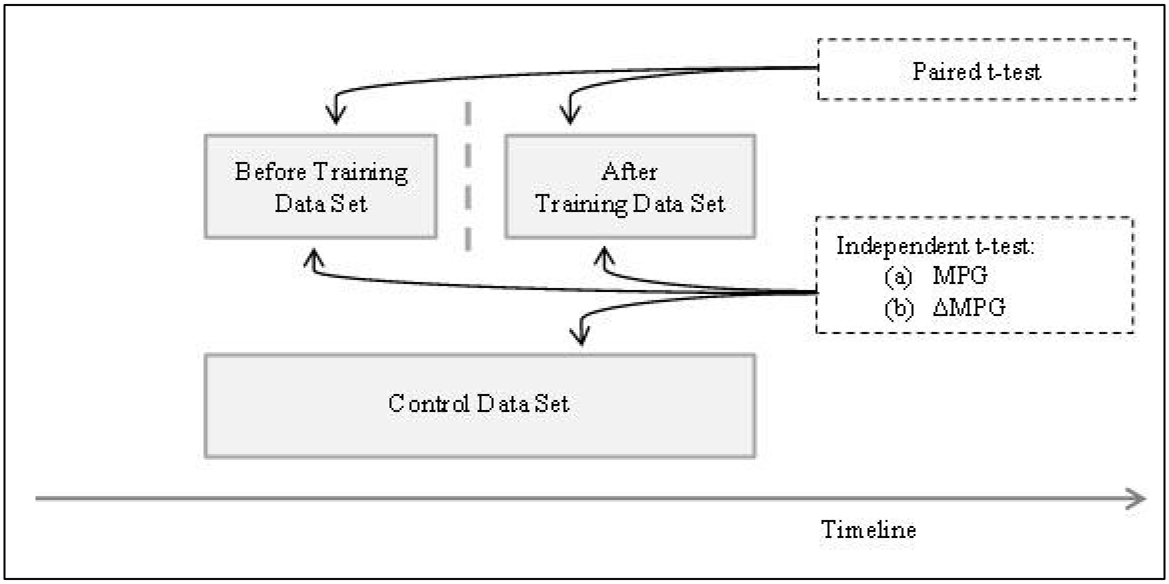



Figure 6.7: Parametric t-Tests for the driving style questionnaire data sets for heavy/medium and light vehicle categories

The theory of the t-Statistic (see Walpole et al, 2012) as an inferential statistical method is based on the following main assumptions when assessing whether the means of two data sets are different from one another:

- The dependent variables are continuous (non-ordinal);
- The data sets are from approximately a normally distributed population.

The formulas for describing the paired and independent t-Tests based on Larson and Farber (2012) are provided in Appendix D-7.

The SPSS™ statistical software (IBM, 2010) was used to carry out the analysis using the key parameters given in Table 6-8.

Table 6-8: Summary of the key parameters of the t-statistic analysis using the SPSS™

| Parameter | Applicable Test | Meaning |
|---|---|---|
| Number, $N$ | Both independent and paired | Number of observations |
| Mean, $\bar{y}$ | Both independent and paired | Mean of the observations |

| Parameter | Applicable Test | Meaning |
|---|---|---|
| Standard deviation, σ | Both independent and paired | Standard deviation of the observations |
| Critical region, *F* | Independent | A measure of the critical region of the F-distribution in the Levene's test for equality of variances (Walpole et al, 2012) |
| Significance, *p* | Both independent and paired | Significance of the estimate that the means are the same |

### *6.6.5.2 Non-Parametric Tests (Questionnaires Data Sets)*

In order to assess the impact of the training on driver behaviour the DSQ data (provided in Appendix D-6) was analysed to compare the before and after effects. The data collected using the DSQ generated ordinal non-parametric data sets which meant that such analysis could not be directly carried out using the traditional t-Statistic tests described in Section 6.6.5.1.

The two test hypotheses were as follows: the null hypothesis, *Ho*, tested that there was no difference between the median rank of the data sets, and *Ho* was rejected at a significance level ($\alpha$) when the significance value *(p)* ≤ *(α=0.05*, that is 95% confidence interval (CI)) and the alternative hypothesis, *Ha*, was accepted, that there were statistically significant differences between the means of the data sets.

The Wilcoxon Signed Ranks and the Mann-Whitney (sometimes also called Wilcoxon Rank Sums) tests for non-parametric data sets (Siegel, 1957; Norman, 1993; Bellera et al, 2010) were used to compare the before/after and training/control data sets for the from the DSQ in order to determine the influence of the training on the indicators of driver behaviour related to vehicle fuel consumption. The structure of the analysis carried out on the DSQ data sets is summarized in Figure 6.8.

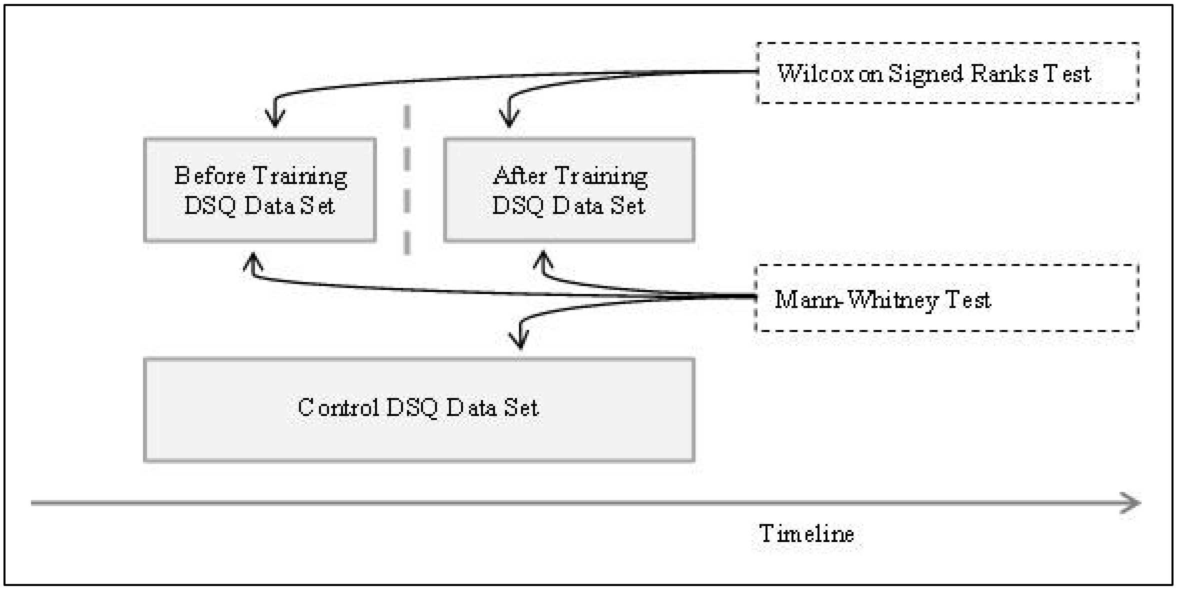



Figure 6.8: Non-parametric tests for the driving style questionnaire data sets for heavy/medium and light vehicle categories

The Wilcoxon Signed Ranks test assumes that the data sets are non-parametric and are from related groups. This test was carried out assuming that there was no control group. Unlike the traditional t-Tests described in Section 6.6.5.1, the Wilcoxon Signed Ranks test relies only on the sign of the comparison, that is, positive (+) or negative (-), it is easy to carry out moreover for data fitting for any distribution (Bellera et al, 2010). The Wilcoxon Signed-Ranks test for paired comparisons, described in detail in (Norman, 1993; Bellera et al, 2010; Larson and Farber, 2012) is summarised in Appendix D-7 using formulae from Larson and Farber (2012). In summary, the ranks of the absolute differences between the data and the hypothesised median were calculated and the ranks for the negative and the positive differences were summed separately to generate $W-$ and $W+$ respectively. The minimum of these was taken as the test statistic, $W$. The SPSS™ statistical software (IBM, 2010) was used to conduct the analysis and the results are provided in Section 7.6.3.

The Mann-Whitney test assumes that the data sets are from unrelated (independent) groups, have equal variances and follow approximately normal distributions. The Mann-Whitney test, described in detail in (Norman, 1993; Bellera et al, 2010; Larson and Farber, 2012) is summarised in Appendix D-7 using formulae from Larson and Farber (2012). In summary, the two data sets were combined and ranked together before summing the ranks of each data set separately. The rank sums were then compared and related to the expected statistic $W$ given by formulae in Appendix D-7. The SPSS™ statistical software (IBM, 2010) was used to conduct the analysis and the results are provided in Section 7.6.3.

## 6.7 Summary

The methodology concerning the training of divers for fuel economy conducted with drivers of heavy medium and light vehicle categories working for Amey has been described in this Chapter. The methodology covered the selection of the participants, vehicle categorisation, training aspects including design and training materials, data capture, and the analysis of the raw data to exclude poor quality data.

The later part of the Chapter described the statistical methods and tools that were used to analyse the data including regression and test statistics methods. The results of the analysis are provided in the next Chapter.

# CHAPTER 7 TRAINING ANALYSIS RESULTS

## 7.1 Introduction

The results of the analysis carried out on the data regarding driver training for fuel economy of drivers working for Amey in the management and the operation of the motorway and trunk road network in the West Midlands in the United Kingdom are provided in this Chapter.

The results include the analysis of annual vehicle-km, average miles per gallon (MPG), change in MPG after training, trend and regression analysis, t-Statistic tests and the associated tabular and graphical representations. The methodology used was described in Chapter 6.

## 7.2 Vehicle-km

### 7.2.1 Annual Vehicle-km

#### *7.2.1.1 Heavy Vehicle*

The distributions of the drivers' annual vehicle-km covering the study duration for the heavy vehicle category are shown in Figure 7.1 for the training group and Figure 7.2 for the control group.

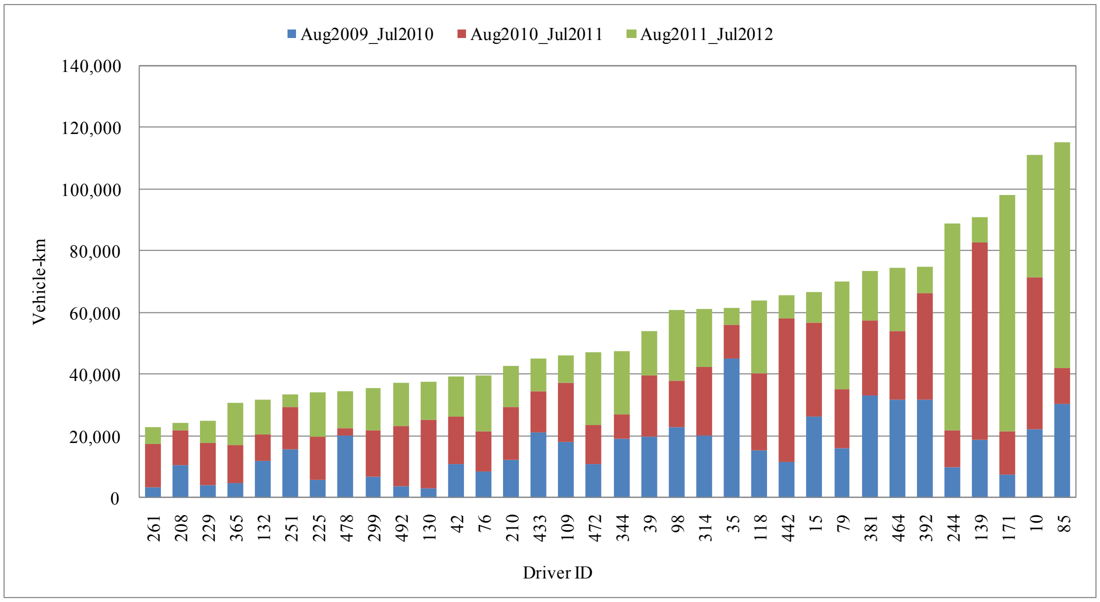



Figure 7.1: Annual vehicle-km for the training group for the heavy vehicle

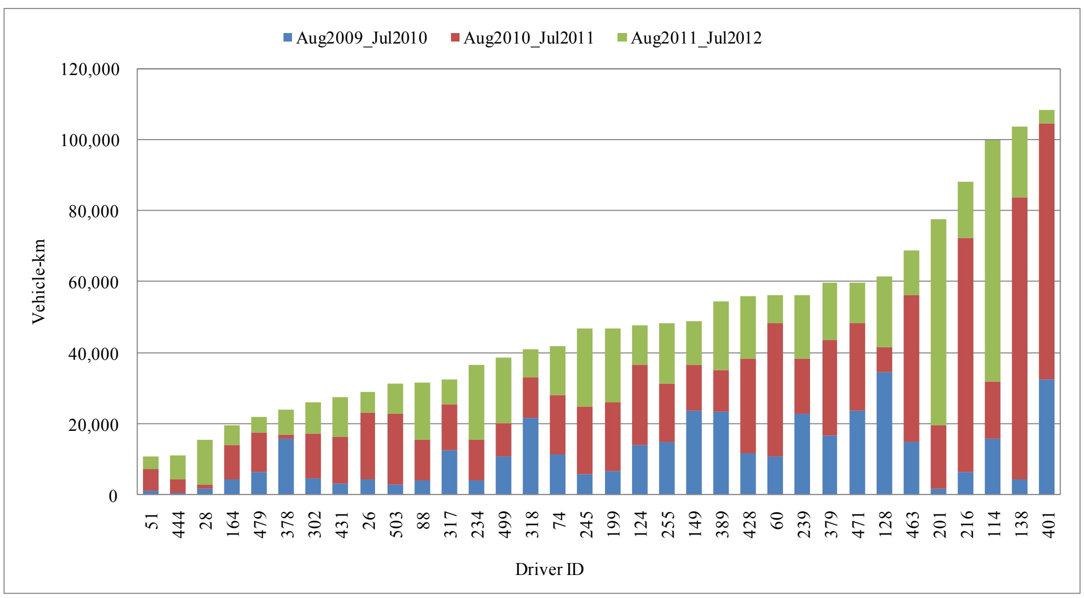



Figure 7.2: Annual vehicle-km for the control group for the heavy vehicle

The average annual heavy vehicle-km over the training periods for the training group was 18,514 for the training group and 16,001 for the control group, a difference of about 16%. The results show that both the training and the control drivers travel similar annual distances, thus suggesting a good control group in this respect. Statistically, independent t-Tests were conducted on the data sets on an annual basis. The results (shown in Appendix E-1) revealed that there were no significant differences (at 95% confidence interval) between the training and the control groups' annual heavy vehicle-km.

### *7.2.1.2 Medium Vehicle*

The distributions of the drivers' annual vehicle-km covering the study duration for the medium vehicle category are shown in Figure 7.3 for the training group and Figure 7.4 for the corresponding control group.

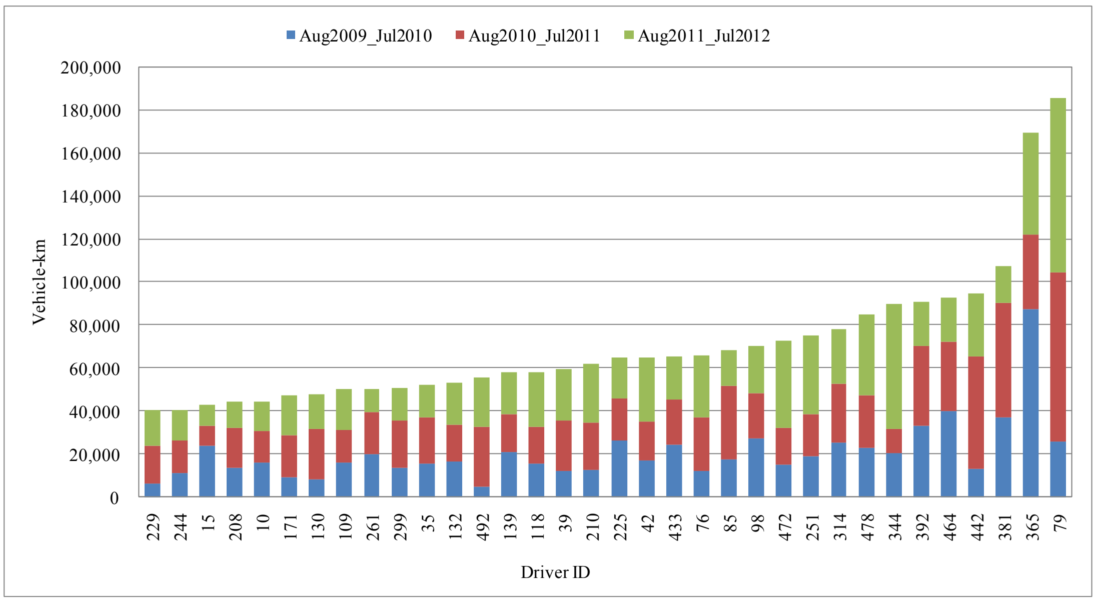



Figure 7.3: Annual vehicle-km for the training group for the medium vehicle

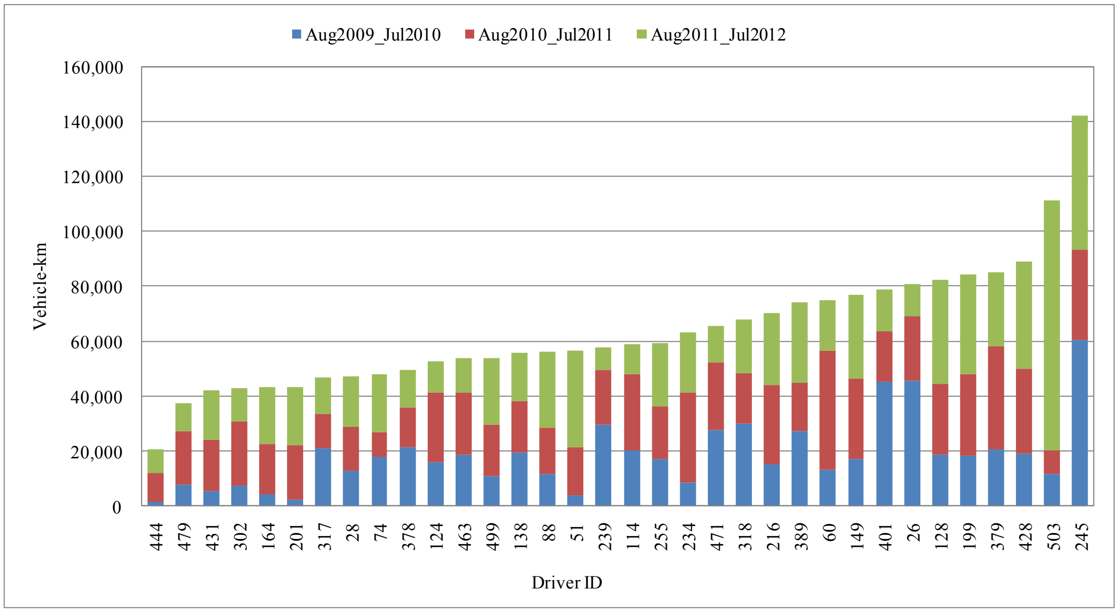



Figure 7.4: Annual vehicle-km for the control group for the medium vehicle

The annual medium vehicle-km over the training periods was 23,563 for the training group and 21,359 for the control group, a difference of about 10%. The results show that both the training and the control drivers travel similar annual distances, therefore suggesting a good control group in this respect. Statistically, independent t-Tests were conducted on the data sets on an annual basis. The results (shown in Appendix E-1) revealed that there were no significant differences (at 95% confidence interval) between the training and the control groups' annual medium vehicle-km.

### *7.2.1.3 Light Vehicle*

The distributions of the drivers' annual vehicle-km covering the study duration for the light vehicle category are shown in Figure 7.5 for both the training and control groups.

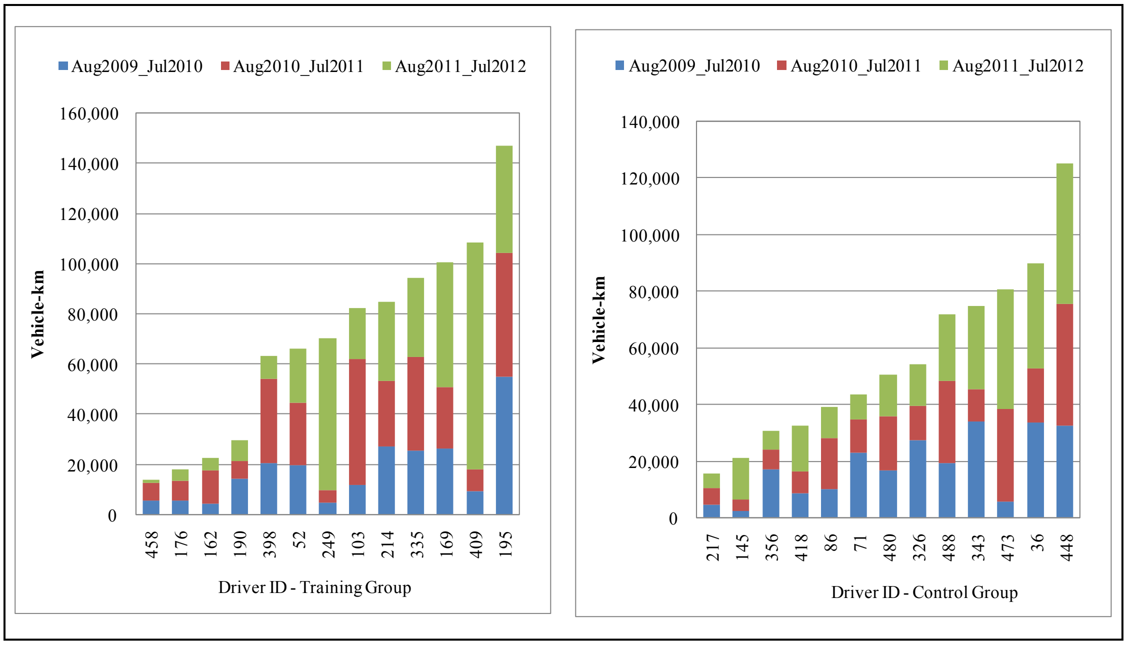



Figure 7.5: Annual vehicle-km for the training and control group for the light vehicle

The average light vehicle-km over the training periods for the training group was 23,089 for the training group and 18,707 for the control group, a difference of about 23%. The results show that the training drivers travelled a greater distance than the control group over the training duration, possibly because of the location of the training depot relative to the work zones or due to the differences in the types of works carried out, for example route inspection which involves continuous driving versus roadside maintenance involves less driving. Statistically, independent t-Tests were conducted on the data sets on an annual basis. The results (shown in Appendix E-1) revealed that there were no significant differences (at 95% confidence interval) between the training and the control groups' annual light vehicle-km.

### 7.2.2 Heavy vs Medium Vehicle-km

The proportion of annual vehicle-km between heavy and medium vehicles for the multi-vehicle drivers (heavy/medium) over the training periods is provided in Appendix E-2. The vehicle-km by the multi-vehicle (heavy/medium) drivers over the training periods was generally well distributed between the heavy and the medium vehicles for both the training and the control group.

## 7.3 Average MPG

### 7.3.1 Pilot Training

The analysis of the pilot training covers only heavy and medium vehicle categories because there was very limited number of light vehicle drivers who initially volunteered to participate in the study; only 4 drivers of the light vehicles had volunteered for the pilot training.

#### *7.3.1.1 Heavy Vehicle*

The monthly (sub-period) average MPG before and after the pilot training for the training and control groups are shown in Figure 7.6 and Figure 7.7 respectively for the heavy vehicle category.

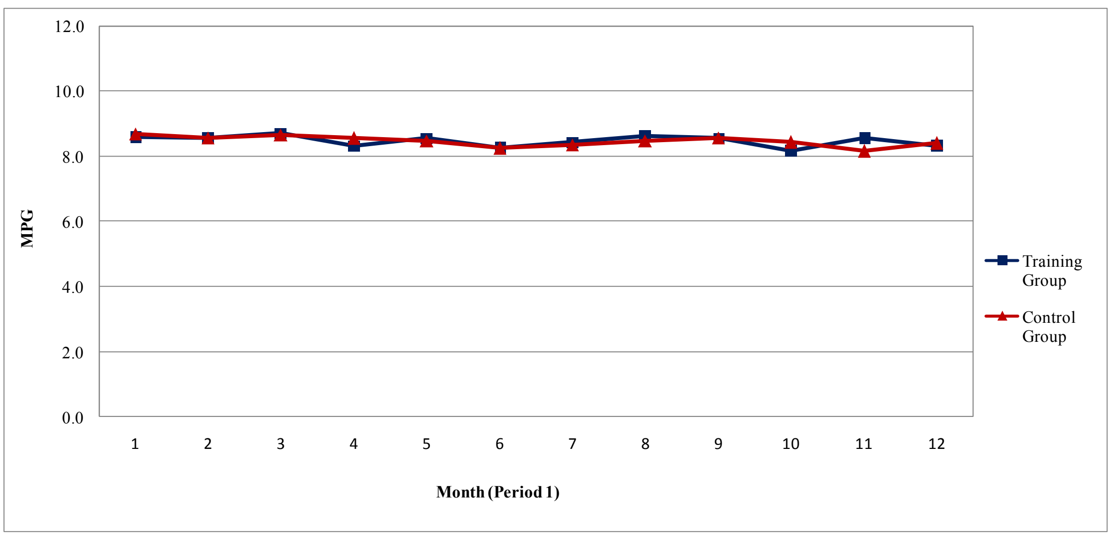



Figure 7.6: Average MPG for the 12-month period before the pilot training (period1) for the heavy vehicle category

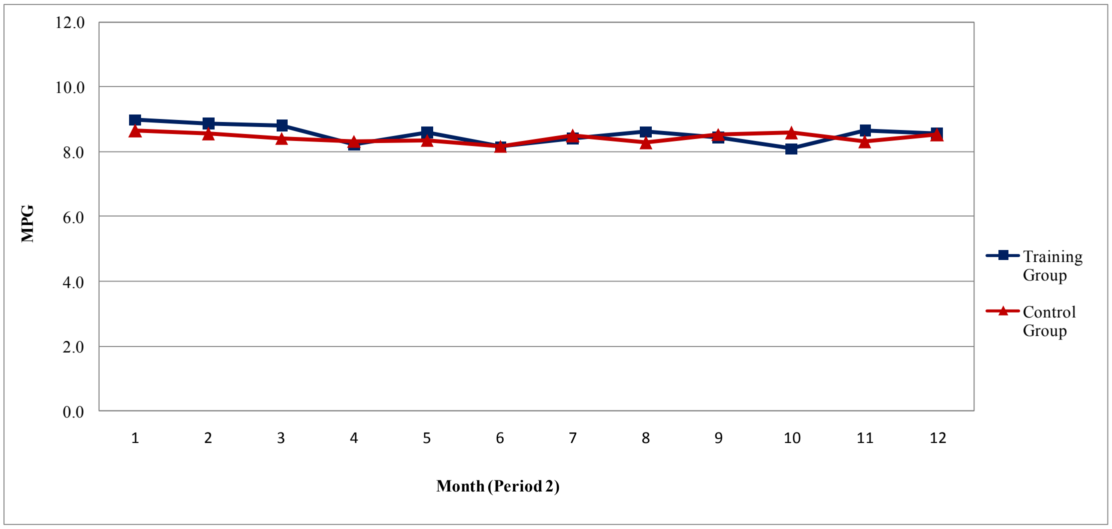



Figure 7.7: Average MPG for the 12-month period after the pilot training (period2) for the heavy vehicle category

Figure 7.6 shows that during the 12-month period before the pilot training both the training and the control drivers had similar average MPG, which suggested a reliable control group in this regards. After the training, potential improvements in the average MPG were observed in the training group as shown in Figure 7.7 and analysed in detail in the subsequent sections. Similar observations were also made for the medium vehicle category during the pilot training as shown in Figure 7.8 and Figure 7.9.

#### *7.3.1.2 Medium Vehicle*

The monthly (sub-period) average MPG before and after the pilot training for the training and control groups are shown in Figure 7.8 and Figure 7.9 respectively for the medium vehicle category.

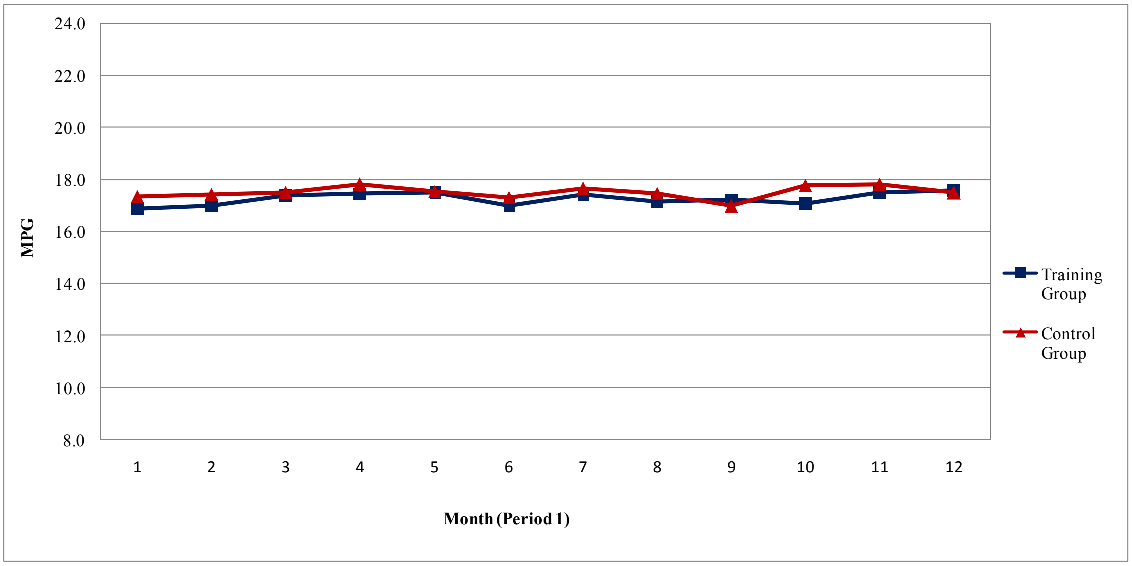



Figure 7.8: Average MPG for 12-month period before the pilot training (period1) for the medium vehicle category

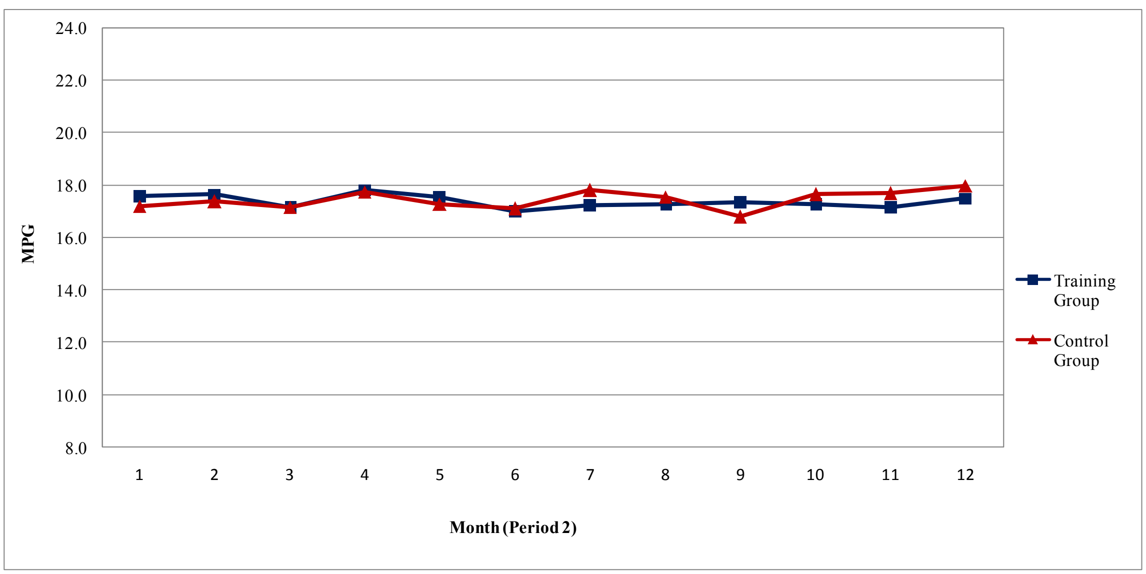



Figure 7.9: Average MPG for 12-month period after the pilot training (period2) for the medium vehicle category

## 7.3.2 Large-scale Training

### *7.3.2.1 Heavy Vehicle*

The monthly (sub-period) drivers' average MPG before and after the large-scale training for the training and control groups are shown in Figure 7.10 and Figure 7.11, respectively, for the heavy vehicle category.

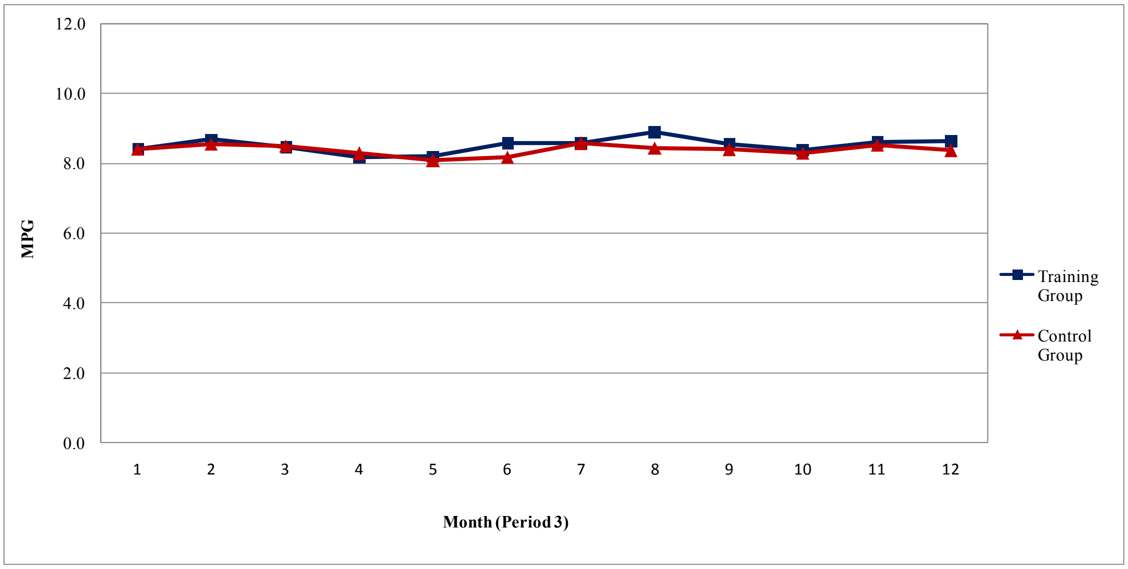



Figure 7.10: Average MPG for 12-month period before the large-scale training (period3) for the heavy vehicle category

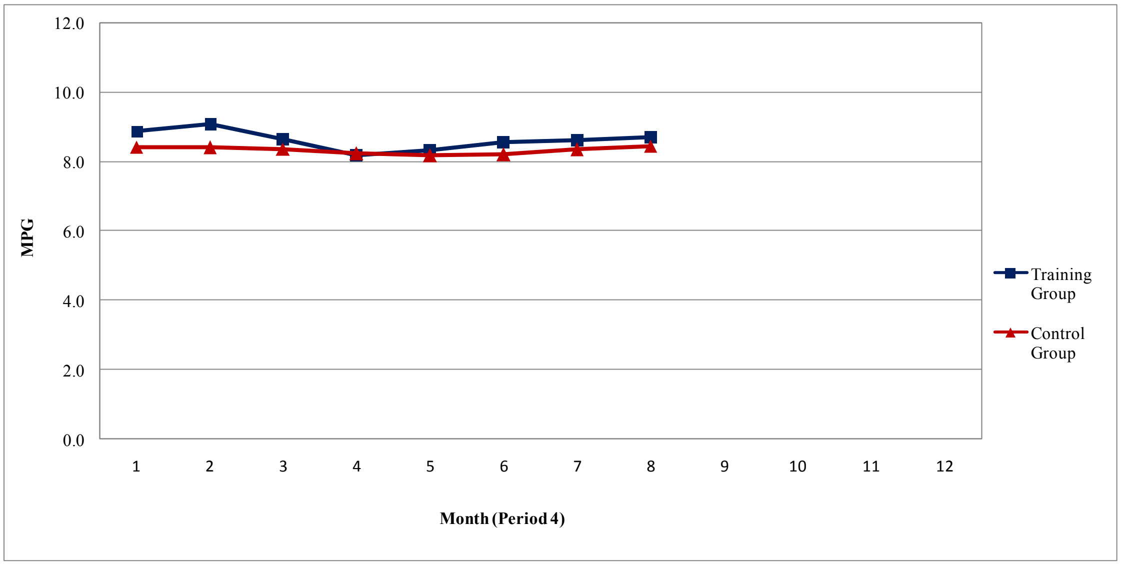



Figure 7.11: Average MPG for 8-month period after the large-scale (period4) for the heavy vehicle category

Figure 7.10 shows that during the 12-month period before the large-scale training both the training and the control drivers had similar average MPG which suggested the control group was reliable in this respect. After the training, potential improvements in average MPG were observed in the training group as shown in Figure 7.11 and analysed in detail in the subsequent sections.

### *7.3.2.2 Medium Vehicle*

The monthly (sub-period) drivers' average MPG before and after the large-scale training for the training and control groups, are shown in Figure 7.12 and Figure 7.13 respectively for the medium vehicle category.

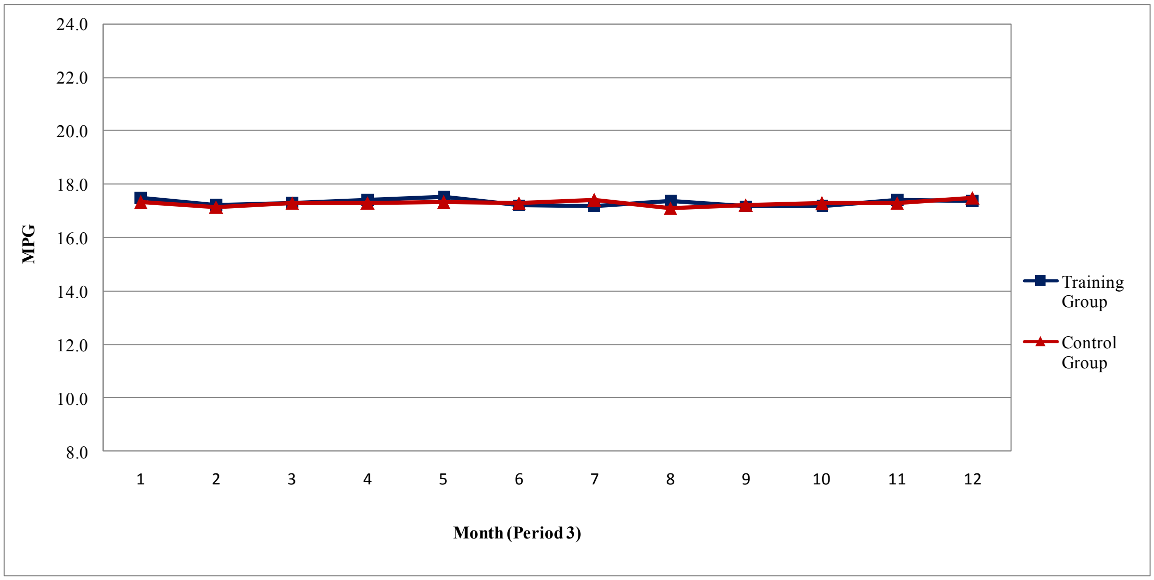



Figure 7.12: Average MPG for 12-month period before the large-scale training (period3) for the medium vehicle category

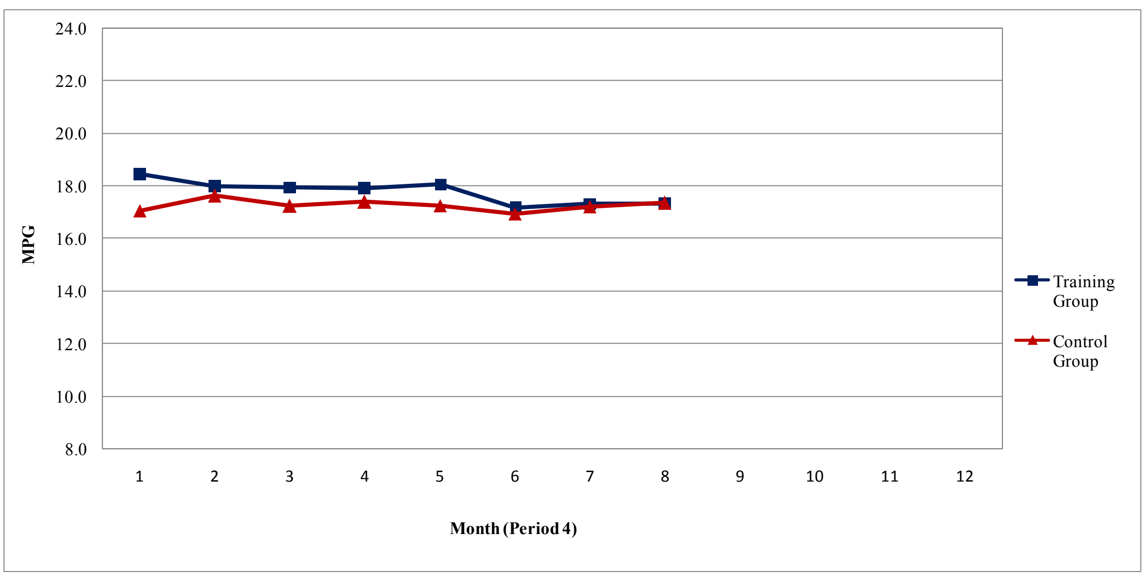



Figure 7.13: Average MPG for 8-month period after the large-scale training (period4) for the medium vehicle category

Figure 7.12 shows that during the 12-month period before the large-scale training both the training and the control heavy vehicle drivers had similar average MPG which suggested the control group continued to be reliable. After the training, potential improvements in average

MPG were observed in the training group, as shown in Figure 7.13 and analysed in detail in the subsequent sections.

#### *7.3.2.3 Light Vehicle*

The monthly (sub-period) drivers' average MPG before and after the large-scale training for the training and control groups are shown in Figure 7.14 and Figure 7.15, respectively, for the light vehicle category.

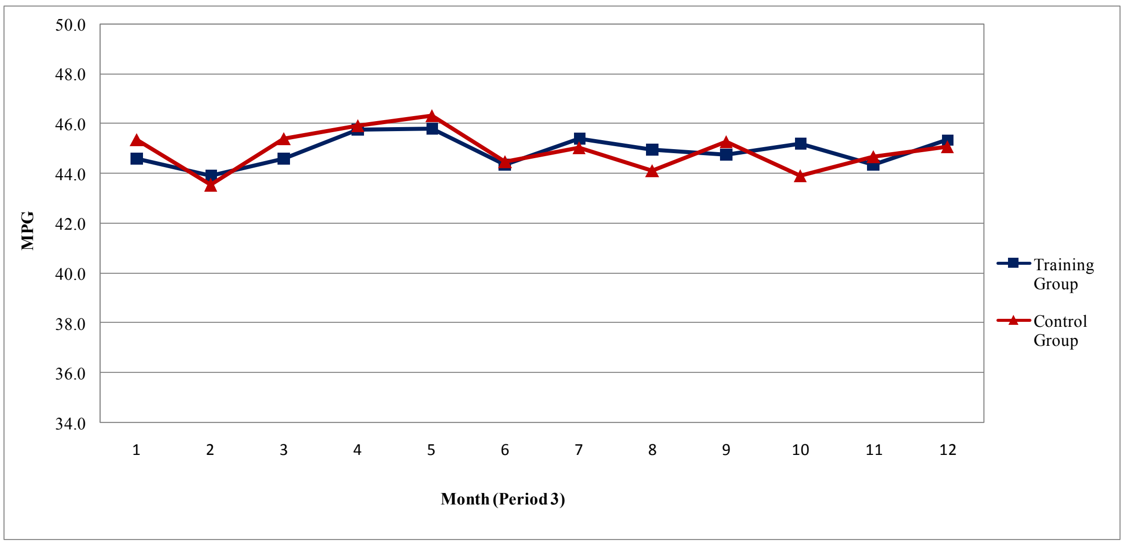



Figure 7.14: Average MPG for 12-month period before the large-scale training (period3) for the light vehicle category


Figure 7.15: Average MPG for 8-month period after the large-scale training (period4) for the light vehicle category

For the light vehicle category, the average MPG after the large-scale training is also similar for the training for both the training and the control drivers, as shown in Figure 7.14 for the 12-month period before the training, again suggesting a reliable control group. After the training, potential improvements in average MPG were observed in the training group as shown in Figure 7.15 and also analysed in the subsequent sections.

## 7.4 Change in MPG

The change in the MPG has been calculated using Equation 6.1 as, described in Section 6.6.3. The results are provided below.

### 7.4.1 Pilot Training

#### *7.4.1.1 Heavy Vehicle*

The effective change in MPG, calculated using Equation 6.1, for the heavy vehicle category after the pilot training is shown in Figure 7.16.

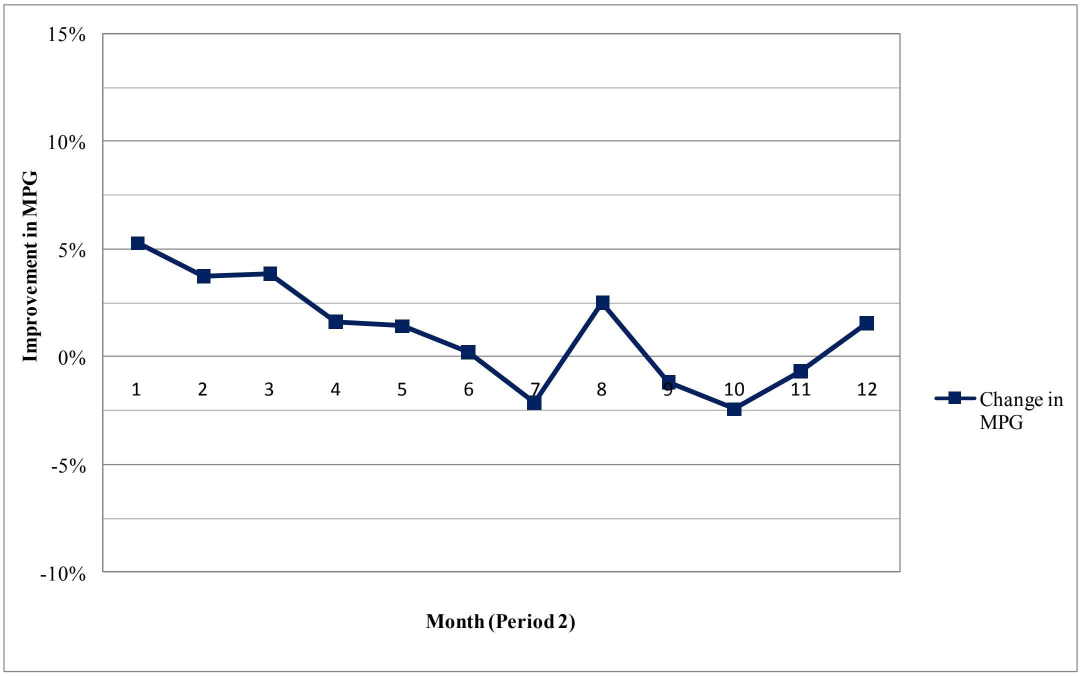



Figure 7.16: Change in MPG after the pilot training for the heavy vehicle category after the pilot training

It is shown in Figure 7.16 that there was an improvement (positive) in the average MPG performance of about 5% in the first month after the pilot training after which it gradually diminished in the sixth month after the training. The performance in MPG then fluctuated between positive and negative values onwards.

#### *7.4.1.2 Medium Vehicle*

The effective change in MPG for the medium vehicle category after the pilot training is shown in Figure 7.17.

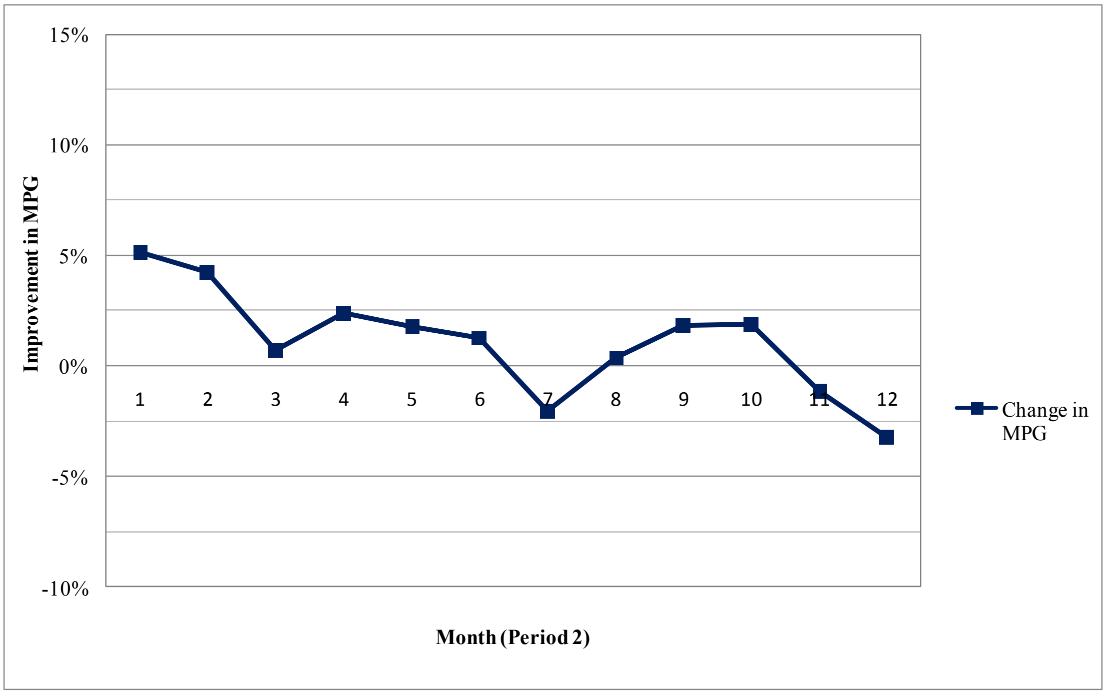



Figure 7.17: Change in MPG after the pilot training for the medium vehicle category after the pilot training

Figure 7.17 shows that there was an improvement in the average MPG performance of the medium vehicle drivers of about 5% in the first month after the pilot training, after which the improvement gradually diminished over a 5-month period. The performance in MPG then fluctuated between positive and negative values.

### 7.4.2 Large-scale Training

#### *7.4.2.1 Heavy Vehicle*

The effective change in MPG for the heavy vehicle category after the large-scale training is shown in Figure 7.18.

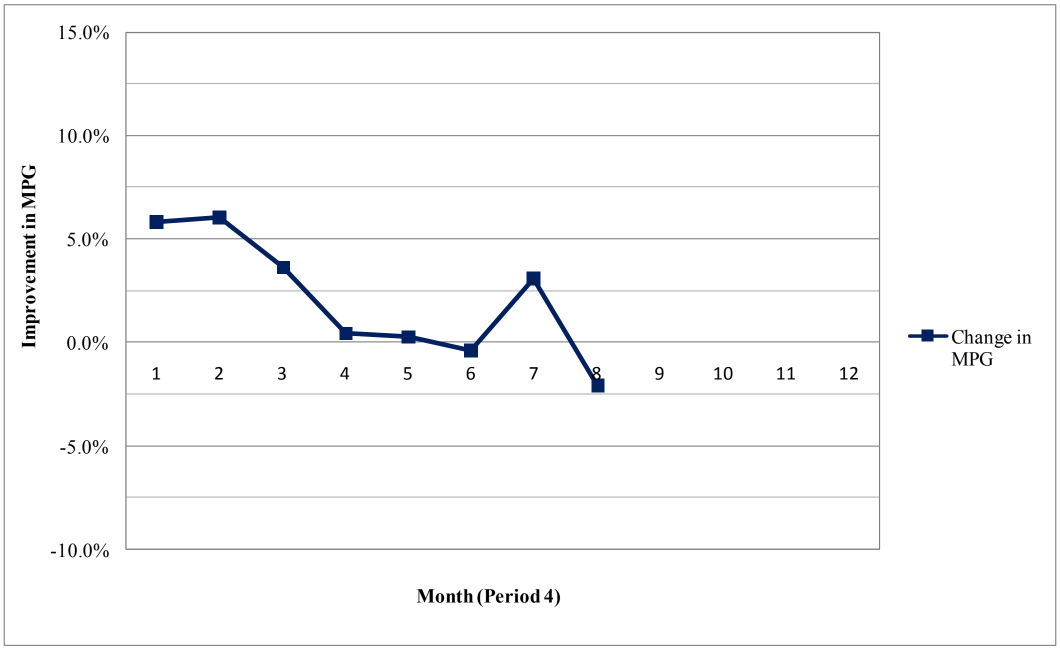



Figure 7.18: Change in MPG after the large-scale training for the heavy vehicle category

It is shown in Figure 7.18 that there was an improvement in the average MPG performance of about 6% in the first two months after the large-scale training, after which the improvement gradually diminished between months 5 and 6. After this, the MPG performance fluctuated between positive and negative values.

### *7.4.2.2 Medium Vehicle*

The effective change in MPG for the medium vehicle category after the large-scale training is shown in Figure 7.19.

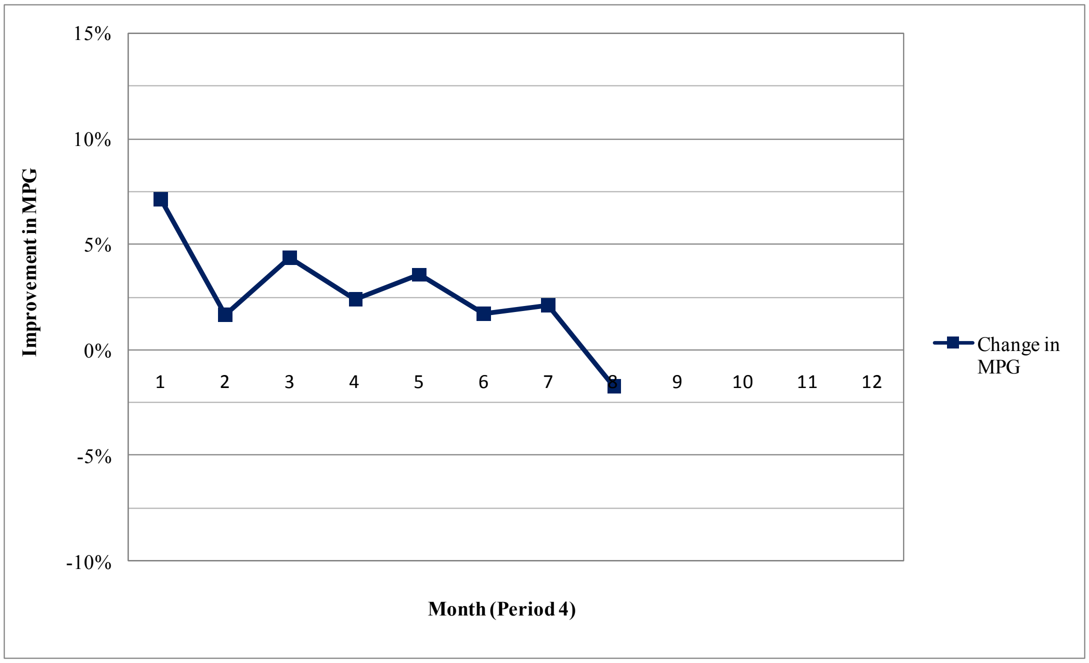



Figure 7.19: Change in MPG after the large-scale training for the medium vehicle category

It is shown in Figure 7.19 that there was an improvement in the average MPG performance of about 7% in the month after the large-scale training, after which the improvement gradually diminished between months 7 and 8. After this, the MPG performance would be expected to fluctuate between positive and negative values.

### *7.4.2.3 Light Vehicle*

The effective change in MPG for the light vehicle category after the large-scale training is shown in Figure 7.20.

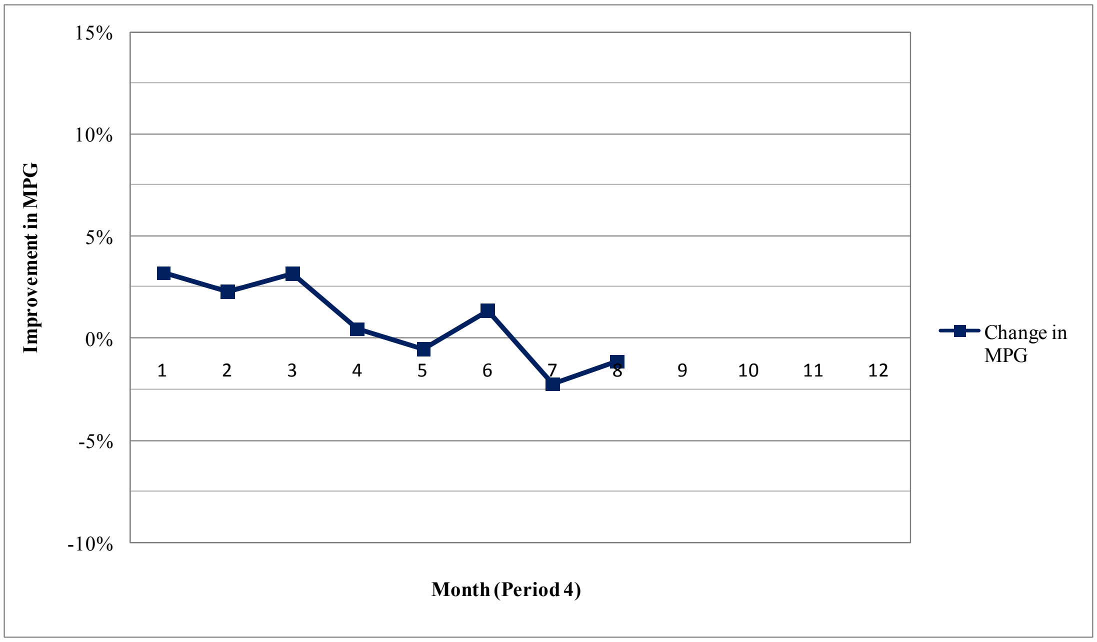



Figure 7.20: Change in MPG after the large-scale training for the light vehicle category

Figure 7.20 shows that there was an improvement in the average MPG performance of the medium vehicle drivers of about 3% over the 3 months after the large-scale training, after which it gradually diminished between the fourth and fifth month after the training. The performance in MPG then fluctuated between positive and negative values.

The discussion concerning the magnitude of the initial effect of training and the decay time for different vehicle types is provided in Section 8.6.1.

## 7.5 T-Statistic Tests

In the following paragraphs, the significance of the training is tested to determine whether the training could be extended to the wider population of drivers involved in similar work as in road network maintenance and operations. The t-Statistics (Walpole et al, 2012; Larson and Farber, 2012) was applied to the large-scale training to test the significance in differences in the MPG resulting from the training (Trained-Month$X_i$ before and after the training compared to the corresponding Control-Month$X_i$ before and after the training). Since the design included a control group the differences were tested using the unpaired (independent) t-Statistic test. However, a separate analysis was also conducted, assuming that the control group were absent; using a paired t-Statistic (see Section 7.5.2) applied to observations at interesting times for the trained group only (i.e., Month$X_i$ before the training compared to the corresponding Month$X_i$ after the training) (Hopkins, 2000).

The tests are as illustrated in Figure 6.7 in Section 6.6.5. The results from the unpaired (independent) t-Statistic test for heavy, medium and light vehicle categories are presented in Section 7.5.1 and the results of the paired t-Tests are presented in Section 7.5.2.

### 7.5.1 Unpaired (Independent) t-Test

#### *7.5.1.1 Heavy Vehicle*

The results from the independent t-Tests for the large vehicle category are summarised in Table 7-1 for the period before and after the training. At the selected significance level of 0.05 (95% confidence interval (CI)) it was observed that there were no significant differences in the MPG for the two groups before and after the training. However, as supported by the plots of the change in MPG after the training, the *p* values for the 3-month period immediately after the training were lower compared to the other *p* values, but not sufficiently statistically significant to be applied to the wider population of such drivers.

#### *7.5.1.2 Medium Vehicle*

Similarly, the results from the independent t-Tests for the medium vehicle category summarised in Table 7-2, for the period before and after the training, did not show statistically significant differences in the MPG for the two groups. The *p* values for the 5-month period immediately after the training were low compared to the rest of the *p* values (except for the second month after the training), but again, not sufficiently statistically significant to support the influence of the training that could be applied to a wider population.

#### *7.5.1.3 Light Vehicle*

The results from the independent t-Tests for the light vehicle category are summarised in Table 7-3 for the period before and after the training. At the selected significance level of 0.05 (95% confidence interval (CI)) no significant differences in the MPG for the two groups were observed.

#### *7.5.1.4 Change in MPG*

Further investigations were also conducted on the percentage change in the MPG values for the drivers, using the independent t-Test to compare the training results with the control results. The results, shown in Table 7-4, show that the observed changes in MPG were not sufficiently statistically significant at 95% CI (except for the light vehicle in the first month after the training) to be applied to the wider population of such drivers.

Table 7-1: Independent t-Statistic tests involving the training and the control groups for heavy vehicle category MPG before and after the large-scale training

| *Before (Period 3)* | MPG Before Month 1 | | MPG Before Month 2 | | MPG Before Month 3 | | MPG Before Month 4 | | MPG Before Month 5 | | MPG Before Month 6 | | MPG Before Month 7 | | MPG Before Month 8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Training | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control |
| Number | 24 | 23 | 26 | 30 | 26 | 32 | 30 | 29 | 33 | 30 | 32 | 30 | 30 | 32 | 27 | 32 |
| Mean | 8.40 | 8.40 | 8.71 | 8.55 | 8.46 | 8.49 | 8.17 | 8.27 | 8.20 | 8.07 | 8.57 | 8.19 | 8.57 | 8.56 | 8.87 | 8.43 |
| Standard Deviation | 1.54 | 1.66 | 1.88 | 1.92 | 1.56 | 2.13 | 1.26 | 1.48 | 1.51 | 1.65 | 1.74 | 1.99 | 2.11 | 2.16 | 1.91 | 2.00 |
| *p* value | 1.00 | | 0.75 | | 0.96 | | 0.80 | | 0.75 | | 0.43 | | 0.98 | | 0.38 | |
| | | | | | | | | | | | | | | | | |
| *After (Period 4)* | MPG After Month 1 | | MPG After Month 2 | | MPG After Month 3 | | MPG After Month 4 | | MPG After Month 5 | | MPG After Month 6 | | MPG After Month 7 | | MPG After Month 8 | |
| Training | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control |
| Number | 25 | 25 | 28 | 25 | 30 | 28 | 31 | 28 | 29 | 26 | 29 | 26 | 28 | 26 | 33 | 29 |
| Mean | 9.48 | 8.41 | 10.55 | 8.42 | 9.96 | 8.36 | 9.54 | 8.24 | 9.72 | 8.17 | 8.57 | 8.20 | 8.62 | 8.78 | 11.21 | 9.94 |
| Standard Deviation | 3.24 | 1.55 | 7.89 | 1.62 | 7.36 | 2.09 | 7.68 | 1.59 | 7.59 | 1.42 | 2.09 | 1.51 | 2.35 | 2.72 | 8.98 | 3.86 |
| *p* value | 0.14 | | 0.19 | | 0.27 | | 0.38 | | 0.31 | | 0.46 | | 0.82 | | 0.48 | |

Table 7-2: Independent t-Statistic tests involving the training and the control groups for medium vehicle category MPG before and after the large-scale training

| *Before (Period 3)* | MPG Before Month 1 | | MPG Before Month 2 | | MPG Before Month 3 | | MPG Before Month 4 | | MPG Before Month 5 | | MPG Before Month 6 | | MPG Before Month 7 | | MPG Before Month 8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Training | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control |
| Number | 28 | 26 | 29 | 28 | 27 | 27 | 28 | 31 | 27 | 25 | 27 | 29 | 28 | 25 | 31 | 25 |
| Mean | 17.49 | 17.33 | 17.23 | 17.14 | 17.30 | 17.32 | 17.42 | 17.30 | 17.52 | 17.33 | 17.24 | 17.31 | 17.18 | 17.40 | 17.38 | 17.11 |
| Standard Deviation | 3.06 | 4.12 | 4.45 | 2.90 | 3.91 | 3.36 | 3.86 | 2.90 | 3.00 | 3.75 | 3.10 | 3.46 | 3.76 | 3.28 | 3.20 | 2.79 |
| *p* value | 0.88 | | 0.93 | | 0.99 | | 0.89 | | 0.84 | | 0.93 | | 0.82 | | 0.74 | |
| | | | | | | | | | | | | | | | | |
| *After (Period 4)* | MPG After Month 1 | | MPG After Month 2 | | MPG After Month 3 | | MPG After Month 4 | | MPG After Month 5 | | MPG After Month 6 | | MPG After Month 7 | | MPG After Month 8 | |
| Training | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control |
| Number | 30 | 28 | 31 | 26 | 32 | 26 | 32 | 29 | 29 | 22 | 29 | 20 | 27 | 19 | 32 | 20 |
| Mean | 18.45 | 17.06 | 19.02 | 17.61 | 18.90 | 17.23 | 18.92 | 17.38 | 19.12 | 17.26 | 18.22 | 16.95 | 18.50 | 17.19 | 20.65 | 17.34 |
| Standard Deviation | 3.01 | 2.67 | 6.78 | 2.67 | 6.12 | 2.93 | 6.83 | 3.13 | 6.12 | 2.71 | 6.44 | 2.94 | 6.40 | 2.23 | 9.38 | 2.99 |
| *p* value | 0.07 | | 0.32 | | 0.21 | | 0.27 | | 0.19 | | 0.41 | | 0.40 | | 0.07 | |

Table 7-3: Independent t-Statistic tests involving the training and the control groups for light vehicle category MPG before and after the large-scale training

| *Before* | MPG Before Month 1 | | MPG Before Month 2 | | MPG Before Month 3 | | MPG Before Month 4 | | MPG Before Month 5 | | MPG Before Month 6 | | MPG Before Month 7 | | MPG Before Month 8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Training | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control |
| N | 11 | 10 | 11 | 11 | 11 | 10 | 11 | 10 | 10 | 10 | 12 | 12 | 10 | 9 | 12 | 10 |
| Mean | 44.57 | 45.39 | 43.94 | 43.55 | 44.59 | 45.44 | 45.76 | 45.93 | 45.80 | 46.33 | 44.37 | 44.48 | 45.40 | 45.04 | 44.95 | 44.15 |
| Standard Deviation | 8.11 | 6.38 | 7.31 | 7.83 | 6.24 | 6.24 | 4.26 | 4.06 | 5.60 | 6.39 | 6.67 | 5.10 | 5.03 | 2.68 | 7.96 | 4.49 |
| *p* value | 0.802 | | 0.905 | | 0.759 | | 0.928 | | 0.846 | | 0.962 | | 0.853 | | 0.781 | |
| | | | | | | | | | | | | | | | | |
| *After* | MPG After Month 1 | | MPG After Month 2 | | MPG After Month 3 | | MPG After Month 4 | | MPG After Month 5 | | MPG After Month 6 | | MPG After Month 7 | | MPG After Month 8 | |
| Training | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control |
| N | 13 | 10 | 13 | 11 | 11 | 11 | 13 | 10 | 11 | 9 | 8 | 9 | 7 | 10 | 7 | 8 |
| Mean | 45.93 | 45.29 | 45.68 | 44.32 | 45.87 | 45.27 | 44.42 | 44.37 | 44.06 | 44.84 | 47.01 | 46.54 | 44.74 | 45.38 | 45.71 | 45.39 |
| Standard Deviation | 6.71 | 6.29 | 6.25 | 6.08 | 4.80 | 8.37 | 7.04 | 7.06 | 6.93 | 6.19 | 3.27 | 2.38 | 2.80 | 4.45 | 3.63 | 2.78 |
| *p* value | 0.818 | | 0.594 | | 0.839 | | 0.988 | | 0.796 | | 0.739 | | 0.743 | | 0.847 | |

Table 7-4: Summary of the independent t-Statistic tests on the percentage change in MPG for heavy, medium and light vehicle categories after the large-scale training for the training and the control groups

| *Heavy* | Change in MPG Month 1 | | Change in MPG Month 2 | | Change in MPG Month 3 | | Change in MPG Month 4 | | Change in MPG Month 5 | | Change in MPG Month 6 | | Change in MPG Month 7 | | Change in MPG Month 8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Training | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control |
| Mean (%) | 12.22 | 6.63 | 14.42 | 5.73 | 8.43 | 4.75 | 0.29 | 4.39 | 8.34 | 7.61 | 2.43 | 5.80 | 0.07 | 7.37 | 3.72 | 3.61 |
| *p* value | 0.53 | | 0.29 | | 0.67 | | 0.54 | | 0.91 | | 0.68 | | 0.43 | | 0.99 | |
| | | | | | | | | | | | | | | | | |
| *Medium* | Change in MPG Month 1 | | Change in MPG Month 2 | | Change in MPG Month 3 | | Change in MPG Month 4 | | Change in MPG Month 5 | | Change in MPG Month 6 | | Change in MPG Month 7 | | Change in MPG Month 8 | |
| Training | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control |
| Mean (%) | 10.75 | 4.95 | 7.40 | 5.00 | 6.98 | 2.56 | 1.97 | 2.09 | 4.99 | 1.81 | -2.79 | 2.94 | 5.80 | 4.77 | -0.29 | 1.25 |
| *p* value | 0.39 | | 0.78 | | 0.57 | | 0.99 | | 0.63 | | 0.49 | | 0.89 | | 0.80 | |
| | | | | | | | | | | | | | | | | |
| *Light* | Change in MPG Month 1 | | Change in MPG Month 2 | | Change in MPG Month 3 | | Change in MPG Month 4 | | Change in MPG Month 5 | | Change in MPG Month 6 | | Change in MPG Month 7 | | Change in MPG Month 8 | |
| Training | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control | Trained | Control |
| Mean (%) | 10.67 | -7.43 | 5.39 | 4.13 | 4.76 | 1.63 | 2.09 | -5.79 | 4.13 | 2.11 | -0.39 | 6.19 | -0.04 | 1.10 | -5.83 | 2.63 |
| *p* value | 0.04 | | 0.88 | | 0.72 | | 0.22 | | 0.86 | | 0.35 | | 0.85 | | 0.19 | |

### 7.5.2 Paired t-Test

The paired t-Test was carried as illustrated in Figure 6.7 in Section 6.6.5, under the assumption that there were no control groups. In order to find out whether there had been a significant change in the performance of the drivers in terms of their MPG, the pre and post MPGs for the respective months had to be compared. The analysis results for this paired t-Test are provided in Appendix E-3. In summary, the results show that the training had a statistically significant impact on the MPG values for both heavy and medium vehicles in the first month after the training, and that for all the vehicle categories the p-values for the comparisons for the 3-month period immediately after the training were low compared to the rest of the *p* values, which suggests that some influence existed, though not statistically significant for the whole period. Indeed this can be visually observed from the plots showing the change in MPG in Figure 7.18, Figure 7.19 and Figure 7.20. The results also bear similarities with the independent t-Test whereby there is a noticeable improvement (though not statistically significant) in the MPG in the first few months after the training. However, because the control groups were used in this training, the analysis results using the independent t-Tests are recommended.

## 7.6 Trend Lines and Regression Analysis

The trend and regression analysis were carried out to determine the models or mathematical equations that could be used to explain the performance of the trained drivers' in terms of fuel economy or MPG. Even if the t-Tests showed that the improvements in the drivers' MPG after the training interventions were not sufficiently statistically significant at 95% Confident Interval (CI), regression analysis was conducted using the results. This is because the methodology and the analysis results could provide a basis for future modelling or tests based on improved data or methods as described in Sections 4.3 and 4.4 and recommended under future research work in Section 9.5.

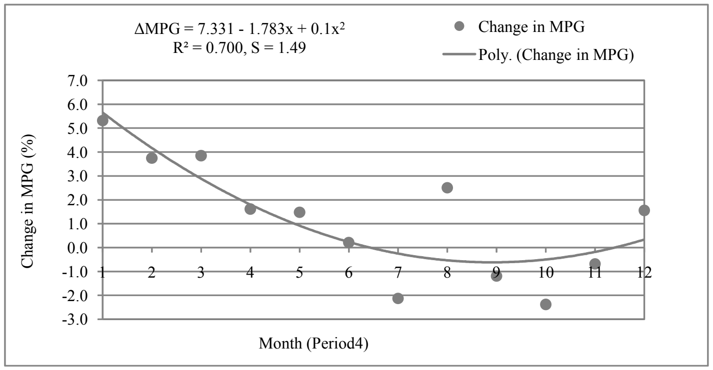
### 7.6.1 Pilot Training

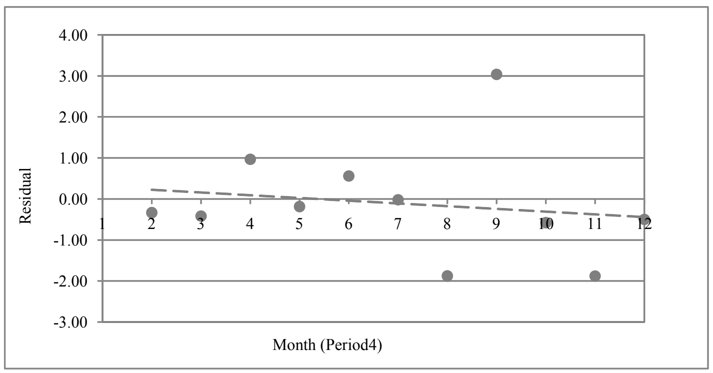
#### *7.6.1.1 Heavy Vehicle*

The results of the trend and regression analysis for the heavy vehicle driver after the pilot training are presented below. The initial results of the regression analysis using the polynomial model (Equation 6.2) are summarised in Figure 7.21. The model fit ($R^2$) indicated that the polynomial model was a better model than the logarithmic model (Equation 6.3) in predicting the change in the average MPG for the heavy vehicle drivers. The results of the logarithmic model analysis are summarised in Figure 7.22. The summary of the regression analysis results used to compare the polynomial model with the logarithmic model is shown in Table 7-5.

Table 7-5: Summary of the key parameters of the trend and regression analysis for the polynomial and the logarithmic model forms

| Parameter | Polynomial Model | Logarithmic | Comment |
|---|---|---|---|
| *R* squared, $R^2$ | 0.7 | 0.6 | Polynomial model has a better fit |
| Standard error, *S* | 1.49 | 1.59 | Polynomial model has smaller error |
| Significance, *p-value,* Intercept | 0.00 | 0.00 | Similar level of significance |
| Significance, *p-value,* first variable | 0.01 | 0.00 | Logarithmic is more significant |
| Residual (error) plots | No pattern | No pattern | Visually observed, with horizontal fairly linear plot |




| Regression Statistics | |
|---|---|
| Multiple R | 0.84 |
| R Square | 0.70 |
| Adjusted R Square | 0.63 |
| Standard Error | 1.49 |
| Observations | 12 |

ANOVA

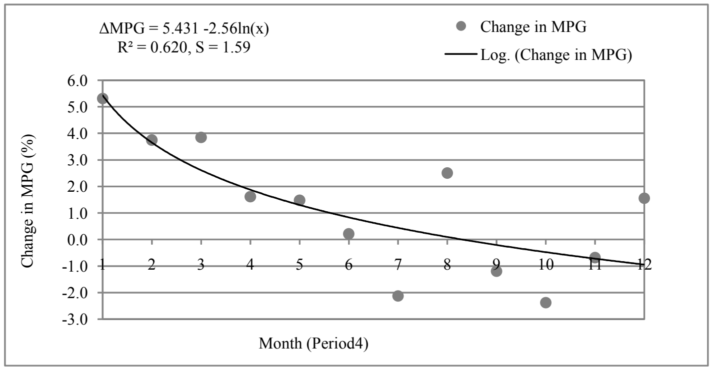
| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 46.72 | 23.36 | 10.54 | 0.004 |
| Residual | 9 | 19.94 | 2.22 | | |
| Total | 11 | 66.66 | | | |

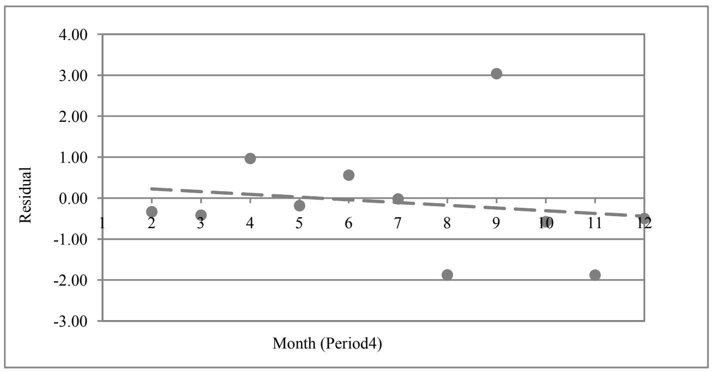
| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 7.33 | 1.54 | 4.77 | 0.00 | 3.85 | 10.81 |
| X Variable 1 | -1.78 | 0.54 | -3.28 | 0.01 | -3.01 | -0.55 |
| X Variable 2 | 0.10 | 0.04 | 2.46 | 0.04 | 0.01 | 0.19 |

RESIDUAL OUTPUT

| Observation | Predicted Y | Residuals |
|---|---|---|
| 1 | 5.65 | -0.33 |
| 2 | 4.16 | -0.42 |
| 3 | 2.88 | 0.97 |
| 4 | 1.80 | -0.18 |
| 5 | 0.92 | 0.56 |
| 6 | 0.23 | -0.02 |
| 7 | -0.25 | -1.88 |
| 8 | -0.53 | 3.04 |
| 9 | -0.62 | -0.58 |
| 10 | -0.50 | -1.88 |
| 11 | -0.18 | -0.50 |
| 12 | 0.34 | 1.22 |

Figure 7.21: Summary of the trend and regression analysis for the polynomial model form for the heavy vehicle drivers after the pilot training




| Regression Statistics | |
|---|---|
| Multiple R | 0.79 |
| R Square | 0.62 |
| Adjusted R Square | 0.58 |
| Standard Error | 1.59 |
| Observations | 12 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 41.37 | 41.37 | 16.36 | 0.002 |
| Residual | 10 | 25.29 | 2.53 | | |
| Total | 11 | 66.66 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 5.43 | 1.15 | 4.72 | 0.001 | 2.86 | 8.00 |
| X Variable 1 | -2.57 | 0.63 | -4.05 | 0.002 | -3.98 | -1.15 |

RESIDUAL OUTPUT

| Observation | Predicted Y | Residuals |
|---|---|---|
| 1 | 5.43 | -0.12 |
| 2 | 3.65 | 0.10 |
| 3 | 2.61 | 1.24 |
| 4 | 1.87 | -0.26 |
| 5 | 1.30 | 0.17 |
| 6 | 0.83 | -0.62 |
| 7 | 0.44 | -2.57 |
| 8 | 0.10 | 2.41 |
| 9 | -0.21 | -0.99 |
| 10 | -0.48 | -1.90 |
| 11 | -0.72 | 0.04 |
| 12 | -0.94 | 2.50 |

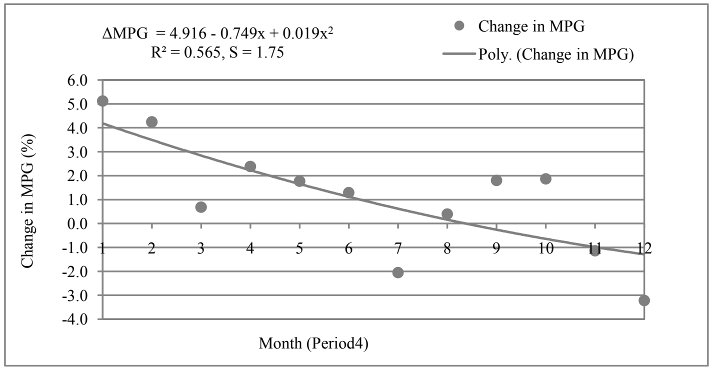
Figure 7.22: Summary of the trend and regression analysis for the logarithmic model form for the heavy vehicle drivers after the pilot training

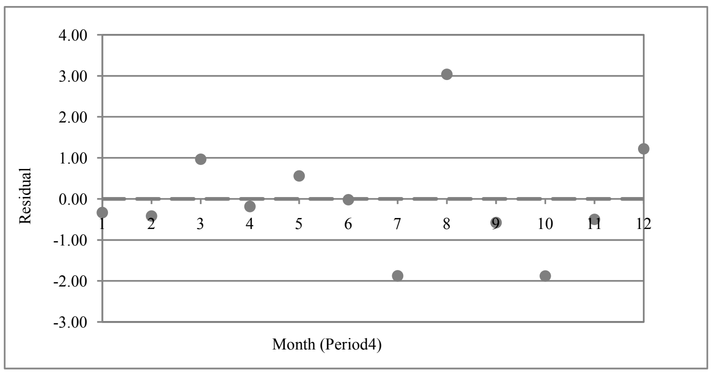
#### *7.6.1.2 Medium Vehicle*

The results of the trend and regression analysis for the medium vehicle drivers' performance in terms of their average change in MPG are presented below. The initial results of the regression analysis using the polynomial model (Equation 6.2) summarised in Figure 7.23 suggested that the $x^2$ variable was statistically insignificant. Therefore, a linear model (Equation 6.4) was tested instead (Figure 7.24). The final regression analysis results suggested that a logarithmic model (Figure 7.25) was a better model to predict the change in MPG for the drivers, as summarised in Table 7-6. However, for both models, the $R^2$ were significantly low to effectively predict the change in the MPG at 95% Confident Interval (CI).

Table 7-6: Summary of the key parameters of the trend and regression analysis for the linear and the logarithmic model forms

| Parameter | Linear Model | Logarithmic | Comment |
|---|---|---|---|
| $R$ squared, $R^2$ | 0.6 | 0.6 | Similar fit |
| Standard error, $S$ | 1.68 | 1.61 | Logarithmic has smaller error |
| Significance, *p-value,* Intercept | 0.002 | 0.001 | Logarithmic is more significant |
| Significance, *p-value,* first variable | 0.005 | 0.003 | Logarithmic is more significant |
| Residual (error) plots | No pattern | No pattern | Visually observed, with horizontal linear plot |




| Regression Statistics | |
|---|---|
| Multiple R | 0.75 |
| R Square | 0.57 |
| Adjusted R Square | 0.47 |
| Standard Error | 1.75 |
| Observations | 12 |

ANOVA

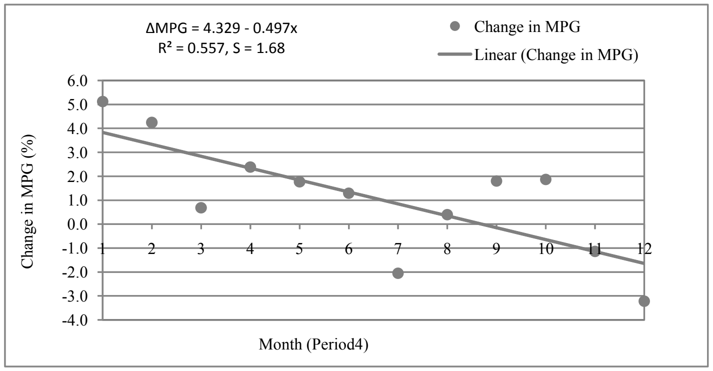
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 35.91 | 17.95 | 5.85 | 0.024 |
| Residual | 9 | 27.64 | 3.07 | | |
| Total | 11 | 63.55 | | | |

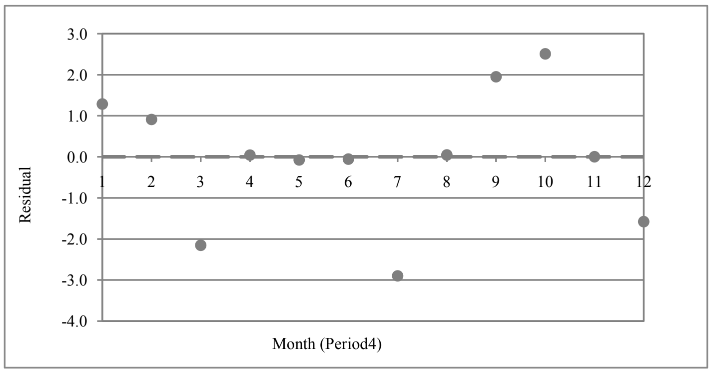
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 4.92 | 1.81 | 2.71 | 0.02 | 0.82 | 9.01 |
| X Variable 1 | -0.75 | 0.64 | -1.17 | 0.27 | -2.20 | 0.70 |
| X Variable 2 | 0.02 | 0.05 | 0.40 | 0.70 | -0.09 | 0.13 |

RESIDUAL OUTPUT

| *Observation* | *Predicted Y* | *Residuals* |
|---|---|---|
| 1 | 4.19 | 0.93 |
| 2 | 3.50 | 0.75 |
| 3 | 2.84 | -2.16 |
| 4 | 2.23 | 0.16 |
| 5 | 1.65 | 0.11 |
| 6 | 1.12 | 0.17 |
| 7 | 0.62 | -2.67 |
| 8 | 0.16 | 0.23 |
| 9 | -0.26 | 2.06 |
| 10 | -0.64 | 2.50 |
| 11 | -0.98 | -0.16 |
| 12 | -1.29 | -1.93 |

Figure 7.23: Summary of the trend and regression analysis for the polynomial model form for the medium vehicle drivers after the pilot training




| Regression Statistics | |
|---|---|
| Multiple R | 0.75 |
| R Square | 0.56 |
| Adjusted R Square | 0.51 |
| Standard Error | 1.68 |
| Observations | 12 |

ANOVA

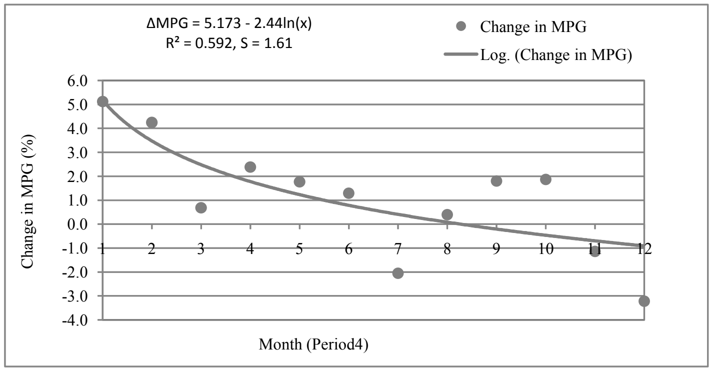
| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 35.41 | 35.41 | 12.58 | 0.005 |
| Residual | 10 | 28.14 | 2.81 | | |
| Total | 11 | 63.55 | | | |

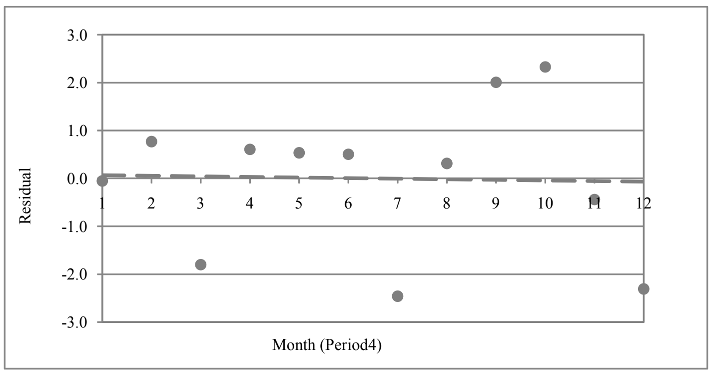
| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 4.33 | 1.03 | 4.19 | 0.002 | 2.03 | 6.63 |
| X Variable 1 | -0.50 | 0.14 | -3.55 | 0.005 | -0.81 | -0.19 |

RESIDUAL OUTPUT

| Observation | Predicted Y | Residuals |
|---|---|---|
| 1 | 3.8 | 1.3 |
| 2 | 3.3 | 0.9 |
| 3 | 2.8 | -2.2 |
| 4 | 2.3 | 0.0 |
| 5 | 1.8 | -0.1 |
| 6 | 1.3 | -0.1 |
| 7 | 0.8 | -2.9 |
| 8 | 0.3 | 0.0 |
| 9 | -0.1 | 2.0 |
| 10 | -0.6 | 2.5 |
| 11 | -1.1 | 0.0 |
| 12 | -1.6 | -1.6 |

Figure 7.24: Summary of the trend and regression analysis for the linear model form for the medium vehicle drivers after the pilot training




| *Regression Statistics* | |
|---|---|
| Multiple R | 0.77 |
| R Square | 0.59 |
| Adjusted R Square | 0.55 |
| Standard Error | 1.61 |
| Observations | 12 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 37.67 | 37.67 | 14.55 | 0.003 |
| Residual | 10 | 25.88 | 2.59 | | |
| Total | 11 | 63.55 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 5.17 | 1.17 | 4.44 | 0.001 | 2.58 | 7.77 |
| X Variable 1 | -2.45 | 0.64 | -3.82 | 0.003 | -3.88 | -1.02 |

RESIDUAL OUTPUT

| *Observation* | *Predicted Y* | *Residuals* |
|---|---|---|
| 1 | 5.2 | -0.1 |
| 2 | 3.5 | 0.8 |
| 3 | 2.5 | -1.8 |
| 4 | 1.8 | 0.6 |
| 5 | 1.2 | 0.5 |
| 6 | 0.8 | 0.5 |
| 7 | 0.4 | -2.5 |
| 8 | 0.1 | 0.3 |
| 9 | -0.2 | 2.0 |
| 10 | -0.5 | 2.3 |
| 11 | -0.7 | -0.4 |
| 12 | -0.9 | -2.3 |

Figure 7.25: Summary of the trend and regression analysis for the logarithmic model form for the medium vehicle drivers after the pilot training

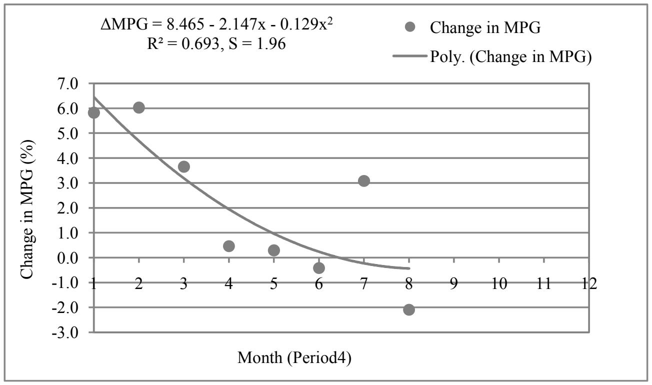
## 7.6.2 Large-scale Training

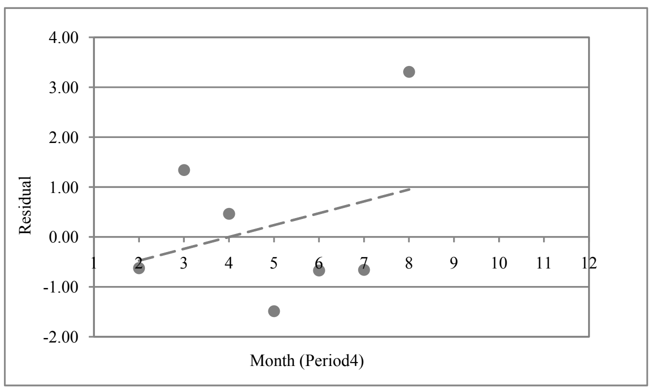
### *7.6.2.1 Heavy Vehicle*

The initial result of the regression analysis using the polynomial model (Equation 6.2) is shown in Figure 7.26. Although the model fit ($R^2$) indicated that the model was better than the logarithmic model (Equation 6.3), for which the results are shown in Figure 7.27. The $x^2$ variable was statistically insignificant. Therefore, a linear model (Equation 6.4) was used instead (Figure 7.28). The final regression analysis results suggested that the logarithmic model was a better model than the linear model to predict the change in MPG for the drivers, as summarised in Table 7-7.

Table 7-7: Summary of the key parameters of the trend and regression analysis for the linear and logarithmic model forms

| Parameter | Linear Model | Logarithmic | Comment |
|---|---|---|---|
| $R$ squared, $R^2$ | 0.6 | 0.7 | Logarithmic has a better fit |
| Standard error, $S$ | 1.92 | 1.84 | Logarithmic has smaller error |
| Significance, *p-value,* Intercept | 0.005 | 0.004 | Logarithmic is more significant |
| Significance, *p-value,* first variable | 0.02 | 0.01 | Logarithmic is more significant |
| Significance, *p-value,* overall equation | 0.02 | 0.01 | Logarithmic is more significant |
| Residual (error) plots | No pattern | No pattern | Visually observed, with horizontal linear plot |




| Regression Statistics | |
|---|---|
| Multiple R | 0.83 |
| R Square | 0.69 |
| Adjusted R Square | 0.57 |
| Standard Error | 1.96 |
| Observations | 8 |

ANOVA

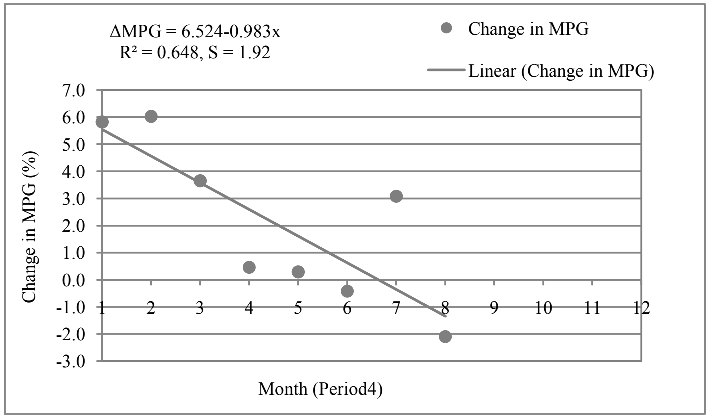
| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 43.41 | 21.70 | 5.65 | 0.05 |
| Residual | 5 | 19.20 | 3.84 | | |
| Total | 7 | 62.61 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 8.47 | 2.73 | 3.10 | 0.03 | 1.44 | 15.49 |
| X Variable 1 | -2.15 | 1.39 | -1.54 | 0.18 | -5.73 | 1.44 |
| X Variable 2 | 0.13 | 0.15 | 0.86 | 0.43 | -0.26 | 0.52 |

RESIDUAL OUTPUT

| Observation | Predicted Y | Residuals |
|---|---|---|
| 1 | 6.45 | -0.63 |
| 2 | 4.69 | 1.34 |
| 3 | 3.19 | 0.46 |
| 4 | 1.95 | -1.49 |
| 5 | 0.96 | -0.67 |
| 6 | 0.24 | -0.66 |
| 7 | -0.23 | 3.31 |
| 8 | -0.43 | -1.66 |

Figure 7.26: Summary of the trend and regression analysis for the polynomial model form for the heavy vehicle drivers after the large-scale training

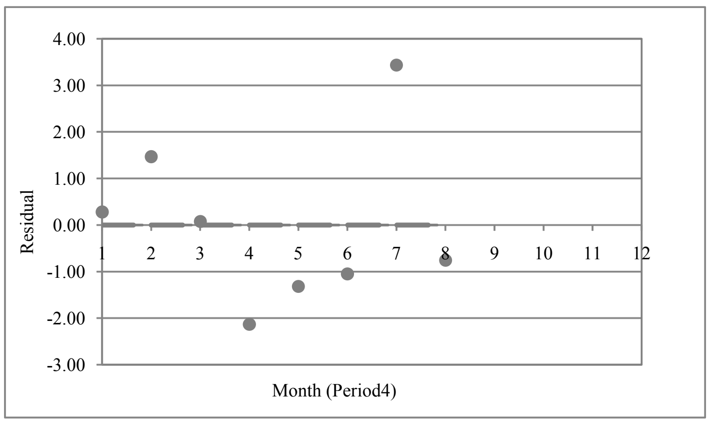



| Regression Statistics | |
|---|---|
| Multiple R | 0.81 |
| R Square | 0.65 |
| Adjusted R Square | 0.59 |
| Standard Error | 1.92 |
| Observations | 8.00 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 40.60 | 40.60 | 11.07 | 0.02 |
| Residual | 6 | 22.01 | 3.67 | | |
| Total | 7 | 62.61 | | | |

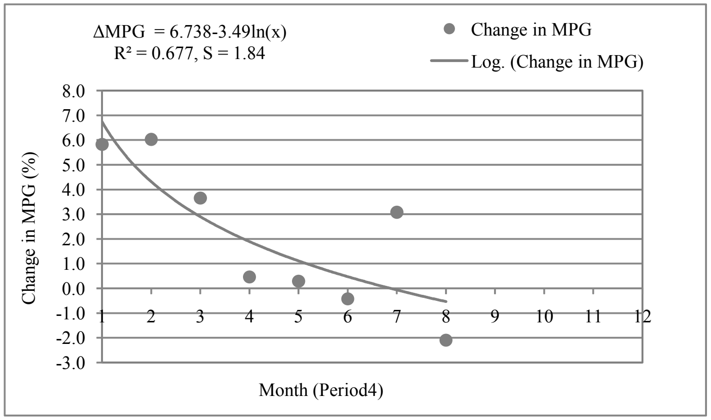
| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 6.52 | 1.49 | 4.37 | 0.00 | 2.87 | 10.18 |
| X Variable 1 | -0.98 | 0.30 | -3.33 | 0.02 | -1.71 | -0.26 |

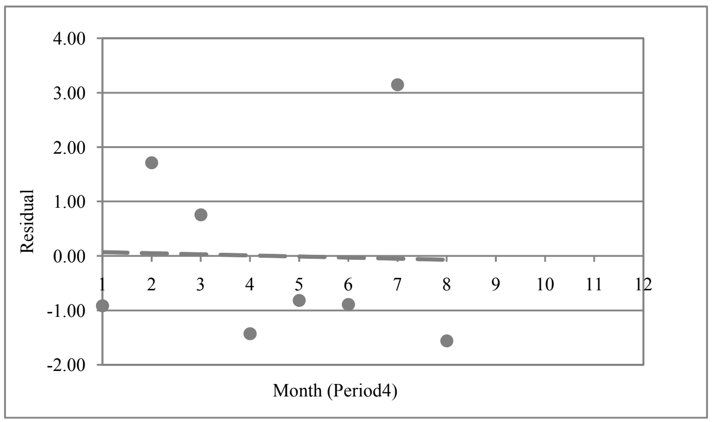



RESIDUAL OUTPUT

| Observation | Predicted Y | Residuals |
|---|---|---|
| 1 | 5.54 | 0.28 |
| 2 | 4.56 | 1.47 |
| 3 | 3.58 | 0.08 |
| 4 | 2.59 | -2.13 |
| 5 | 1.61 | -1.32 |
| 6 | 0.63 | -1.05 |
| 7 | -0.36 | 3.44 |
| 8 | -1.34 | -0.76 |

Figure 7.27: Summary of the trend and regression analysis for the linear model form for the heavy vehicle drivers after the large-scale training




| Regression Statistics | |
|---|---|
| Multiple R | 0.82 |
| R Square | 0.68 |
| Adjusted R Square | 0.62 |
| Standard Error | 1.84 |
| Observations | 8.00 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 42.40 | 42.40 | 12.59 | 0.01 |
| Residual | 6 | 20.21 | 3.37 | | |
| Total | 7 | 62.61 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 6.74 | 1.46 | 4.62 | 0.00 | 3.17 | 10.31 |
| X Variable 1 | -3.50 | 0.99 | -3.55 | 0.01 | -5.91 | -1.09 |

RESIDUAL OUTPUT

| Observation | Predicted Y | Residuals |
|---|---|---|
| 1 | 6.74 | -0.92 |
| 2 | 4.31 | 1.71 |
| 3 | 2.89 | 0.76 |
| 4 | 1.89 | -1.43 |
| 5 | 1.11 | -0.82 |
| 6 | 0.47 | -0.89 |
| 7 | -0.07 | 3.15 |
| 8 | -0.54 | -1.56 |

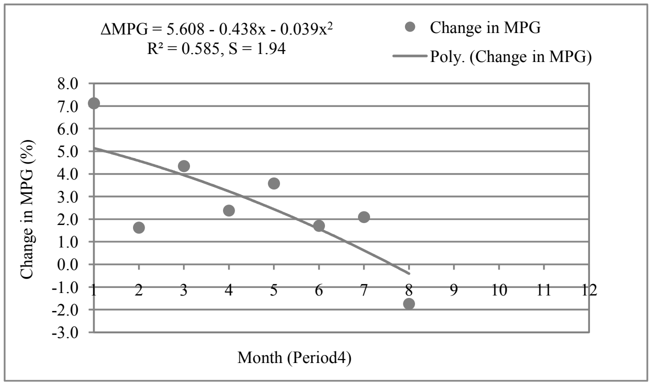
Figure 7.28: Summary of the trend and regression analysis for the logarithmic model form for the heavy vehicle drivers after the large-scale training

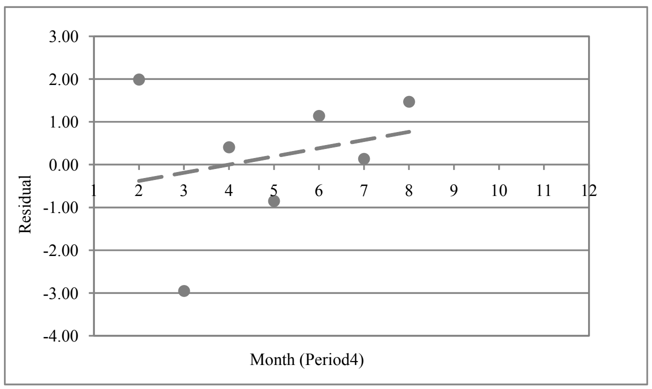
#### *7.6.2.2 Medium Vehicle*

The initial result of the regression analysis using the polynomial model (Equation 6.2) is shown in Figure 7.29. The model fit ($R^2$) was significantly low and the $x^2$ variable was also statistical insignificant. Therefore, a linear model (Equation 6.4) was used instead (Figure 7.30). The final regression analysis results suggested that the linear model was marginally better than a logarithmic model (Figure 7.31) for predicting the change in MPG for the medium drivers after the large-scale training, as summarised in Table 7-8.

Table 7-8: Summary of the key parameters of the trend and regression analysis for the linear and logarithmic model forms

| Parameter | Linear Model | Logarithmic | Comment |
|---|---|---|---|
| *R* squared, $R^2$ | 0.6 | 0.6 | Similar fit |
| Standard error, *S* | 1.78 | 1.79 | Similar error |
| Significance, *p-value,* Intercept | 0.004 | 0.005 | Linear model marginally more significant |
| Significance, *p-value,* first variable | 0.028 | 0.029 | Similar level of significance |
| Significance, *p-value,* overall equation | 0.028 | 0.029 | Similar level of significance |
| Residual (error) plots | No pattern | No pattern | Visually observed, with fairly horizontal linear plot |




| Regression Statistics | |
|---|---|
| Multiple R | 0.76 |
| R Square | 0.59 |
| Adjusted R Square | 0.42 |
| Standard Error | 1.94 |
| Observations | 8 |

ANOVA

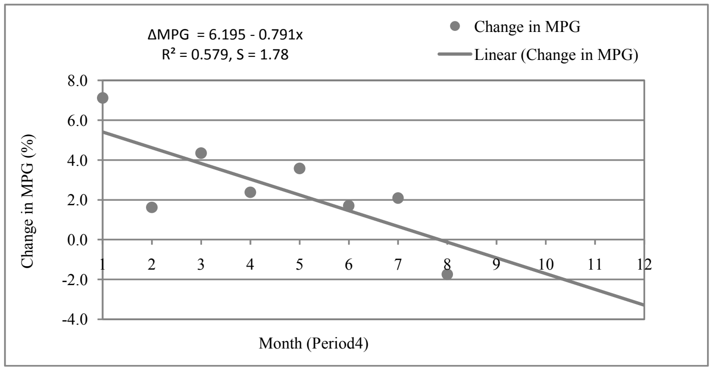
| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 26.53 | 13.27 | 3.53 | 0.111 |
| Residual | 5 | 18.81 | 3.76 | | |
| Total | 7 | 45.35 | | | |

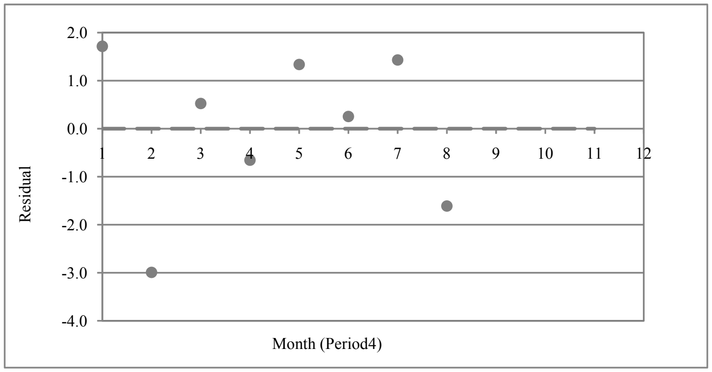
| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 5.61 | 2.71 | 2.07 | 0.093 | -1.35 | 12.57 |
| X Variable 1 | -0.44 | 1.38 | -0.32 | 0.763 | -3.99 | 3.11 |
| X Variable 2 | -0.04 | 0.15 | -0.26 | 0.804 | -0.42 | 0.35 |

RESIDUAL OUTPUT

| Observation | Predicted Y | Residuals |
|---|---|---|
| 1 | 5.13 | 1.99 |
| 2 | 4.57 | -2.95 |
| 3 | 3.94 | 0.41 |
| 4 | 3.23 | -0.85 |
| 5 | 2.44 | 1.14 |
| 6 | 1.57 | 0.14 |
| 7 | 0.62 | 1.47 |
| 8 | -0.41 | -1.34 |

Figure 7.29: Summary of the trend and regression analysis for the polynomial model form for the medium vehicle drivers after the large-scale training




| Regression Statistics | |
|---|---|
| Multiple R | 0.76 |
| R Square | 0.58 |
| Adjusted R Square | 0.51 |
| Standard Error | 1.78 |
| Observations | 8 |

ANOVA

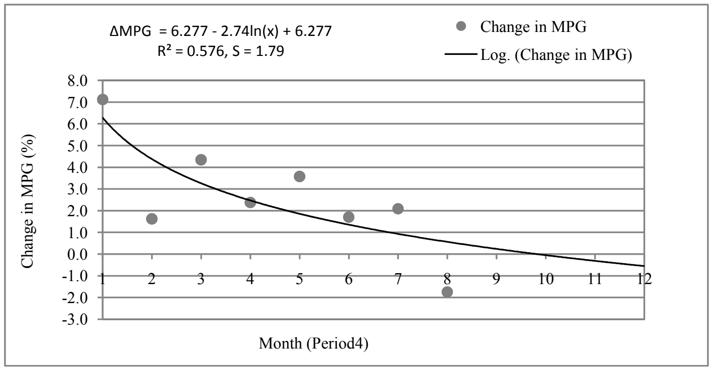
| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 26.28 | 26.28 | 8.27 | 0.028 |
| Residual | 6 | 19.07 | 3.18 | | |
| Total | 7 | 45.35 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 6.20 | 1.39 | 4.46 | 0.004 | 2.80 | 9.59 |
| X Variable 1 | -0.79 | 0.28 | -2.88 | 0.028 | -1.46 | -0.12 |

RESIDUAL OUTPUT

| Observation | Predicted Y | Residuals |
|---|---|---|
| 1 | 5.4 | 1.7 |
| 2 | 4.6 | -3.0 |
| 3 | 3.8 | 0.5 |
| 4 | 3.0 | -0.7 |
| 5 | 2.2 | 1.3 |
| 6 | 1.4 | 0.3 |
| 7 | 0.7 | 1.4 |
| 8 | -0.1 | -1.6 |

Figure 7.30: Summary of the trend and regression analysis for the linear model form for the medium vehicle drivers after the large-scale training

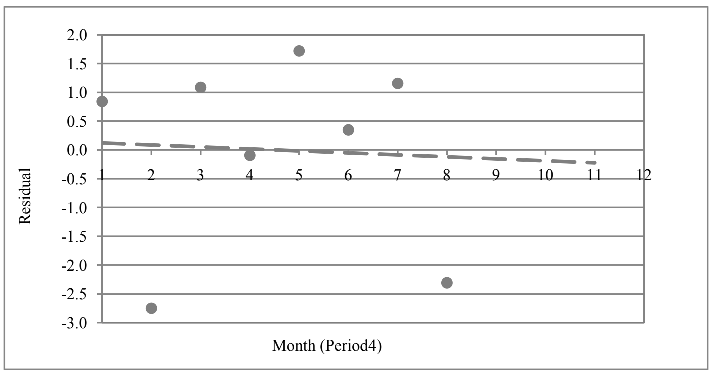



| Regression Statistics | |
|---|---|
| Multiple R | 0.76 |
| R Square | 0.58 |
| Adjusted R Square | 0.51 |
| Standard Error | 1.79 |
| Observations | 8 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 26.14 | 26.14 | 8.17 | 0.029 |
| Residual | 6 | 19.21 | 3.20 | | |
| Total | 7 | 45.35 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 6.28 | 1.42 | 4.41 | 0.005 | 2.80 | 9.76 |
| X Variable 1 | -2.75 | 0.96 | -2.86 | 0.029 | -5.10 | -0.39 |




RESIDUAL OUTPUT

| Observation | Predicted Y | Residuals |
|---|---|---|
| 1 | 6.3 | 0.8 |
| 2 | 4.4 | -2.8 |
| 3 | 3.3 | 1.1 |
| 4 | 2.5 | -0.1 |
| 5 | 1.9 | 1.7 |
| 6 | 1.4 | 0.3 |
| 7 | 0.9 | 1.2 |
| 8 | 0.6 | -2.3 |

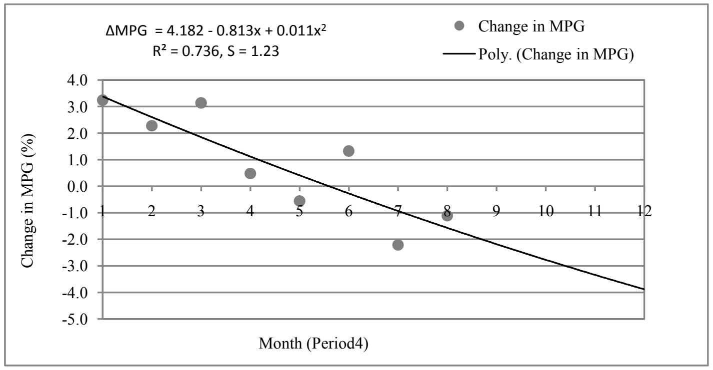
Figure 7.31: Summary of the trend and regression analysis for the logarithmic model form for the medium vehicle drivers after the large-scale training

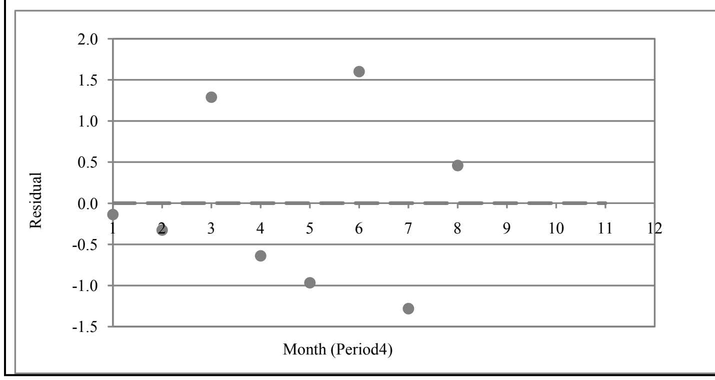
### *7.6.2.3 Light Vehicle*

The initial result of the regression analysis using the polynomial model (Equation 6.2) is shown in Figure 7.32. Although the model fit ($R^2$) was significant, the $x^2$ variable was statistically insignificant. Therefore, a linear model (Equation 6.4) was used instead (Figure 7.33). The final regression analysis results suggested that the linear model was a better model than the logarithmic model (Figure 7.34) to use to predict the change in MPG for the light vehicle drivers, as summarised in Table 7-9.

Table 7-9: Summary of the key parameters of the trend and regression analysis for the linear and logarithmic model forms

| Parameter | Linear Model | Logarithmic | Comment |
|---|---|---|---|
| *R* squared, $R^2$ | 0.7 | 0.7 | Similar fit |
| Standard error, *S* | 1.12 | 1.24 | Less error with the linear model |
| Significance, *p-value,* Intercept | 0.004 | 0.007 | Linear model marginally more significant |
| Significance, *p-value,* first variable | 0.006 | 0.012 | Linear model is more significant |
| Significance, *p-value,* first variable | 0.006 | 0.012 | Linear model is more significant |
| Residual (error) plots | No pattern | Potential pattern | Visually observed, with potentially some pattern for the logarithmic model form |




| Regression Statistics | |
|---|---|
| Multiple R | 0.86 |
| R Square | 0.74 |
| Adjusted R Square | 0.63 |
| Standard Error | 1.23 |
| Observations | 8 |

ANOVA

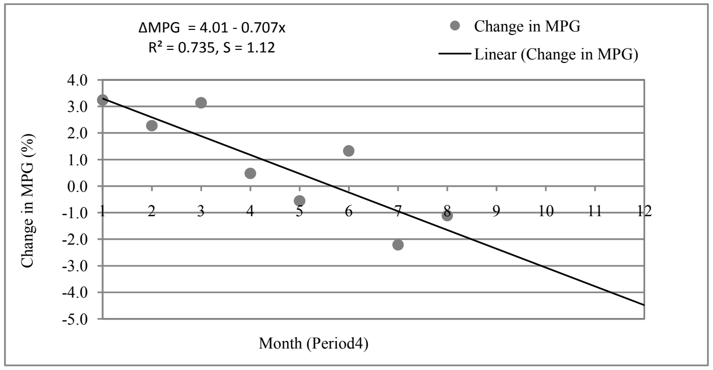
| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 21.05 | 10.52 | 6.98 | 0.036 |
| Residual | 5 | 7.54 | 1.51 | | |
| Total | 7 | 28.59 | | | |

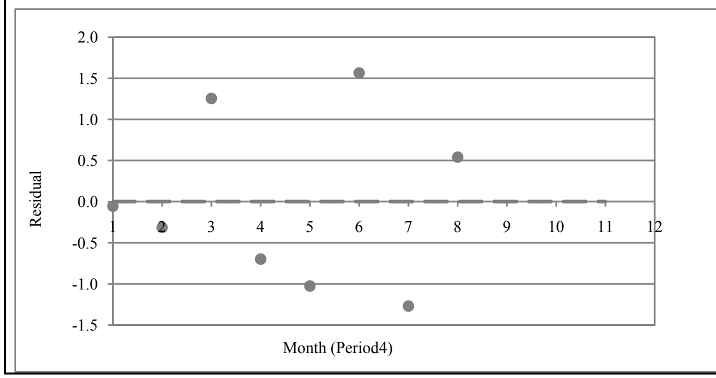
| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 4.18 | 1.71 | 2.44 | 0.059 | -0.22 | 8.59 |
| X Variable 1 | -0.81 | 0.87 | -0.93 | 0.395 | -3.06 | 1.43 |
| X Variable 2 | 0.01 | 0.09 | 0.12 | 0.91 | -0.23 | 0.26 |

RESIDUAL OUTPUT

| Observation | Predicted Y | Residuals |
|---|---|---|
| 1 | 3.4 | -0.1 |
| 2 | 2.6 | -0.3 |
| 3 | 1.8 | 1.3 |
| 4 | 1.1 | -0.6 |
| 5 | 0.4 | -1.0 |
| 6 | -0.3 | 1.6 |
| 7 | -0.9 | -1.3 |
| 8 | -1.6 | 0.5 |

Figure 7.32: Summary of the trend and regression analysis for the polynomial model form for the light vehicle drivers after the large-scale training




| Regression Statistics | |
|---|---|
| Multiple R | 0.86 |
| R Square | 0.74 |
| Adjusted R Square | 0.69 |
| Standard Error | 1.12 |
| Observations | 8 |

ANOVA

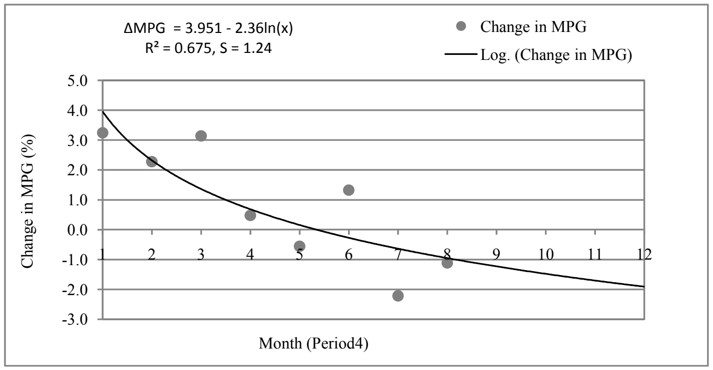
| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 21.02 | 21.02 | 16.67 | 0.006 |
| Residual | 6 | 7.57 | 1.26 | | |
| Total | 7 | 28.59 | | | |

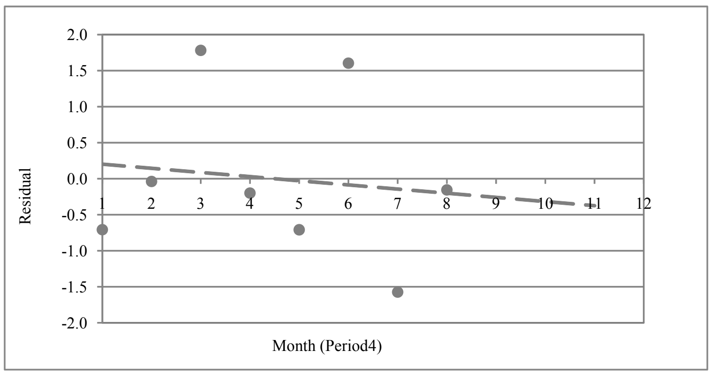
| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 4.01 | 0.88 | 4.58 | 0.004 | 1.87 | 6.15 |
| X Variable 1 | -0.71 | 0.17 | -4.08 | 0.006 | -1.13 | -0.28 |

RESIDUAL OUTPUT

| Observation | Predicted Y | Residuals |
|---|---|---|
| 1 | 3.3 | -0.1 |
| 2 | 2.6 | -0.3 |
| 3 | 1.9 | 1.3 |
| 4 | 1.2 | -0.7 |
| 5 | 0.5 | -1.0 |
| 6 | -0.2 | 1.6 |
| 7 | -0.9 | -1.3 |
| 8 | -1.7 | 0.5 |

Figure 7.33: Summary of the trend and regression analysis for the linear model form for the light vehicle drivers after the large-scale training




| Regression Statistics | |
|---|---|
| Multiple R | 0.82 |
| R Square | 0.68 |
| Adjusted R Square | 0.62 |
| Standard Error | 1.24 |
| Observations | 8 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 19.30 | 19.30 | 12.47 | 0.012 |
| Residual | 6 | 9.29 | 1.55 | | |
| Total | 7 | 28.59 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 3.95 | 0.99 | 3.99 | 0.007 | 1.53 | 6.37 |
| X Variable 1 | -2.36 | 0.67 | -3.53 | 0.012 | -4.00 | -0.72 |

RESIDUAL OUTPUT

| Observation | Predicted Y | Residuals |
|---|---|---|
| 1 | 4.0 | -0.7 |
| 2 | 2.3 | 0.0 |
| 3 | 1.4 | 1.8 |
| 4 | 0.7 | -0.2 |
| 5 | 0.2 | -0.7 |
| 6 | -0.3 | 1.6 |
| 7 | -0.6 | -1.6 |
| 8 | -1.0 | -0.2 |

Figure 7.34: Summary of the trend and regression analysis for the logarithmic model form for the light vehicle drivers after the large-scale training

### 7.6.3 Summary of Regression Analysis

The regression analysis was carried out to develop models to predict the improvement in the average MPG for the drivers as a function of time (in months). The appropriate model forms for the vehicle categories based on the large-scale training were established as follows:

1. Heavy vehicle – logarithmic model form;
2. Medium vehicle – linear model form;
3. Light vehicle – linear model form.

The analysis results suggest that the logarithmic and the linear model forms could be suitable for predicting the performance of the drivers in terms of their MPG. The prediction variables used were assessed as being statistically significant, as given by the *p* values. The overall model regression in terms of the $R^2$ was about 0.7. A further discussion of the results of the regression analysis and their potential applications is provided in Section 8.6.1.3.

## 7.7 Driver Behaviour (Driving Style Questionnaire)

The data collected through the driving style questionnaire (DSQ) was used to assess the influence of the large-scale training on driver behavioural attributes associated with driving for fuel economy. The attributes are shown in Table 7-10. The DSQ used (provided in Appendix D-2) shows the questions that were asked of the participants. The higher the score given to an attribute-related question, the less was the expected fuel efficient driving or contribution to fuel economy. The attributes and the related questions were given reference numbers 1 to 15, as shown in Table 7-10, in order to manage the data analysis.

Table 7-10: Summary of the attributes' reference numbers and the related questions used in the driving style questionnaire

| Attribute Reference No. | Attribute | Attribute Related Question |
|---|---|---|
| 1 | Hazard | Do you sometimes fail to drive cautiously? |
| 2 | Driver Behaviour | Do you dislike people who give you advice about you driving? |
| 3 | Driver Fatigue | Do you sometimes drive when feeling tired? |
| 4 | Initial Checks | How often do you forget to check your vehicle tyre pressure? |

| Attribute Reference No. | Attribute | Attribute Related Question |
|---|---|---|
| 5 | Acceleration and Speed | Do you drive fast? |
| 6 | Braking | Do you sometimes fail to apply smooth braking? |
| 7 | Gear Changes /Selection | Do you sometimes forget to use block gear changes for example 1-3-5 0r 2-4-6? |
| 8 | Clutch Control | Do you sometimes use the clutch control to balance the car whilst stationary? |
| 9 | Forward Planning | Do you sometimes forget to plan ahead? |
| 10 | Vehicle Idling | Do leave the vehicle engine on when it is not needed? |
| 11 | Route Planning | Do you sometimes forget to plan your journey? |
| 12 | Loads and Loading Pattern | Do you sometime forget to plan about loading the vehicle? |
| 13 | Adjustable Aerodynamics and windows | Do you forget to carry out necessary aerodynamic adjustments if available to reduce drag? |
| 14 | Culture Change | Have you ever doubted the benefits fuel efficient driving like fuel economy and safety? |
| 15 | Management | Do you sometimes fail to get the support you need regarding fuel efficient driving? |

The SPSS$^{TM}$ statistical software (IBM, 2010) was used to conduct the analysis using the methodology described in Section 6.6.5.2. The results are provided in the following sections.

### 7.7.1 Heavy/Medium Vehicle Drivers

The Mann-Whitney test (Walpole et al, 2012; Larson and Farber, 2012), as illustrated in Figure 6.8, is analogous to the independent t-Test. The test was applied to the corresponding training and control scores generated using the DSQ before and after the training in order to find out if there were significant differences in the scores between the groups for each of the attributes. The analysis results are summarised in Table 7-11 for the situation before the Training and Table 7-12 after the training.

Table 7-11: Summary of the Mann-Whitney test statistic regarding the difference in driver behaviour for the heavy/medium vehicle training and control drivers before the training

| Test Statistics, *a* | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Attribute1 | Attribute2 | Attribute3 | Attribute4 | Attribute5 | Attribute6 | Attribute7 | Attribute8 | Attribute9 | Attribute 10 | Attribute 11 | Attribute12 | Attribute13 | Attribute14 | Attribute15 |
| Mann-Whitney *U* | 570 | 573 | 542 | 514 | 568 | 505 | 486 | 479 | 546 | 532 | 481 | 567 | 541 | 515 | 550 |
| Wilcoxon W | 1165 | 1168 | 1137 | 1109 | 1163 | 1100 | 1081 | 1074 | 1141 | 1127 | 1076 | 1162 | 1136 | 1110 | 1145 |
| *Z* | -0.11 | -0.06 | -0.47 | -0.86 | -0.13 | -0.93 | -1.19 | -1.28 | -0.42 | -0.59 | -1.26 | -0.15 | -0.48 | -0.82 | -0.37 |
| Asymp. Sig. (2-tailed) | 0.91 | 0.95 | 0.64 | 0.39 | 0.90 | 0.35 | 0.24 | 0.20 | 0.67 | 0.55 | 0.21 | 0.88 | 0.63 | 0.42 | 0.71 |
| a. Grouping variable: Group = Training, Control | | | | | | | | | | | | | | | |

Table 7-12: Summary of the Mann-Whitney test statistic regarding the difference in driver behaviour for the heavy/medium vehicle training and control drivers after the training

| Test Statistics, *a* | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Attribute1 | Attribute2 | Attribute3 | Attribute4 | Attribute5 | Attribute6 | Attribute7 | Attribute8 | Attribute9 | Attribute 10 | Attribute 11 | Attribute12 | Attribute13 | Attribute14 | Attribute15 |
| Mann-Whitney *U* | 424 | 505.5 | 480 | 540 | 576 | 510 | 476 | 365.5 | 450.5 | 535.5 | 463 | 293.5 | 516.5 | 541 | 569.5 |
| Wilcoxon W | 1019 | 1100.5 | 1075 | 1135 | 1171 | 1105 | 1071 | 960.5 | 1045.5 | 1130.5 | 1058 | 888.5 | 1111.5 | 1136 | 1164.5 |
| *Z* | -1.935 | -0.922 | -1.28 | -0.494 | -0.026 | -0.875 | -1.311 | -2.726 | -1.661 | -0.56 | -1.479 | -3.609 | -0.792 | -0.474 | -0.11 |
| Asymp. Sig. (2-tailed) | 0.05 | 0.357 | 0.201 | 0.621 | 0.98 | 0.381 | 0.19 | 0.006 | 0.097 | 0.575 | 0.139 | 0 | 0.429 | 0.636 | 0.912 |
| a. Grouping variable: Group = Training, Control | | | | | | | | | | | | | | | |

The *Z* and *p* values for the comparisons in Table 7-11 suggest that there were no significant differences between the scores provided by the control group and those provided by the training group before the training, as the *p* values are all greater than α (0.05). This would be expected before the training. After the training, the Mann-Whitney test shows that the training did not educe statistically significant change in most of the driving behavioural attributes (for the *Z* values, *p* values are greater than α (0.05)) used except for attributes number 1, 8 and 12 which showed significant changes at the 95% confidence interval (CI) (for the *Z* values, *p* values are less than α (0.05)), all towards driving for better fuel economy in the heavy/medium vehicle category. Generally, a greater number of the drivers entered lower scores after the training, which corresponds to better driving for fuel economy. The attributes which showed significant changes are (1, 8 and 12) are as follows:

1. Driving cautiously (1);
2. Clutch control (8); and,
3. Planning when loading the vehicle (12).

The results show that the attributes that were thought to have the greatest influence on fuel economy according to the experts' priorities given in Table 5-5 did not change as much as those which were thought to have a lesser influence. Consequently, it is difficult to assign the improvement in the MPG performances of the drivers to any particular factor or driver attributes, at this stage.

The Wilcoxon signed-rank test (Walpole et al, 2012; Larson and Farber, 2012), as illustrated in Figure 6.8, is analogous to the paired t-Test for parametric data. The test was applied to the before and after scores generated using the DSQ regarding each attribute question for the training group, in order to find out if there were significant change in the fuel efficiency driving within the group. This tests was carried out assuming that there was no control group. The results of the analysis are summarised in Table 7-13 for the drivers of heavy/medium vehicles.

Table 7-13: Wilcoxon signed-rank test statistics regarding the change in driver behaviour before and after the training for the heavy/medium vehicle drivers

| Attribute No. | Comparison Before and After the Training | Test Statistic,*b* | |
|---|---|---|---|
| | | *Z* | Asymp. Sig. (2-tailed), *p* |
| 1 | Do you sometimes fail to drive cautiously? | -2.622*a* | 0.009 |
| 2 | Do you dislike people who give you advice about you driving? | -1.109*a* | 0.267 |
| 3 | Do you sometimes drive when feeling tired? | -1.220*a* | 0.222 |
| 4 | How often do you forget to check your vehicle tyre pressure? | -0.662*a* | 0.508 |
| 5 | Do you drive fast? | -0.341*a* | 0.733 |
| 6 | Do you sometimes fail to apply smooth braking? | -2.291*a* | 0.022 |
| 7 | Do you sometimes forget to use block gear changes for example 1-3-5 0r 2-4-6? | -0.265*a* | 0.791 |
| 8 | Do you sometimes use the clutch control to balance the car whilst stationary? | -1.628*a* | 0.104 |
| 9 | Do you sometimes forget to plan ahead? | -2.666*a* | 0.008 |
| 10 | Do leave the vehicle engine on when it is not needed? | -1.248*a* | 0.212 |
| 11 | Do you sometimes forget to plan your journey? | -0.491*a* | 0.623 |
| 12 | Do you sometime forget to plan about loading the vehicle? | -4.021*a* | 0.001 |
| 13 | Do you forget to carry out necessary aerodynamic adjustments if available to reduce drag? | -1.664*a* | 0.096 |
| 14 | Have you ever doubted the benefits fuel efficient driving like fuel economy and safety? | -0.505*a* | 0.613 |
| 15 | Do you sometimes fail to get the support you need regarding fuel efficient driving? | -0.654*a* | 0.513 |
| *a*. Based on positive ranks. | | | |
| *b*. Wilcoxon Signed Ranks Test | | | |

By examining the *Z* and *p* values for each of the paired comparisons given in Table 7-13, it can be deduced that the training did not educe statistically significant change in most of the driving behavioural attributes (for the *Z* values, *p* values are greater than α (0.05)) used except for attributes number 1, 6, 9 and 12 which showed significant changes at the 95% confidence interval (CI) (for the *Z* values, *p* values are less than α (0.05)), all towards driving for better fuel economy. Generally, a greater number of the drivers entered lower scores after the training, which corresponds to better driving for fuel economy. The attributes which showed significant changes are (1, 6, 9 and 12) are as follows:

1. Driving cautiously (1);
2. Applying smooth braking (6);
3. Planning ahead (9); and,

4. Planning when loading the vehicle (12).

The tests shows some similar results to that from the Mann-Whitney test in particularly for the driving attributes 1 and 12 which improved significantly. The corresponding quartile statistics for the comparison ranks related to the Mann-Whitney and Wilcoxon signed-rank tests above are provided in Appendix E-4. However, since a control group was used in the study the Mann-Whitney test results are recommended.

### 7.7.2 Light Vehicle Drivers

Similarly, the Mann-Whitney test (Walpole et al, 2012; Larson and Farber, 2012) was also applied to the corresponding training and control scores before and after the training. The analysis results are summarised in Table 7-14 and Table 7-15 for the light vehicle drivers.

Table 7-14: Summary of the Mann-Whitney test statistic regarding the difference in driver behaviour for the light vehicle training and control drivers before the training

| Test Statistics, *a* | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Attribute1 | Attribute2 | Attribute3 | Attribute4 | Attribute5 | Attribute6 | Attribute7 | Attribute8 | Attribute9 | Attribute 10 | Attribute 11 | Attribute12 | Attribute13 | Attribute14 | Attribute15 |
| Mann-Whitney *U* | 73 | 70 | 56 | 73 | 78 | 58 | 69 | 72 | 68 | 75 | 67 | 76 | 73 | 60 | 65 |
| Wilcoxon W | 164 | 148 | 134 | 164 | 156 | 149 | 160 | 163 | 159 | 166 | 145 | 154 | 164 | 151 | 143 |
| *Z* | -0.28 | -0.48 | -1.31 | -0.31 | -0.03 | -1.16 | -0.54 | -0.35 | -0.60 | -0.17 | -0.64 | -0.12 | -0.30 | -1.06 | -0.76 |
| Asymp. Sig. (2-tailed) | 0.779 | 0.632 | 0.192 | 0.755 | 0.977 | 0.248 | 0.592 | 0.726 | 0.547 | 0.864 | 0.523 | 0.909 | 0.767 | 0.289 | 0.447 |
| a. Grouping variable: Group = Training, Control | | | | | | | | | | | | | | | |

Table 7-15: Summary of the Mann-Whitney test statistic regarding the difference in driver behaviour for the light vehicle training and control drivers after the training

| Test Statistics, *a* | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Attribute1 | Attribute2 | Attribute3 | Attribute4 | Attribute5 | Attribute6 | Attribute7 | Attribute8 | Attribute9 | Attribute 10 | Attribute 11 | Attribute12 | Attribute13 | Attribute14 | Attribute15 |
| Mann-Whitney *U* | 68 | 69 | 75.5 | 65.5 | 61.5 | 65.5 | 64.5 | 66 | 54 | 69 | 71 | 69.5 | 50 | 74.5 | 70 |
| Wilcoxon W | 159 | 160 | 166.5 | 156.5 | 152.5 | 156.5 | 155.5 | 157 | 145 | 160 | 149 | 147.5 | 141 | 152.5 | 148 |
| *Z* | -0.573 | -0.515 | -0.143 | -0.71 | -0.942 | -0.72 | -0.76 | -0.678 | -1.379 | -0.514 | -0.402 | -0.489 | -1.604 | -0.203 | -0.465 |
| Asymp. Sig. (2-tailed) | 0.567 | 0.606 | 0.887 | 0.478 | 0.346 | 0.471 | 0.448 | 0.498 | 0.168 | 0.607 | 0.688 | 0.625 | 0.109 | 0.839 | 0.642 |
| a. Grouping variable: Group = Training, Control | | | | | | | | | | | | | | | |

The *Z* and *p* values for the comparisons in Table 7-14 and Table 7-15 suggest that there were no significant differences between the scores provided by the control group and those provided by the training group in both comparison; before and after the training as the *p* values were all greater than α (0.05). To that end, the training appears not to have significantly influenced the drivers' behaviours in the light vehicle category.

Assuming that there was no control group, the Wilcoxon signed-rank test (Walpole et al, 2012; Larson and Farber, 2012) was also applied to the before and after scores generated from using DSQ for the training group in order to find out if there were significant changes in driving behaviour within the group. The analysis results concerning all the attributes are summarised in Table 7-16 for the light vehicle drivers.

Table 7-16: Wilcoxon signed-rank test statistics regarding the change in driver behaviour before and after the training for the light vehicle drivers

| Attribute No. | Comparison Before and After the Training | Test Statistic,*b* | |
|---|---|---|---|
| | | *Z* | Asymp. Sig. (2-tailed), *p* |
| 1 | Do you sometimes fail to drive cautiously? | -0.054a | 0.957 |
| 2 | Do you dislike people who give you advice about you driving? | -1.406a | 0.16 |
| 3 | Do you sometimes drive when feeling tired? | -1.613a | 0.107 |
| 4 | How often do you forget to check your vehicle tyre pressure? | -0.557a | 0.577 |
| 5 | Do you drive fast? | -1.473a | 0.141 |
| 6 | Do you sometimes fail to apply smooth braking? | -0.289a | 0.773 |
| 7 | Do you sometimes forget to use block gear changes for example 1-3-5 0r 2-4-6? | -1.134a | 0.257 |
| 8 | Do you sometimes use the clutch control to balance the car whilst stationary? | -0.832a | 0.405 |
| 9 | Do you sometimes forget to plan ahead? | -0.979a | 0.327 |
| 10 | Do leave the vehicle engine on when it is not needed? | -0.586a | 0.558 |
| 11 | Do you sometimes forget to plan your journey? | -0.275a | 0.783 |
| 12 | Do you sometime forget to plan about loading the vehicle? | -0.491a | 0.623 |
| 13 | Do you forget to carry out necessary aerodynamic adjustments if available to reduce drag? | -1.931a | 0.05 |
| 14 | Have you ever doubted the benefits fuel efficient driving like fuel economy and safety? | -1.473a | 0.141 |
| 15 | Do you sometimes fail to get the support you need regarding fuel efficient driving? | -0.372a | 0.71 |
| *a*. Based on positive ranks. | | | |
| *b*. Wilcoxon Signed Ranks Test | | | |

The examination of the $Z$ and $p$ values for each of the paired comparison given in Table 7-16 revealed that the training did not educe statistically significant change in all the driving behavioural attributes used (i.e., for the $Z$ values, $p$ values were less than α (0.05)) except for attribute number 13 which was just statistically significant at 95% confidence interval (CI) ($Z$=1.931, $p$=0.05) towards driving for better fuel economy (a greater number of the drivers entered lower scores after the training). The driving attribute where significant change was registered is related to the use of aerodynamic adjustments to reduce drag. For light vehicle this was primarily concerned with the keeping the vehicle windows closed at higher speeds. However, given that the monitoring period (August 2012 to March 2013) is usually colder than the summer period in which part of the pre-training took place, it could be argued that the cold weather influenced the drivers to behave this way.

The corresponding quartile statistics for the comparison ranks related to the Mann-Whitney and Wilcoxon signed-rank tests above are provided in Appendix E-4. Since a control group was used in this study, the results of the Mann-Whitney test are recommended.

### 7.7.3 About the Training

Related to the above parametric tests, the drivers were also asked whether they thought the training was important or not or whether they were unsure about its importance (see Questionnaire in Appendix D-2). The results of the drivers' responses are shown in Figure 7.35 for the heavy/medium and Figure 7.36 for the light vehicles.

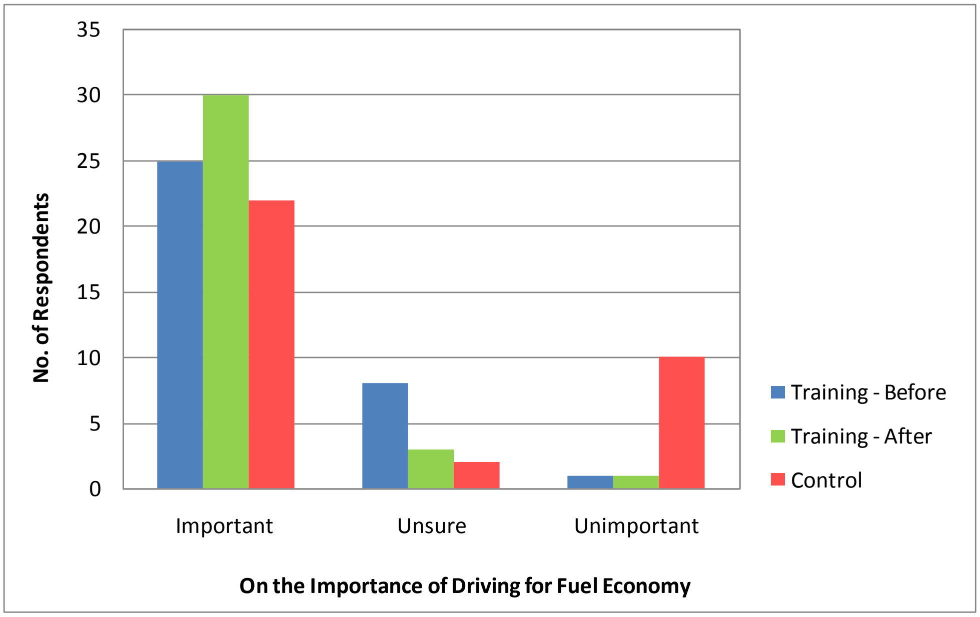



Figure 7.35: Drivers response regarding the importance of the training with regard to fuel economy (heavy/medium vehicle)

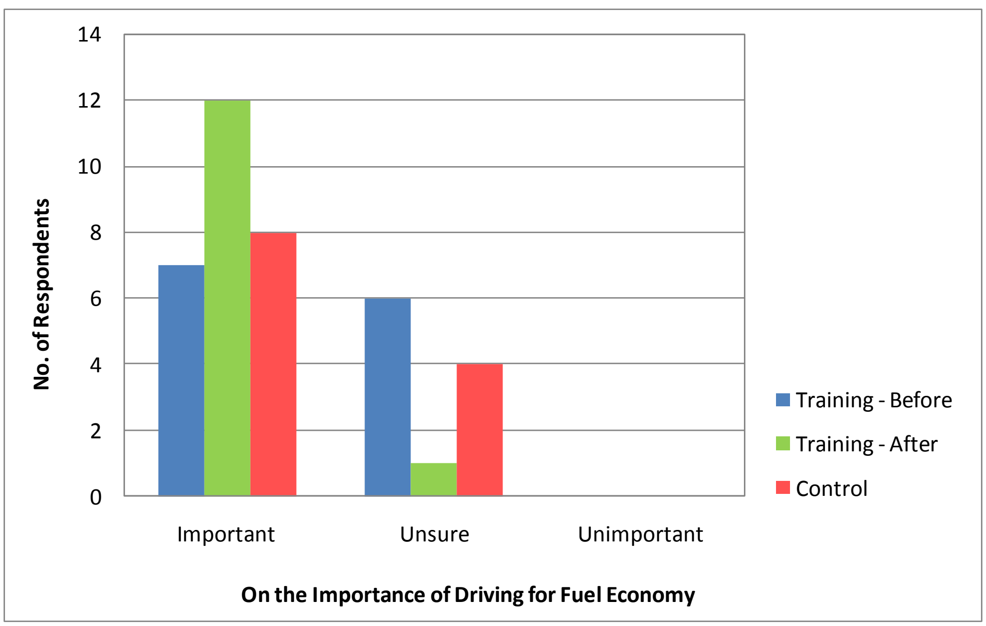



Figure 7.36: Drivers response regarding the importance of the training with regard to fuel economy (light vehicle)

The results show that after the training, the drivers became more aware about the importance fuel economy. The control group had a similar response to the training group before the training, which suggested that the control group was reliable.

### 7.7.4 Post-Training Feedback

The post-training feedback was provided to the drivers in the form of average monthly change in MPG by the vehicle category as shown in Figure 7.37. The feedback posted on the notice-board at the training depot.

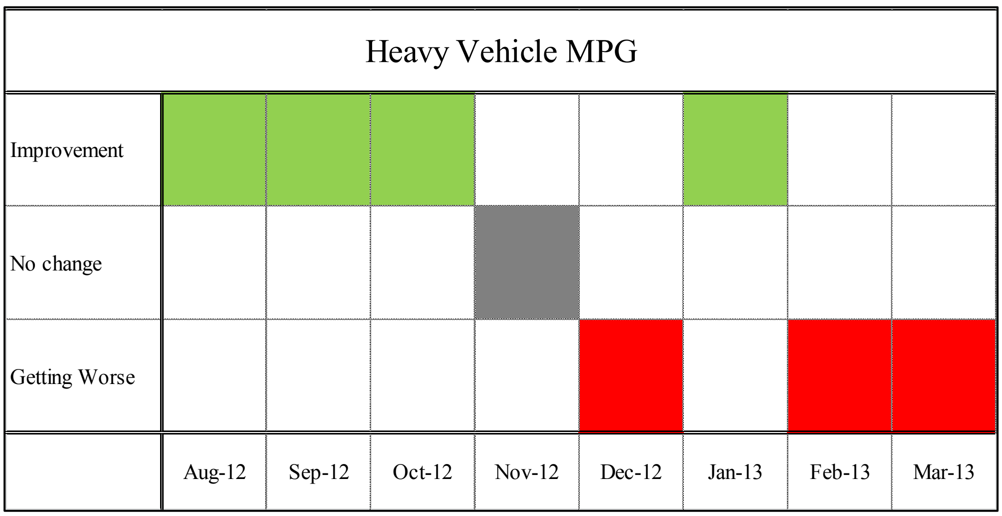



Figure 7.37: Provision of MPG performance feedback to the trained drivers

The trained drivers also had meetings with their supervisors and the trainer for various consultation topics related to the training. The consultations were mainly made through direct verbal discussions and the use of mobile phone calls. Some consultations were also made during the completion of the questionnaires. On average, about 5 consultations were received on a monthly basis after the training. Some of the consultations are summarised in Table 7-17.

Table 7-17: Frequency of monthly driver consultations after the large-scale training

| Consultation Topic | Month (Period 4) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Odometer | 2 | - | 1 | - | 1 | - | - | - |
| Leave | - | 1 | - | - | - | 1 | - | - |
| Performance | 1 | 4 | - | 1 | 1 | - | - | 1 |
| Drive sharing during a working shift | - | - | 1 | - | - | 1 | - | - |
| Limited driving between heavy and medium vehicle | - | - | - | - | 1 | - | - | 1 |
| Leaving job | - | - | - | - | - | - | - | 1 |

## 7.8 Summary

The results of the analysis carried out on the data regarding driver training for fuel economy of drivers working for Amey in the management and the operation of the motorway and trunk road network in the West Midlands in the United Kingdom were provided in this Chapter. The results includes the analysis of the annual vehicle-km, the average miles per gallon (MPG), change in MPG after training, trend and regression analysis, t-Statistic tests and the associated tabular and graphical representations. The results are discussed further in Section 8.6.

# CHAPTER 8 DISCUSSION

## 8.1 Introduction

The aim of this research project has been to investigate the possibility of designing and applying an effective and efficient driver training programme for fuel economy for drivers involved in road network maintenance and operations, through a greater understanding of the factors that affect vehicle fuel consumption. To this end, research objectives were devised to: (1) review and analyse vehicle fuel consumption as a component of the total road transport energy use (Chapter 2); (2) to identify the factors that affect vehicle fuel consumption (Chapter 2); (3) to review the influence of driving style on vehicle fuel consumption (Chapter 3); (4) to review existing driver training programmes for fuel economy (Chapter 4); (5) to prioritise the influence of attributes associated with driving for fuel economy to improve the effectiveness of driver training approaches (Chapter 5); (6) to design, apply and investigate the benefits of a cost effective driver training programme for fuel economy, relevant to drivers involved in road network maintenance and operations (Chapters 6 and 7), and; (7) to compare the costs and benefits of the training with the recommended national training approach for fuel economy in the UK (England) (Chapter 8). The degrees to which these objectives have been met in the research are discussed in the following sections.

## 8.2 Factors Affecting Vehicle Fuel Consumption

In Section 2.2.1 fuel consumption was shown to be the biggest component of total road transport energy use and in Section 2.2.2 the importance or impact of fuel consumption were related to economic activities, price, environmental and social impacts, and sustainability. Since these impacts are of global concern the factors which affect vehicle fuel consumption needed to be better understood. To this end, a framework was outlined (Figure 2.6) which can be used to identify and structure the factors that affect vehicle fuel consumption. In outlining the framework a focus was given to socio-technological factors associated with the driving environment, as opposed to other broader classifications of the factors which affect vehicle fuel consumption, like economic factors (e.g., supply, demand and cost of transport) and socio-economic and political factors (e.g., climate change, sustainability and energy security).

The factors identified were prioritised (ranked) in terms of their influence on vehicle fuel consumption, based on the mechanistic principle that fuel consumption is directly proportional to the forces opposing motion (Bennett and Greenwood, 2003). The mechanistic principle was used to group the factors, as shown in Table 2-2, including driver influence. The ranking was based on subjective views of vehicle fleet, road management and driver training professionals. The results suggested that vehicle-related factors like engine efficiency and drive-train efficiency are seen as the most influential factors affecting vehicle fuel consumption. Several authors (Kobayashi et al, 2009; Murrel, 1975; Bennett and Greenwood, 2003; Amann, 1977; Tolouei and Titheridge, 2009) support the finding. The results also suggested that interventions aimed at improving engine and transmission efficiencies are much more expensive than other interventions like driver training for fuel economy (Turpin and Scott, 2010; af Wåhlberg, 2006; af Wåhlberg, 2007), logistical planning (McKinnon et al, 1993), and improving road space utilisation to reduce traffic congestion (DfT, 2007).

The study also suggested that influencing drivers to drive more fuel economically could be the most cost-effective intervention to improve vehicle fuel consumption economy and this premise is also supported in the literature (see for example, Evans, 1979; Siero et al, 1989; Nader, 1991; Ericsson, 2001; van der Voort et al, 2001; af Wåhlberg, 2002; Parkes and Reed, 2005; af Wåhlberg, 2006; af Wåhlberg, 2007; Zarkadoula et al, 2007; Beusen et al, 2009; Symmons and Rose, 2009; Manser et al, 2010; Scott et al, 2012; Turpin and Scott, 2010; Luther and Baas, 2011). However, as described in Section 3.3.3, there are several challenges which are still thought to limit the potential benefits from driving more fuel economically including:

- Existing methods of training drivers have not yet been fully adapted to the needs of the drivers in terms of their local driving conditions;
- Methods of training do not fully engage the drivers so that the objectives and methods of the training are not accepted by the drivers;

- The monitoring of driver performance before and after driver training programme is still inadequate; the provision of feedback to drivers regarding the performance still needs to be improved. Moreover, this requires more accurate methods for recording or capturing the data;
- There is a need for driver training to be more cost effective, so that the training can be adopted by vehicle operators;
- There is still a lack of in-vehicle devices to provide the driver with continuous information regarding the driving actions to be carried out safely to improve their fuel economy; this could translate into what could be referred to as continuous driver training;
- Often there is a lack of clarity regarding the objective or purpose of the training; say, fuel economy, driver 'spying' or safety. The objective of the driver training needs to be clear in order to avoid potentially competing and conflicting driving goals, and to create confidence within the drivers.

The use of in-vehicle devices did not form part of this research; however, as described in Section 3.3.4, several studies have been conducted in this area.

## 8.3 Driving Style and Vehicle Fuel Consumption

In Section 3.2 driving style and its influence on vehicle fuel consumption was reviewed. The review showed that the influence of driving style on vehicle fuel consumption has been known for decades. It was also found that several methods have been used to classify driving styles with regards to vehicle fuel consumption. For example, Cacciabue and Carsten (2010) identified behavioural factors, which affect driving style including experience, attitude, task demand, driver state and situation awareness, as summarised in Table 3-1.

In order to improve or maximise the potential performance of a driver with regard to improved fuel economy, an individual's behavioural factors need to be changed (or influenced to change). Cacciabue and Carsten (2010) further suggested parameters (see Table 3-1) that could be used as a measure of these behavioural factors. It was also observed that, while some of the factors could be influenced through driver training (see literature review in Section 3.2.2), others were difficult, if not impossible to change (e.g., driver experience). In this training approach, the change observed in the MPG of the drivers is assumed to be related to the influence of the training on the factors, as discussed in Section 8.6.2. Although some of the behaviours that are known to influence driver fuel economy were observed to change statistically significantly, the changes have not been apportioned to the individual factors. Hypothesis tests related to the specific characteristics of the drivers have been recommended for further research in Section 9.5. Indeed, in the literature review (see literature review in Section 3.3) it was suggested that, where improvements in fuel economy were achieved after driver training, it was difficult to assign such improvements to particular parameters (or behaviours) related to driving style. Some literature (Berry, 2010; Virtos, 2010; Jenness et al, 2009; Cacciabue and Carsten, 2010) suggests that this could be due to lack of appropriate driver models based on accurate data regarding the specific driving style, and it has been suggested that both driver behaviour and fuel consumption need to be collected at a level which can support the relevant modelling.

## 8.4 Driver Training Methods for Fuel Economy

A review of driver training methods for fuel economy was carried out in Section 4.2. It was found that, in the UK, the Department for Transport has developed a method known as the safe and fuel efficient driving training (SAFED) method which may be regarded as the national standard with respect to driver training for fuel economy, while in continental Europe, an analogous method called EcoDriving has been developed (Barkenbus, 2010). Both training methods have been mainly targeted at helping existing drivers to improve their vehicle fuel economy, but there were also other objectives of the training, for example, the SAFED training is also aimed at improving road safety.

It was also observed that the Driver Certificate of Professional Competence (Driver CPC) training for professional bus, coach or lorry drivers in the European member states also contains a fuel economy element, which is not mandatory (JAUPT, 2010) potentially suggesting lack of regulatory support with respect fuel economy initiatives.

In Section 4.3 several ways were suggested which could help to maximise the benefits, in terms of improvements in fuel efficiency, of the existing driver training methods. The suggested ways were described under the pre-training, during training and post-training stages. It was also found that the pre-training and the post-training stages were not focused on as much as the actual training events, yet the literature (DfT, 2006c; Bryman, 2001; Siero et al, 1989; DfT, 2008; Turpin and Scott, 2010) suggested that the pre-training stages are a very important element if the training is to be successful.

In-vehicle driver feedback devices, based on real-time driving data, are emerging as useful ways for improving of driver fuel economy. These systems could improve both the short-term and long-term improvements in fuel economy of the drivers (besides other performance areas like safety and journey times) following related advice or training. Several recent studies including those carried out by Jenness et al (2009), Cacciabue and Carsten, 2010; Manser et al (2010) and ecoDriver Project (2013) suggest that the improvements associated with such systems could be related to several areas, including:

- The use of finer and real-time data to provide information regarding performance and feedback to the drivers;
- Provision of guidance to the drivers using an optimised human–machine interface (HMI) to provide guidance to the drivers to improve performance;

## 8.5 Driving Attributes for Fuel Economy

The driving attributes were identified in Section 4.5 and were related to the factors which influenced vehicle fuel economy or consumption. The factors were prioritised using a rational method known as the Analytical Hierarchy Process (AHP) in terms of their influence on fuel economy when driving (see Chapter 5). The results of the prioritisation (see Table 5-5) ensured that appropriate focus was given to the most influential attributes during the driver training. The results showed that the experts consulted thought that acceleration events and speed have the highest influence on vehicle fuel consumption, followed by the need for culture change and management aspects, while driver fatigue has the least influence. These results from the consultation process may be regarded as having some bias since the chosen experts were trainers of drivers for improving safety and fuel economy.

The driver trainers are tasked with imparting skills to their drivers related to both safe driving and driving for fuel economy. A number of authors (for example, Haworth and Symmons, 2001; Young et al, 2011; af Wåhlberg, 2006) suggest that there is a broad overlap between safe driving and eco-driving (driving to improve fuel economy). According to Young et al (2011), for example, both speed and acceleration have similar impacts on safe driving and eco-driving; speed being much more related to safe driving than eco-driving, and acceleration being much more related to eco-driving than safe driving. Theoretically, some eco-driving techniques could have a negative influence on safety, e.g., avoiding harsh braking when one's driving is interfered by another road user and maintaining constant speeds. However, for real-world driving conditions, the supporting literature is rare. It is most likely that driver fuel economy improvements are benchmarked against their normal real-world driving conditions where drivers are expected to drive safety. Indeed many driver training studies have suggested that there are associated reductions in accidents (Young et al, 2011). Therefore, attributes identified and used in this research could also be related to safe driving, however, a separate analysis and ranking would be required with respect to the influence of the attributes on safe driving.

## 8.6 Driver Training Study

The driver training carried out was described in Chapter 6, and the results reported and described in Chapter 7. The influence of the full- or large-scale training in terms of fuel economy (Sections 7.3 to 7.5) and driving style (Section 7.6.3) are discussed in the following sections. The results of the training are also compared to those of the SAFED programme in the later part of this Chapter (i.e., Section 8.6.3) in terms of the short-term and long-term improvement in driver fuel economy. Further comparison of the training programmes was in terms of their costs and benefits over selected training regimes (intervals).

### 8.6.1 Influence of the Training on Fuel Economy

#### *8.6.1.1 Short-term Effect*

The greatest effect of the training in terms of the improved driver MPG was noticed in the first month after the training for all the vehicle categories. This is consistent with other studies (Siero et al, 1989; Park and Reed, 2005; af Wåhlberg, 2007; Turpin and Scott, 2010) where such improvement was noticed immediately after the training. The average improvements in the first month after the training were about 6% for the heavy vehicle, about 7% for the medium vehicle and about 3% for the light vehicle categories. As described in Section 3.3.1, Siero et al (1989) found about 7% improvement after training van drivers while Turpin and Scott (2010) found about 8% improvement in van (medium) vehicle and less than 2% in heavy vehicle in the first month after SAFED training. On average, the improvement in the average MPG for HGV seems much higher (3 times) than that reported by Turpin and Scott (2010).

The observed improvements in the average MPG in the first month of the training was only statistically significant (at 95% confidence interval) for the light vehicle. Turpin and Scott (2010) also reported that the improvements in the medium and heavy vehicle categories were not statistically significant at this level. Therefore, although the improvements in the average MPG can still translate into real savings in monetary terms (and other non-fuel saving benefits like vehicle sympathy and safety) the results cannot be applied to the wider population of the drivers involved in road network maintenance and operations. Even for the light vehicle category where the improvement in the first month after the training was found to be statistically significant (at 95% confidence interval), the improvements there after were not.

#### *8.6.1.2 Long-term Effect*

Generally, the effects of the training, in terms of the improved average MPG, decreased over time, as shown in Section 7.4. The improvements in the average MPG were found to disappear from between 5 to 7 months from the training. The study reported by Turpin and Scott (2010) suggested that the effect of SAFED training would disappear after 9 and 14 months for heavy and medium vehicle categories respectively. There is not much literature regarding the longevity of the benefits of driver training for fuel economy. Based on the results of the training undertaken in this research and existing literature (Siero et al, 1989; Park and Reed, 2005; af Wåhlberg, 2007; Turpin and Scott, 2010), the benefits of the training diminish with time and thus there is a need for regular training renewal. The improvement of the average MPG were statistically insignificant although the test statistics for the heavy and medium vehicles were much closer to the critical values for a few months after the training, as summarised in Table 7-1, Table 7-2 and Table 7-3.

#### *8.6.1.3 Predicting the Effect of Training and HDM-4*

In Section 7.6 an analysis was carried out to develop models to predict the improvement in the average MPG for the drivers as a function of time (in month). The analysis suggested that the logarithmic and the linear model forms could be suitable for the task, as the prediction variables used were statistically significant, as given by the $p$ values. However, the overall model regression in terms of the $R^2$, were about 0.7 thus about 70% of the improvement in MPG could be explained and therefore predicted by the selected variables in the equations. The suggested model structure should be used with caution because the observed changes in the MPG were not statistically significant; also the post-training events need to be considered, for example, in this training, the post-training events (described in Section 7.7.4) involved the provision of feedback to the drivers in the form of postings (average performances) on the notice-board in the training depot; a leaflet with suggestions to improve fuel economy was also provided to each trained driver.

The Highway Development and Management (HDM-4) tool is the result of the International Study of Highway Development and Management (ISOHDM) that was carried out to extend the scope of the World Bank HDM-III model. The HDM-4 tool can be used to assess technical, economic, social and environmental impacts of particular investments in roads, for both MT and NMT modes of transport (Odoki and Kerali, 2000). Several road investments worth billions of UKP across the world have been justified with the HDM-4 tool over the last decade (World Bank, 2014).

The prediction of the influence of driving style on the vehicle fuel consumption ($\Delta FUEL_T$), the key energy cost in road transport, is still deficient in HDM-4, however, a model (see Figure 2.10 and Equation 2.1) has been suggested as a result of the present research. The regression analysis carried out is an attempt to provide models that can be used to predict the performance of drivers or groups of drivers for specific training regimes within the road network being investigated, in this case, drivers of Amey vehicles in the West Midlands, UK.

Further work (see Section 9.5) will be required to develop robust models for such predictions in HDM-4.

### 8.6.2 Influence of the Training on Driving Behaviour

The influence of the training on driver behaviour was measured in terms of the driving attributes associated with vehicle fuel economy. The methodology used was described in Section 6.6.5.2 and the results in Section 7.6.3. Statistically significant changes (at the 95% confidence interval) towards better fuel economy were observed in the following attributes for the heavy/medium vehicle category based on the results from the Mann-Whitney test:

1. Driving cautiously;
2. Clutch control; and,
3. Planning when loading the vehicle.

The changes in the attributes were not statistically significant (at 95% confidence interval) for the light vehicle category. The changes in the attributes could be associated with the improvement in the average MPG because the improvements in fuel economy of the drivers of heavy/medium vehicles were greater than those of the light vehicle. Further analysis suggested that the attributes that were thought to have the greatest influence on fuel economy did not change as much as those which were thought to have lesser influence according to the experts' priorities given in Table 5-5. The improvement in the fuel economy of the drivers is likely to have resulted from changes in driving behaviour associated with fuel economy; however, it is still difficult to apportion the change to specific factors without better data capture techniques and finer models.

### 8.6.3 Training Comparison with SAFED

#### *8.6.3.1 Rationale, Assumptions and Data*

The costs and benefits regarding fuel economy for the training carried out in this study were compared to that of the SAFED training reported by Turpin and Scott (2010). The report by Turpin and Scott was obtained from the Department for Transport (DfT), UK, to support the analysis. The comparison covered heavy and medium vehicle categories as these were the only vehicle categories covered in the study reported by Turpin and Scott (2010). There was limited description of the driving tasks associated with the groups trained in the study reported by Turpin and Scott (2010); therefore, the comparison was based on the average performance of the entire groups. The training comparison period of 12 month was used as this period approximated the retention periods reported by Turpin and Scott (2010).

There is currently no national guidance regarding the training regimes for fuel economy, however, fleet managers are advised to monitor the performance of their drivers so that training renewal is carried out periodically. The training carried out in this study can be easily renewed due to its low cost so it was assumed that the training could be renewed whenever the improvement in the MPG reaches zero.

It was also assumed that the reduction in the improvement of the average MPG after the training followed a linear model, as reported by Turpin and Scott (2010) and also found in this training. The comparison was carried out over the longevity of the benefit (improvement in MPG) of the SAFED training, called the training comparison period in Figure 8.1. Thus the benefits of the training programme were proportional to the areas under the curves, as shown in Figure 8.1. The benefits of the Amey based training over the SAFED training for the comparison period is proportional to area *C* less area *B* in Figure 8.1. The longevity parameters used in Figure 8.1 for the medium and heavy vehicle categories are outlined in Section 8.6.1.2.

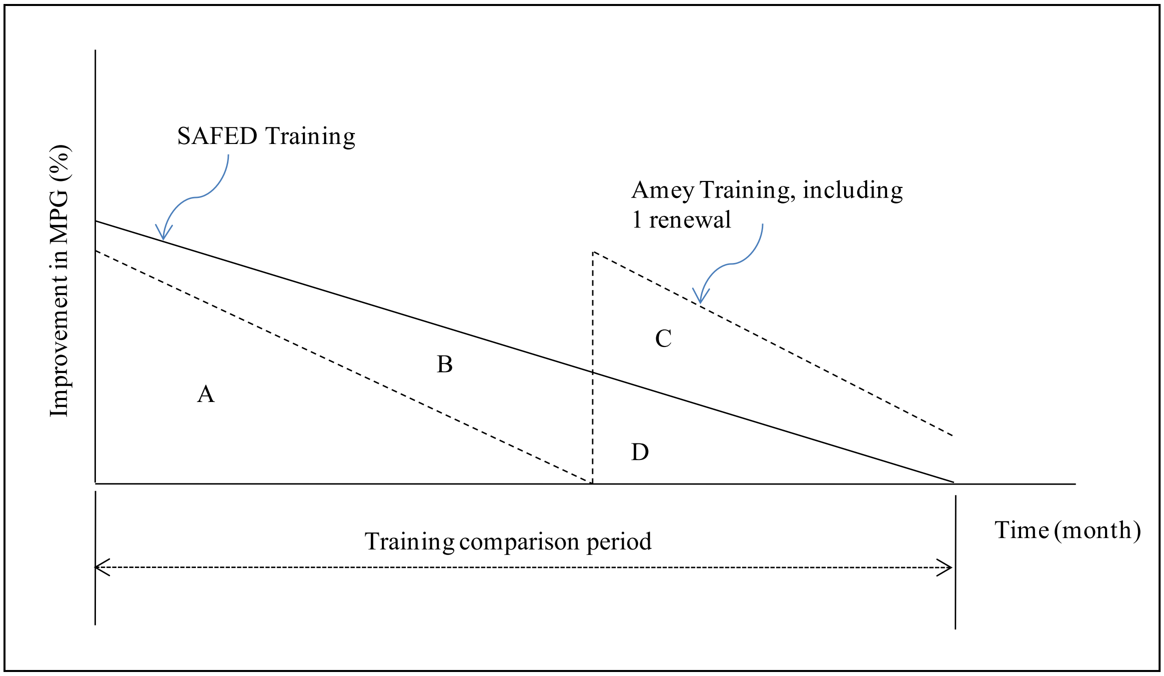



Figure 8.1: Illustration of the approach used to compare the benefits of the SAFED and the method developed herein

The data sets regarding the costs of training were collated from the training providers and beneficiaries in England, as summarised in Table 8-1. The costs cover the provision of training, travel to/from the training, the current industry hourly rate for medium and heavy vehicles drivers and the average length of a working day.

Table 8-1: Data regarding training costs

| Item | Cost | Remark |
|---|---|---|
| Training | 1. £278/delegate for heavy<br>2. £225/delegate for medium | 1. The standard SAFED training duration is 1 day<br>2. The total number of rates used was eight (8) |
| Travel | £50.00 | The distribution of training providers in England was considered |
| Duration of working day | 8 hours | DfT (2011c) |
| Hourly rate | £10.00 | WebTAG (DfT, 2003b) |
| Average annual distance travelled | 22,500 km | DfT (2011c) |
| Fuel cost/litre (diesel) | £1.39 | DECC (2011) |

#### 8.6.3.2 Summary of Results

The results of the comparisons are summarised for the heavy and medium vehicle categories as shown in Table 8-2 and Table 8-3 respectively. The costs of providing the training provided to the Amey drivers have been neglected because the training was carried out in the work depot and potentially by the drivers' depot managers. The training was also carried out before the start of the drivers' work shift.

The analysis results (for both drivers of heavy and medium vehicle categories) suggest that the SAFED driver training might not be economically beneficial when the cost savings from improved fuel efficiency are offset by the cost of providing the training and the longevity of the benefits. Therefore, even if the SAFED training appeared to have a better longevity than that of the method developed as part of this research, this training method could yield higher net benefits in term of fuel economy. Moreover, the training method proposed herein could be delivered to several drivers at the same time.

Table 8-2: Training comparison between Amey based training and SAFED in terms of costs related to the improvement in fuel economy for a heavy vehicle driver

| Training | | | SAFED | Amey |
|---|---|---|---|---|
| Costs | Training | | £278.00 | |
| | Travel | | £50.00 | |
| | *Duration of working day* | *8 hours* | | |
| | *Hourly rate* | *£10.00* | | |
| | Lost production | | £80.00 | £20.00 |
| Benefits (MPG) | *Average annual distance travelled* | *22,500 km* | | |
| | *Fuel cost/litre (diesel)* | *£1.39* | | |
| | *Comparison period* | *12 months* | | |
| | *Estimated fuel use, SAFED (10.5 MPG) in litre* | *6,053* | | |
| | *Estimated fuel use, Amey, heavy (8.5 MPG) in litre* | *7,478* | | |
| | *Adjusted fuel use, SAFED, 1% average monthly improvement in litre* | *5,993* | | |
| | *Adjusted fuel use, Amey, 3% average monthly improvement in litre* | *7,253* | | |
| | Benefits | | £84.14 | £311.81 |
| Net Benefit (Benefits less Costs) | | | £-323.86 | £291.81 |

The results of the training provided to the drivers at Amey suggest that: drivers are able to take advice regarding driving for better fuel economy (see also Young et al, 2011); the improvement in terms of fuel economy diminishes after the training; by improving the provision of the training to the drivers the benefits of the training in terms of fuel economy could still be improved both in the short-term and long-term. The training optimisation could cover improvement in the method of the training from the pre-training to post-training periods.

Table 8-3: Training comparison between Amey based training and SAFED in terms of costs related to the improvement in fuel economy for a medium vehicle driver

| Training | | | SAFED | Amey |
|---|---|---|---|---|
| Costs | Training | | £225.00 | |
| | Travel | | £50.00 | |
| | *Duration of working day* | *8 hours* | | |
| | *Hourly rate* | *£10.00* | | |
| | Lost production | | £80.00 | £20.00 |
| Benefits (MPG) | *Average annual distance travelled* | *22,500 km* | | |
| | *Fuel cost/litre (diesel)* | *£1.39* | | |
| | *Comparison period* | *12 months* | | |
| | *Estimated fuel use, SAFED (25.5 MPG) in litre* | *2,493* | | |
| | *Estimated fuel use, Amey, heavy (17.5 MPG) in litre* | *3,632* | | |
| | *Adjusted fuel use, SAFED, 4% average monthly improvement in litre* | *2,393* | | |
| | *Adjusted fuel use, Amey, 3% average monthly improvement in litre* | *3,523* | | |
| | Benefits | | £138.53 | £151.45 |
| Net Benefit (Benefits - Costs) | | | £-216.42 | £131.45 |

The comparison above has been based on the assumption that both the Amey drivers and the SAFED trained drivers are from the same population which is not true; a better comparison would involve the provision of the two training to sub-groups of drivers (from the same population, say, Amey drivers only under similar conditions) and then comparing the results. This is a recommendation for further research in Section 9.5.

### 8.6.4 Limitations of the Training

The training provided to drivers from Amey had some limitations which, if addressed, could lead to improved results. The main limitations were as follows:

- The training was provided to the drivers on a group basis. Therefore, although there were savings in terms of time spent training the drivers, the training may not always have met the individual needs of each of the drivers;
- The trainer was not a qualified driver trainer for fuel economy. Therefore, the effectiveness of the training may not have been maximised. However, the training material was developed based on a rigorous review of the attributes which influence vehicle fuel consumption and supported by expert views of the qualified SAFED instructors;
- The number and choice of the drivers to be trained was limited to those who were available at the selected training depot. A more thorough study of this nature would require a sample size of about 400 participants (see Larson and Farber (2012) for formulae regarding the estimation of population sample sizes) for an adequate representation of the population of such drivers, given the estimation statistics chosen in this study. However, as stated in Section 6.3.2, the number of drivers used in this study was limited by those that were available on the contract and, specifically, at the selected work depots. Therefore, a recommendation has been made in Section 9.5 to increase the sample sizes in future studies;
- Although the data capture device was sufficient to collect the data for the study, additional data regarding behaviours could also have been captured through other devices linked to GPS and vehicle electronic control units (ECU), as suggested by Virtos (2009), Murphy et al (2009), Berry (2010) and Manser et al (2010) among others, in order to improve the scope and accuracy of the data. Other specific data issues were discussed in Section 6.6.1;
- The time constraint was another factor which meant that additional investigations and testing of other hypotheses which may have been of importance were not carried out. These have been identified as future work in Section 9.5.

The summary of this chapter is provided below.

## 8.7 Summary

This Chapter has discussed to what extent the objectives of the research have been met. The discussion focused on the training method developed in the project and provided to the drivers from Amey. It was observed that the improvements in terms of improved MPG from the training could yield net economic benefit to meet or exceed that which can be achieved with a more formal training like the safe and fuel efficient driving (SAFED) training. The results showed that the improvements in the average drivers' MPG were not sufficiently statistically significant at 95% confidence interval to be transferred to the wider population of the drivers involved in road network maintenance and operations or similar works. However, there is potential economic benefit for similar businesses investing in such training and such savings could be enhanced by increasing the frequency of the training renewals.

Driver behaviour associated with fuel economy were found to change towards a better fuel economy even more so in cases where there was marked improvements in the drivers fuel economy performance. The findings suggest that more specific and targeted training methods for fuel economy, like the one developed here, could produce net economic benefit, given the level of investment required, or costs incurred, to meet or exceed that due to more a formal training like SAFED.

# CHAPTER 9 CONCLUSION AND FURTHER RESEARCH

## 9.1 Accomplished Work

The work carried out and reported in this thesis mainly concerned the design, application and analysis of a more effective and efficient training programme for fuel economy for drivers involved in road network maintenance and operations. In order to ensure that appropriate focus was given to the most influential driving techniques or attributes during the training, a number of such driving attributes were identified and prioritised based on literature and the use of a driving style questionnaire (DSQ). A multi-criteria analysis (MCA) method, the analytical hierarchy process (AHP), was used to prioritise the driving attributes. The driver fuel miles per gallon (MPG) performance and behaviour were assessed before and after the training by means of a fuel management system (FMS) and a DSQ. Statistical analysis and tests were carried out to evaluate the influence of the training on fuel economy and the driving style.

## 9.2 Key Conclusions

The key conclusions from the work concerning the driver training for fuel economy are as follows:

1. Driver training for fuel economy can be used to improve the performance of the exiting drivers in terms of their MPG, even for those involved in road maintenance and operations;
2. The benefit of driver training for fuel economy, in terms of improvement in MPG, decays overtime at different rates depending on vehicle category, suggesting that the refresher training regimes could also vary by the vehicle category;
3. Speed and acceleration events are known to be the most influential driving factors or attributes which affect driver fuel economy. Therefore, by avoiding high speeds and maintaining uniform speeds as much as possible, fuel economy could improve;
4. By improving the specification of driver training or feedback methods to meet the specific needs of the drivers, the benefits of the training could improve;

5. The training methodology described in this research could be more effective and efficient than the more formal, nationally recommended training programmes like the safe and fuel efficient driving (SAFED) training.

## 9.3 Findings of the Research

The findings of the research work are as follows:

1. The benefits from driver training for fuel economy by, for example, by optimising the training or by using other feedback methods could still continue to improve;
2. AHP was used to prioritise the influence of the 15 driving attributes or factors on fuel economy. The 5 most influential attributes were found to be:
   - Speed and acceleration;
   - Management aspects;
   - Culture change issue;
   - Gear change or selection; and,
   - Braking.
3. The improvements in fuel economy (MPG) in the first month after the training carried out in this project was about 6% for the heavy, 6% for the medium and 3% for the light vehicle drivers;
4. The improvements in fuel economy (MPG) after the training carried out in this project decayed at varying rates; the improvement disappeared after 5 months from the training for the heavy vehicle category, 7 months for the medium and 4 months for the light vehicle categories. This suggests that the refresher training regimes could also vary by the vehicle category;
5. As suggested by previous studies (for example, af Wåhlberg, 2007; Turpin and Scott, 2010) influence of the driver training in terms of improvement in the drivers' MPG were generally not found to be sufficiently statistically significant at the 95% confidence interval to be applied to the wider population of the drivers involved in road management and operations, or similar work;
6. Even if the t-Tests showed that the improvements in the drivers’ MPG after the training interventions were not sufficiently statistically significant at 95% Confident Interval (CI), regression analysis was conducted using the results. This is because the

methodology and the analysis results could provide a basis for future modelling or tests based on improved data or methods as described in Sections 4.3 and 4.4 and recommended under future research work in Section 9.5. After a series of regression analysis, it was found that a linear or logarithmic model could be used to predict the drivers' performances in terms of the change in MPG after training;

7. Statistical tests were also applied to assess potential changes in drivers' behaviours towards better fuel economy, measured in terms of the driving attributes related to fuel economy. Statistically significant results at 95% confidence interval were observed among the heavy/medium vehicle drivers. To this end the training could be applied to the wider population of the drivers involved in road management and operations to influence specific behaviours towards driving for better fuel economy;
8. Analysis of the results suggest that the driver training provided to the drivers involved in road management and operations was more cost effective than the safe and fuel efficient driving training (SAFED) developed by the Department for Transport (DfT) in the UK. The analysis was based purely on the comparison of the costs and benefits of the training programmes in terms of fuel economy.

## 9.4 Contribution and Applicability of the Research

The following are the contribution and applicability of the research:

1. The factors affecting vehicle fuel consumption (which is the most significant component of total road transport energy use, see Section 2.2.1) have been outlined using a simplified representation of the traffic operating environment. Further, work is still recommended to study the various factors in detail as categorised in Section 2.3.2;
2. The driving attributes associated with driving for fuel economy were identified and prioritised (see Chapter 5) to inform interventions like driver training or other feedback methods aimed at improving drivers fuel economy performances;
3. A driver training programme for drivers involved in road network maintenance and operations has been designed and tested (see Chapter 6); the training methodology could be applied to other drivers (drivers not involved in road work activities) because the principles for the fuel economy are similar;

4. A methodology for comparing the benefits of the driver training provided to the drivers involved in road management and operations with SAFED, in terms of life-cycle costs and benefits, has been demonstrated (see Section 8.6.3). This could provide guidance for other future comparisons.

## 9.5 Further Research Work

The following recommendations are made for further research work:

1. To improve the number of the participants so that more representative samples of the population could be used for such future training;
2. To improve the composition of the participants to include other groups which have not been captured or investigated, for example, female drivers;
3. To conduct additional hypothesis tests related to the characteristics of the drivers like experience, gender and age;
4. To monitor the performance of the participants over a longer periods of time so that the related pre- and post-training initiatives could be investigated, for example, to improve refresher training;
5. To improve the method of capturing the data so that more fine-tuned data sets, including fuel use and driver behaviours, could be used for better investigations;
6. To adopt the suggested improvements (outlined as items 1 to 5 above) to develop more robust models for integration into the Highway Development and Management (HDM-4) tool for road investment appraisal. These models should be able to represent the population of the drivers using the road network under study. This would require knowledge of the various training approaches adopted and the associated maintenance or training renewal regimes to be captured by the models, for the whole of the analysis period. Similarly, the models should also consider other driver feedback methods that are not necessarily based on the traditional training approach, such as vehicle-driver interfaces (see ecoDriver, 2012);
7. To improve the comparison between the training approach developed in this research study and other training programmes like SAFED;

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# APPENDIX A

## Appendix A-1 Questionnaire for the General Factors Affecting Vehicle Fuel Consumption

**FACTORS AFFECTING VEHICLE FUEL CONSUMPTION**

Thank you for taking the time to attend this interview. The information that you will provide will help me to carry out a research into road transport energy use efficiency. The information will only be used for the purpose of the research. I believe that the outcomes of my research will benefit the transport sector in the UK.

Prior to use of any extraction from the results of the interview you will be notified for permission, for examples, publication and thesis reports.

**(A0) General information**

Interviewee (respondent) ..............................................................................................

Role ..............................................................................................

Company/Institution ..............................................................................................

Date of interview ..............................................................................................

Time Start............................................End....................................

**(A0) Researcher Contacts**

**Robert Akena**
College of Engineering and Physical Sciences
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Birmingham
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**(9) Please rate the impact of each of the following specific factors on fuel consumption efficiency**

| | | Car | | | | | Heavy Goods Vehicle | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| **Resistance** | **Factor Affecting Fuel Consumption** | | | | | | | | | | |
| Aerodynamic resistance | Vehicle dimensions | | | | | | | | | | |
| | Vehicle speed | | | | | | | | | | |
| | Wind speed | | | | | | | | | | |
| | Air density | | | | | | | | | | |
| | Aerodynamic aids | | | | | | | | | | |
| | Temperature | | | | | | | | | | |
| | Altitude | | | | | | | | | | |
| | | | | | | | | | | | |
| | Other-state.................. | | | | | | | | | | |
| | Other-state.................. | | | | | | | | | | |
| Rolling resistance | Vehicle weight | | | | | | | | | | |
| | Macro-texture | | | | | | | | | | |
| | Road roughness | | | | | | | | | | |
| | Road strength (Flexible) | | | | | | | | | | |
| | Vehicle speed | | | | | | | | | | |
| | Tyre and wheel characteristics | | | | | | | | | | |
| | Climate (e.g. Seasons) | | | | | | | | | | |
| | | | | | | | | | | | |
| | Other-state.................. | | | | | | | | | | |
| | Other-state.................. | | | | | | | | | | |
| Inertial resistance | Vehicle weight (mass) | | | | | | | | | | |
| | Engine and drive-train weight (mass) | | | | | | | | | | |
| | Wheels weight (mass) | | | | | | | | | | |
| | Acceleration | | | | | | | | | | |
| | | | | | | | | | | | |
| | Other-state.................. | | | | | | | | | | |
| | Other-state.................. | | | | | | | | | | |
| Gradient resistance | Vehicle weight | | | | | | | | | | |
| | Road gradient | | | | | | | | | | |
| | | | | | | | | | | | |
| | Other-state.................. | | | | | | | | | | |
| | Other-state.................. | | | | | | | | | | |

| Resistance | Factor Affecting Fuel Consumption | Car 1 | Car 2 | Car 3 | Car 4 | Car 5 | Heavy Goods Vehicle 1 | Heavy Goods Vehicle 2 | Heavy Goods Vehicle 3 | Heavy Goods Vehicle 4 | Heavy Goods Vehicle 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Curving resistance | Vehicle weight | | | | | | | | | | |
| | Curve geometry | | | | | | | | | | |
| | Tyre and wheel characteristics | | | | | | | | | | |
| | | | | | | | | | | | |
| | Other-state.................. | | | | | | | | | | |
| | Other-state.................. | | | | | | | | | | |
| Vehicle related resistance | Engine drag | | | | | | | | | | |
| | Accessories | | | | | | | | | | |
| | Engine base efficiency | | | | | | | | | | |
| | Engine fuel efficiency (fuel types) | | | | | | | | | | |
| | Drive-train efficiency | | | | | | | | | | |
| | Engine idling | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | Other-state.................. | | | | | | | | | | |
| | Other-state.................. | | | | | | | | | | |
| Driver related | Driver training | | | | | | | | | | |
| | Fuel use monitoring | | | | | | | | | | |
| Congestion impact | Congestion impact | | | | | | | | | | |
| General | Aerodynamic resistance | | | | | | | | | | |
| | Rolling resistance | | | | | | | | | | |
| | Inertial resistance | | | | | | | | | | |
| | Gradient resistance | | | | | | | | | | |
| | Curving resistance | | | | | | | | | | |
| | Vehicle related resistance | | | | | | | | | | |
| | Driver related | | | | | | | | | | |
| | Congestion impact | | | | | | | | | | |

1 = very low 2 = low 3 = medium 4 = high 5 = very high

**End of the pre-interview questionnaire, and thank you**

**Comments**

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**Once again, thank you for taking the time to complete the questionnaire.**

## Appendix A-2 Interview Form for the General Factors Affecting Vehicle Fuel Consumption

### FACTORS AFFECTING VEHICLE FUEL CONSUMPTION

Thank you for taking the time to attend this interview. The information that you will provide will help me to carry out a research into road transport energy use efficiency. The information will only be used for the purpose of the research. I believe that the outcomes of my research will benefit the transport sector in the UK.

Prior to use of any extraction from the results of the interview you will be notified for permission, for examples, publication and thesis reports.

**(B0) General information**

Interviewee (respondent) ....................................................................................

Role ....................................................................................

Company/Institution ....................................................................................

Date of interview ....................................................................................

Time Start............................................End....................................

**(B0) Researcher Contacts**

**Robert Akena**
College of Engineering and Physical Sciences
School of Civil Engineering
University of Birmingham
Birmingham
B15 2TT
Tel: 07533293096 Email: rpa321@bham.ac.uk

**(B1) Definition:**

**How do you define and measure fuel consumption efficiency in your business?**

**(B2) Of what importance is fuel consumption efficiency to your business?**

**(B3) What is your present (short-term) challenges regarding fuel consumption efficiency?**

**(B4)** **What actions are you currently (short-term) taking to tackle the challenges in (B3)?**

**(B5)** **What is your future (long-term) challenges regarding fuel consumption efficiency?**

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**(B6) What actions are/will you (long-term) taking to tackle the challenges in (B5)?**

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**(B7) What policies is your organisation using to improve fuel consumption efficiency in terms of the following aspects (short-term and long-term)?**

(a) Aerodynamic resistance

(b) Rolling resistance

(c) Inertial resistance

(d) Gradient resistance

(e) Curving resistance

(f) Vehicle-related resistance

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(g) Driver-related impacts

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(h) Congestion impacts

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**(B8) Where do you see the biggest opportunity for improving transport fuel efficiency (short-term and long-term on a scale of 1-5)?**

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**(B9) Regarding question in (B8) what would be the relative costs associated with these opportunities on a scale of 1-5?**

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**End of the Interview, and thank you**

**Comments**

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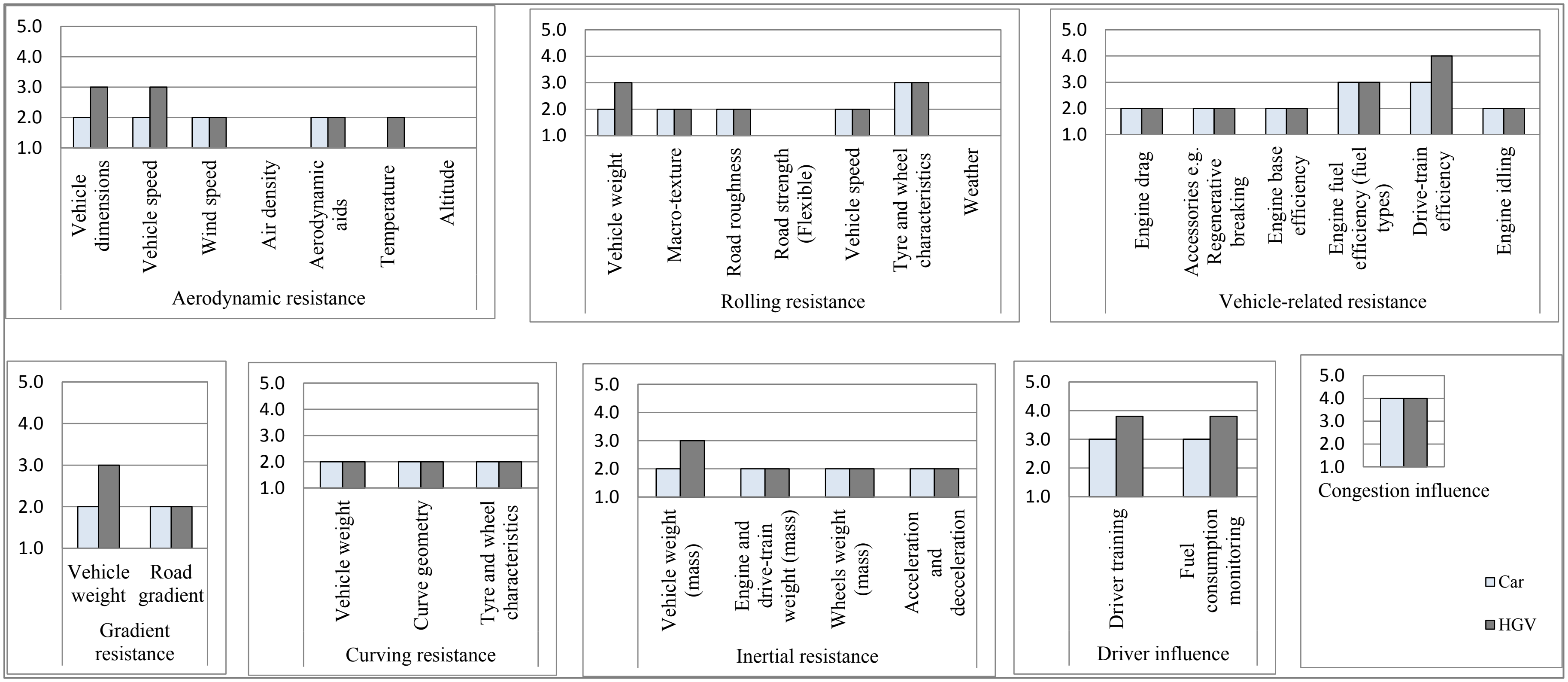
**Once again, thank you for taking the time to attend the interview.**

Appendix A-3 Categorised and prioritised influence of the factors affecting vehicle fuel consumption



# APPENDIX B

# Appendix B-1 SAFED training programmes for HGV (DfT, 2010)

| Time | Summery | Content | Location |
|---|---|---|---|
| 08.00 (15 mins) | INTRODUCTION | Introduction to the aims and objectives of the programme and its contents. Licence check for class of vehicle entitlement, penalty pionts and any other restrictions. | Classroom |
| 08.15 (45 mins) | PRELIMINARY Candidate and vehicle checks | Candidates are informed of the training vehicle's characteristics including weight, height width and length. They are also informed of their responsibilities throughout the training day and their obligations to obay rules and regualtions covering that particular class of vehicle on the road.<br><br>Candidated eyesight checked.<br><br>Hazard perseption discussed using DSA RoadScence material.<br><br>Check it out - Truck Driver video shown outlining correct procedures to carry out vehicle and trailer safety checks.<br><br>Safety checks completed by candidates using Documents 3 and 4. SAFED instructor to observe and record pass/fail directly into Document 9. | Classroom and around the vehicle |
| 09.00 (2 hrs) | FIRST RUN (one hour per candidate) | Candidates assassad in driving abilites. The route selected will include roundabouts, junctions, left and right turns, built up areas and various types of roads including motorways (if possible)<br><br>The SAFED instructor will make detailed notes along the route on Document 5 and record time taken, distance traveled, number of gear changes, fuel used and mpg directly onto Document 9 at the end of the first run. | In-cab |
| | Candidates change over | | |
| 10.00 | FIRST RUN CONTINUED | The second candidate takes control of the vehicle and is assessed. | In-cab |
| 11.00 | VEHICLE AND ROADCRAFT INSTRUCTION | Faults highlighted during the assessment drive are discussed in the classroom and best practice in safe and fuel efficient driving techniques is explained with the help of visual aids. The video Save it! - the Road to Fuel Efficiency is shown. Topics covered include benefits, fundamentals and tips. The SAFED instructor will transfer first drive performance indicators from Document 5 to Document 9. | Classroom |
| 12.00 (45 mins) | LUNCH | | |
| 12.45 (30 mins) | FURTHER INSTRUCTION | The video Save It! - Champions of Fuel is shown to highlight and encourage discussion an safe and fuel efficient driving techniques. | Classroom |
| 13.15 (2 hrs) | SECOND RUN (one hour per candidate) | Each candidate is given the opertunity to demonstrate the techniques learned, with ongoing guidence and input form the instructor.<br><br>The SAFED instructor will again use Document 5 to record detailed performance along the route. At the end of the run, new time taken, distance traveled, gear change, fuel used and mpg figures will be inserted directly onto Document 9 and the performance details transferred from Document 5 to Document 9. | In-cab |
| | Candidates change over | | |
| 14.15 | SECOND RUN CONTINUED | The second candidate takes control of the vehicle and is reassessed. | In-cab |
| 15.15 (30 mins) | UNDERPINNING KNOWLEDGE EXERCISES | Two theory exersises conducted, covering both safe and fuel efficient driving issues. Results from these theory tests will be recorded on Document 9. | Classroom |
| 15.45 (45 mins) | ASSESSMENT SUMMERY AND FEEDBACK REPORT | Summary of the day's events, highlighting the differences between hte two runs. Discuss theory tests, knowledge gained and improvments in driving performance. Completed report returned to candidates. The final grade and instructor's and candidates comments discussed. Target fuel consumption performance figure agreed. Candidates to provide feedback. Certificate issued to successful candidates. | Classroom |
| 16.30 | | Candidates depart. | |

Appendix B-1 SAFED training programmes for Van or light commercial vehicle (LCV) (DfT, 2006)

| Time | Summary | Content | Location |
|---|---|---|---|
| 08:30 (15 minutes) | Introduction | Introductions to the aims and objectives of the course and its contents. | Classroom |
| 08:45 (60 minutes) | Interactive Presentation | This presentation serves to set the scene for the drivers, receive facilitated learning and enables the trainer to gauge a driver's knowledge and attitude towards driving. | Classroom |
| 09:45 (15 minutes) | | BREAK | |
| 10:00 (30 minutes) | Preliminary<br><br>Candidate & Vehicle Checks | Full driver eyesight check and vehicle inspection undertaken. Acronym POWDER is used. (Petrol/diesel, oil, water, damage, electrics and rubber/tyres) | Around the Vehicle |
| 10:30 (60 minutes) | First Drive (30 minutes per driver) | Drivers are assessed on driving abilities. | In Vehicle |
| 11:30 (30 minutes) | Driver Debrief (15 minutes each driver) | Each driver will receive a de-brief on their performance and driving style. | In Vehicle |
| 12:00 (30 minutes) | Demo Drive | The trainer will deliver a demonstration drive tailored to the drivers training objectives. | In Vehicle |
| 12:30 (45 minutes) | | LUNCH | |
| 13:15 (60 minutes) | Vehicle And Roadcraft Instruction (30 minutes per driver) | On road training will be given to both drivers. The training techniques deployed cater for 2:1 training enabling the second driver to benefit from watching and listening to instruction given to the other driver. | In Vehicle |
| 14:15 (30 minutes) | Parking & Manoeuvring | Each driver will undertake two manoeuvres. | In Vehicle |
| 14:45 (15 minutes) | | BREAK | |
| 15:00 (60 minutes) | Second Drive (30 minutes per driver) | Each driver will be given the opportunity to demonstrate the techniques learned, along the original assessment route with ongoing input and guidance, where necessary. | In Vehicle |
| 16:00 (30 minutes) | Knowledge Exercise | A knowledge exercise is conducted covering both pertinent Highway Code, driving knowledge and understanding of safe and fuel efficient driving. | Classroom |
| 16:30 (30 minutes) | Final Debrief | Both drivers will undergo a final debrief and recap and completion of driver course evaluation forms | Classroom |
| 17:00 | Conclusion | | |

# APPENDIX C

## Appendix C-1 Questionnaire for pair-wise comparison of the driving attributes

**FACTORS AFFECTING VEHICLE FUEL CONSUMPTION**

Thank you for taking the time to complete this questionnaire. The information that you will provide will help me to carry out a research into road transport energy use efficiency. The information will only be used for the purpose of the research. I believe that the outcomes of my research will benefit the transport sector in the UK.

Prior to use of any sensitive extraction from the results of the questionnaire you will be notified for permission, for examples, publication and thesis reports.

**(B0) General information**

Respondent ..........................................................................................

Role ..........................................................................................

Company/Institution ..........................................................................................

Date ..........................................................................................

Time Start.............................................End.....................................

**(B0) Researcher Contacts**

**Robert Akena**
College of Engineering and Physical Sciences
School of Civil Engineering
University of Birmingham
Birmingham
B15 2TT
Tel: 07533293096 Email: rpa321@bham.ac.uk

**(C1) Introduction:**

**The following are driving attributes which are affect vehicle fuel consumption:**

| Item | Category | Attribute |
|---|---|---|
| 1 | Driving Environment | Hazard |
| | | Driver Behaviour |
| | | Driver Fatigue |
| 2 | Operating the Vehicle | Initial Checks |
| | | Acceleration and Speed |
| | | Braking |
| | | Gear Changes /Selection |
| | | Clutch Control |
| | | Forward Planning |
| | | Vehicle Idling |
| 3 | Vehicle Dynamics | Route Planning |
| | | Loads and Loading Pattern |
| | | Adjustable Aerodynamics and windows |
| 4 | Awareness | Culture Change |
| | | Management |

**(C2) You are required to carry out a pair-wise comparison of the attributes in C3 using the scale below after Saaty (1980):**

| Intensity of importance | Definition | Explanation |
|---|---|---|
| 1 | Equal importance | Two factors contribute equally to the objective |
| 3 | Somewhat more important | Experience and judgement slightly favour one over the other. |
| 5 | Much more important | Experience and judgement strongly favour one over the other. |
| 7 | Very much more important | Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice. |
| 9 | Absolutely more important. | The evidence favouring one over the other is of the highest possible validity. |
| 2,4,6,8 | Intermediate values | When compromise is needed |

**Example:**

| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Attribute 1 | | | X | | | | | | | Attribute 2 |

**This would mean that Attribute 1 is much more important than 2 in terms of fuel consumption**

**(B3) Please complete all the pair-wise comparisons below:**

| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hazard | | | | | | | | | | Driver Behaviour |
| Hazard | | | | | | | | | | Driver Fatigue |
| Hazard | | | | | | | | | | Initial Checks |
| Hazard | | | | | | | | | | Acceleration and Speed |
| Hazard | | | | | | | | | | Braking |
| Hazard | | | | | | | | | | Gear Changes /Selection |
| Hazard | | | | | | | | | | Clutch Control |
| Hazard | | | | | | | | | | Forward Planning |
| Hazard | | | | | | | | | | Vehicle Idling |
| Hazard | | | | | | | | | | Route Planning |
| Hazard | | | | | | | | | | Loads and Loading Pattern |
| Hazard | | | | | | | | | | Adjustable Aerodynamics and windows |
| Hazard | | | | | | | | | | Culture Change |
| Hazard | | | | | | | | | | Management |
| Driver Behaviour | | | | | | | | | | Driver Fatigue |
| Driver Behaviour | | | | | | | | | | Initial Checks |
| Driver Behaviour | | | | | | | | | | Acceleration and Speed |
| Driver Behaviour | | | | | | | | | | Braking |
| Driver Behaviour | | | | | | | | | | Gear Changes /Selection |
| Driver Behaviour | | | | | | | | | | Clutch Control |
| Driver Behaviour | | | | | | | | | | Forward Planning |
| Driver Behaviour | | | | | | | | | | Vehicle Idling |
| Driver Behaviour | | | | | | | | | | Route Planning |
| Driver Behaviour | | | | | | | | | | Loads and Loading Pattern |
| Driver Behaviour | | | | | | | | | | Adjustable Aerodynamics and windows |
| Driver Behaviour | | | | | | | | | | Culture Change |
| Driver Behaviour | | | | | | | | | | Management |
| Driver Fatigue | | | | | | | | | | Initial Checks |
| Driver Fatigue | | | | | | | | | | Acceleration and Speed |
| Driver Fatigue | | | | | | | | | | Braking |
| Driver Fatigue | | | | | | | | | | Gear Changes /Selection |
| Driver Fatigue | | | | | | | | | | Clutch Control |
| Driver Fatigue | | | | | | | | | | Forward Planning |
| Driver Fatigue | | | | | | | | | | Vehicle Idling |
| Driver Fatigue | | | | | | | | | | Route Planning |

| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Driver Fatigue | | | | | | | | | | Loads and Loading Pattern |
| Driver Fatigue | | | | | | | | | | Adjustable Aerodynamics and windows |
| Driver Fatigue | | | | | | | | | | Culture Change |
| Driver Fatigue | | | | | | | | | | Management |
| Initial Checks | | | | | | | | | | Acceleration and Speed |
| Initial Checks | | | | | | | | | | Braking |
| Initial Checks | | | | | | | | | | Gear Changes /Selection |
| Initial Checks | | | | | | | | | | Clutch Control |
| Initial Checks | | | | | | | | | | Forward Planning |
| Initial Checks | | | | | | | | | | Vehicle Idling |
| Initial Checks | | | | | | | | | | Route Planning |
| Initial Checks | | | | | | | | | | Loads and Loading Pattern |
| Initial Checks | | | | | | | | | | Adjustable Aerodynamics and windows |
| Initial Checks | | | | | | | | | | Culture Change |
| Initial Checks | | | | | | | | | | Management |
| Acceleration and Speed | | | | | | | | | | Braking |
| Acceleration and Speed | | | | | | | | | | Gear Changes /Selection |
| Acceleration and Speed | | | | | | | | | | Clutch Control |
| Acceleration and Speed | | | | | | | | | | Forward Planning |
| Acceleration and Speed | | | | | | | | | | Vehicle Idling |
| Acceleration and Speed | | | | | | | | | | Route Planning |
| Acceleration and Speed | | | | | | | | | | Loads and Loading Pattern |
| Acceleration and Speed | | | | | | | | | | Adjustable Aerodynamics and windows |
| Acceleration and Speed | | | | | | | | | | Culture Change |
| Acceleration and Speed | | | | | | | | | | Management |
| Braking | | | | | | | | | | Gear Changes /Selection |
| Braking | | | | | | | | | | Clutch Control |
| Braking | | | | | | | | | | Forward Planning |
| Braking | | | | | | | | | | Vehicle Idling |
| Braking | | | | | | | | | | Route Planning |
| Braking | | | | | | | | | | Loads and Loading Pattern |
| Braking | | | | | | | | | | Adjustable Aerodynamics and windows |
| Braking | | | | | | | | | | Culture Change |
| Braking | | | | | | | | | | Management |
| Gear Changes /Selection | | | | | | | | | | Clutch Control |

| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gear Changes /Selection | | | | | | | | | | Forward Planning |
| Gear Changes /Selection | | | | | | | | | | Vehicle Idling |
| Gear Changes /Selection | | | | | | | | | | Route Planning |
| Gear Changes /Selection | | | | | | | | | | Loads and Loading Pattern |
| Gear Changes /Selection | | | | | | | | | | Adjustable Aerodynamics and windows |
| Gear Changes /Selection | | | | | | | | | | Culture Change |
| Gear Changes /Selection | | | | | | | | | | Management |
| Clutch Control | | | | | | | | | | Forward Planning |
| Clutch Control | | | | | | | | | | Vehicle Idling |
| Clutch Control | | | | | | | | | | Route Planning |
| Clutch Control | | | | | | | | | | Loads and Loading Pattern |
| Clutch Control | | | | | | | | | | Adjustable Aerodynamics and windows |
| Clutch Control | | | | | | | | | | Culture Change |
| Clutch Control | | | | | | | | | | Management |
| Forward Planning | | | | | | | | | | Vehicle Idling |
| Forward Planning | | | | | | | | | | Route Planning |
| Forward Planning | | | | | | | | | | Loads and Loading Pattern |
| Forward Planning | | | | | | | | | | Adjustable Aerodynamics and windows |
| Forward Planning | | | | | | | | | | Culture Change |
| Forward Planning | | | | | | | | | | Management |
| Vehicle Idling | | | | | | | | | | Route Planning |
| Vehicle Idling | | | | | | | | | | Loads and Loading Pattern |
| Vehicle Idling | | | | | | | | | | Adjustable Aerodynamics and windows |
| Vehicle Idling | | | | | | | | | | Culture Change |
| Vehicle Idling | | | | | | | | | | Management |
| Route Planning | | | | | | | | | | Loads and Loading Pattern |
| Route Planning | | | | | | | | | | Adjustable Aerodynamics and windows |
| Route Planning | | | | | | | | | | Culture Change |
| Route Planning | | | | | | | | | | Management |
| Loads and Loading Pattern | | | | | | | | | | Adjustable Aerodynamics and windows |
| Loads and Loading Pattern | | | | | | | | | | Culture Change |

| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Loads and Loading Pattern | | | | | | | | | | Management |
| Adjustable Aerodynamics and windows | | | | | | | | | | Culture Change |
| Adjustable Aerodynamics and windows | | | | | | | | | | Management |
| Culture Change | | | | | | | | | | Management |

**End of the questionnaire, and thank you**

**Comments**

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**Once again, thank you for taking the time to complete this questionnaire.**

## Appendix C-1 Frequency of pair-wise comparisons between the driving attributes

| Attributes | Rating | | | | | | | | | Attributes |
|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |
| Hazard | 1 | 0 | 1 | 6 | 9 | 12 | 4 | 2 | 1 | Driver behaviour |
| Hazard | 2 | 2 | 3 | 12 | 8 | 6 | 2 | 1 | 0 | Driver fatigue |
| Hazard | 0 | 1 | 3 | 6 | 8 | 8 | 6 | 3 | 1 | Initial checks |
| Hazard | 0 | 1 | 3 | 3 | 4 | 7 | 15 | 3 | 0 | Acceleration and Speed |
| Hazard | 0 | 0 | 11 | 9 | 6 | 8 | 2 | 0 | 0 | Braking |
| Hazard | 0 | 1 | 0 | 3 | 3 | 7 | 15 | 5 | 2 | Gear changes /selection |
| Hazard | 1 | 0 | 1 | 4 | 12 | 12 | 4 | 0 | 2 | Clutch control |
| Hazard | 0 | 0 | 2 | 9 | 9 | 12 | 3 | 1 | 0 | Forward planning |
| Hazard | 0 | 1 | 0 | 2 | 4 | 11 | 11 | 6 | 1 | Vehicle idling |
| Hazard | 0 | 0 | 3 | 2 | 7 | 9 | 8 | 5 | 2 | Route planning |
| Hazard | 0 | 1 | 0 | 2 | 4 | 10 | 13 | 4 | 2 | Loads and Loading Pattern |
| Hazard | 0 | 2 | 1 | 3 | 5 | 9 | 10 | 5 | 1 | Adjustable Aerodynamics and windows |
| Hazard | 1 | 1 | 1 | 3 | 5 | 7 | 8 | 7 | 3 | Culture change |
| Hazard | 1 | 0 | 0 | 5 | 4 | 7 | 10 | 6 | 3 | Management |
| Driver behaviour | 2 | 3 | 9 | 8 | 6 | 5 | 1 | 2 | 0 | Driver fatigue |
| Driver behaviour | 1 | 3 | 8 | 10 | 8 | 4 | 1 | 0 | 1 | Initial checks |
| Driver behaviour | 0 | 1 | 3 | 7 | 12 | 6 | 5 | 0 | 2 | Acceleration and Speed |
| Driver behaviour | 0 | 0 | 6 | 7 | 9 | 11 | 3 | 0 | 0 | Braking |
| Driver behaviour | 0 | 2 | 1 | 5 | 4 | 7 | 8 | 7 | 2 | Gear changes /selection |
| Driver behaviour | 0 | 1 | 0 | 8 | 11 | 7 | 6 | 2 | 1 | Clutch control |
| Driver behaviour | 1 | 1 | 2 | 7 | 8 | 9 | 6 | 2 | 0 | Forward planning |
| Driver behaviour | 0 | 0 | 1 | 7 | 11 | 12 | 4 | 0 | 1 | Vehicle idling |
| Driver behaviour | 0 | 1 | 3 | 7 | 14 | 9 | 1 | 1 | 0 | Route planning |
| Driver behaviour | 1 | 0 | 5 | 12 | 11 | 6 | 1 | 0 | 0 | Loads and Loading Pattern |
| Driver behaviour | 0 | 0 | 1 | 7 | 17 | 8 | 2 | 0 | 1 | Adjustable Aerodynamics and windows |
| Driver behaviour | 0 | 0 | 1 | 4 | 5 | 8 | 9 | 6 | 3 | Culture change |
| Driver behaviour | 0 | 2 | 3 | 3 | 8 | 10 | 5 | 4 | 1 | Management |
| Driver fatigue | 0 | 1 | 1 | 3 | 6 | 13 | 7 | 4 | 1 | Initial checks |
| Driver fatigue | 0 | 1 | 0 | 2 | 3 | 4 | 10 | 12 | 4 | Acceleration and Speed |
| Driver fatigue | 0 | 0 | 1 | 1 | 3 | 9 | 11 | 9 | 2 | Braking |
| Driver fatigue | 0 | 0 | 2 | 2 | 6 | 5 | 7 | 10 | 4 | Gear changes /selection |

| Attributes | Rating | | | | | | | | | Attributes |
|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |
| Driver fatigue | 1 | 1 | 2 | 3 | 5 | 12 | 6 | 4 | 2 | Clutch control |
| Driver fatigue | 0 | 0 | 2 | 4 | 4 | 7 | 11 | 6 | 2 | Forward planning |
| Driver fatigue | 0 | 2 | 1 | 5 | 7 | 4 | 8 | 6 | 3 | Vehicle idling |
| Driver fatigue | 0 | 1 | 1 | 4 | 6 | 7 | 9 | 6 | 2 | Route planning |
| Driver fatigue | 1 | 1 | 2 | 7 | 7 | 8 | 5 | 3 | 2 | Loads and Loading Pattern |
| Driver fatigue | 1 | 2 | 4 | 6 | 7 | 6 | 3 | 5 | 2 | Adjustable Aerodynamics and windows |
| Driver fatigue | 0 | 1 | 1 | 4 | 5 | 8 | 9 | 7 | 1 | Culture change |
| Driver fatigue | 0 | 2 | 2 | 4 | 4 | 7 | 8 | 5 | 4 | Management |
| Initial checks | 0 | 0 | 3 | 6 | 6 | 7 | 5 | 6 | 3 | Acceleration and Speed |
| Initial checks | 2 | 0 | 3 | 5 | 5 | 8 | 5 | 7 | 1 | Braking |
| Initial checks | 1 | 1 | 2 | 4 | 6 | 11 | 4 | 5 | 2 | Gear changes /selection |
| Initial checks | 0 | 0 | 7 | 6 | 8 | 7 | 3 | 4 | 1 | Clutch control |
| Initial checks | 0 | 1 | 1 | 5 | 6 | 12 | 8 | 2 | 1 | Forward planning |
| Initial checks | 2 | 4 | 8 | 12 | 6 | 2 | 1 | 0 | 1 | Vehicle idling |
| Initial checks | 1 | 0 | 2 | 10 | 11 | 7 | 3 | 1 | 1 | Route planning |
| Initial checks | 3 | 8 | 11 | 5 | 5 | 2 | 1 | 1 | 0 | Loads and Loading Pattern |
| Initial checks | 1 | 3 | 4 | 10 | 7 | 3 | 3 | 4 | 1 | Adjustable Aerodynamics and windows |
| Initial checks | 1 | 2 | 4 | 5 | 8 | 8 | 5 | 1 | 2 | Culture change |
| Initial checks | 0 | 0 | 2 | 4 | 7 | 11 | 8 | 3 | 1 | Management |
| Acceleration and Speed | 0 | 2 | 8 | 8 | 7 | 6 | 4 | 1 | 0 | Braking |
| Acceleration and Speed | 1 | 1 | 3 | 9 | 8 | 7 | 4 | 2 | 1 | Gear changes /selection |
| Acceleration and Speed | 2 | 6 | 11 | 6 | 5 | 5 | 1 | 0 | 0 | Clutch control |
| Acceleration and Speed | 5 | 8 | 9 | 8 | 3 | 1 | 2 | 0 | 0 | Forward planning |
| Acceleration and Speed | 2 | 9 | 10 | 9 | 3 | 2 | 0 | 1 | 0 | Vehicle idling |
| Acceleration and Speed | 6 | 9 | 8 | 6 | 6 | 1 | 0 | 0 | 0 | Route planning |
| Acceleration and Speed | 2 | 8 | 13 | 7 | 3 | 1 | 1 | 1 | 0 | Loads and Loading Pattern |
| Acceleration and Speed | 6 | 13 | 12 | 3 | 0 | 2 | 0 | 0 | 0 | Adjustable Aerodynamics and windows |
| Acceleration and Speed | 1 | 1 | 3 | 7 | 13 | 6 | 3 | 1 | 1 | Culture change |
| Acceleration and Speed | 0 | 1 | 5 | 6 | 10 | 5 | 5 | 2 | 2 | Management |
| Braking | 2 | 1 | 3 | 12 | 11 | 3 | 1 | 2 | 1 | Gear changes /selection |
| Braking | 2 | 7 | 9 | 5 | 5 | 4 | 2 | 1 | 1 | Clutch control |
| Braking | 0 | 7 | 6 | 8 | 4 | 5 | 6 | 0 | 0 | Forward planning |

| Attributes | Rating | | | | | | | | | Attributes |
|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |
| Braking | 2 | 3 | 4 | 9 | 5 | 6 | 4 | 1 | 2 | Vehicle idling |
| Braking | 0 | 0 | 7 | 8 | 9 | 6 | 3 | 2 | 1 | Route planning |
| Braking | 2 | 2 | 4 | 11 | 7 | 7 | 2 | 1 | 0 | Loads and Loading Pattern |
| Braking | 0 | 3 | 4 | 5 | 10 | 6 | 6 | 1 | 1 | Adjustable Aerodynamics and windows |
| Braking | 0 | 2 | 6 | 6 | 10 | 5 | 6 | 0 | 1 | Culture change |
| Braking | 1 | 0 | 1 | 5 | 7 | 8 | 7 | 5 | 2 | Management |
| Gear changes /selection | 2 | 5 | 8 | 6 | 7 | 3 | 3 | 0 | 2 | Clutch control |
| Gear changes /selection | 2 | 5 | 7 | 9 | 8 | 2 | 1 | 1 | 1 | Forward planning |
| Gear changes /selection | 2 | 8 | 10 | 7 | 4 | 2 | 2 | 0 | 1 | Vehicle idling |
| Gear changes /selection | 0 | 2 | 5 | 11 | 10 | 6 | 2 | 0 | 0 | Route planning |
| Gear changes /selection | 0 | 11 | 12 | 11 | 1 | 0 | 1 | 0 | 0 | Loads and Loading Pattern |
| Gear changes /selection | 6 | 9 | 8 | 5 | 2 | 2 | 1 | 2 | 1 | Adjustable Aerodynamics and windows |
| Gear changes /selection | 0 | 0 | 0 | 2 | 7 | 16 | 5 | 4 | 2 | Culture change |
| Gear changes /selection | 1 | 1 | 1 | 2 | 9 | 12 | 8 | 2 | 0 | Management |
| Clutch control | 1 | 0 | 3 | 3 | 10 | 10 | 6 | 2 | 1 | Forward planning |
| Clutch control | 1 | 4 | 3 | 4 | 6 | 9 | 7 | 2 | 0 | Vehicle idling |
| Clutch control | 0 | 2 | 3 | 6 | 4 | 9 | 5 | 4 | 3 | Route planning |
| Clutch control | 2 | 4 | 5 | 7 | 7 | 6 | 3 | 1 | 1 | Loads and Loading Pattern |
| Clutch control | 0 | 3 | 6 | 11 | 9 | 3 | 4 | 0 | 0 | Adjustable Aerodynamics and windows |
| Clutch control | 0 | 0 | 3 | 1 | 4 | 5 | 12 | 7 | 4 | Culture change |
| Clutch control | 0 | 1 | 0 | 3 | 3 | 3 | 8 | 10 | 8 | Management |
| Forward planning | 2 | 4 | 3 | 6 | 6 | 6 | 6 | 2 | 1 | Vehicle idling |
| Forward planning | 3 | 1 | 4 | 5 | 6 | 4 | 5 | 6 | 2 | Route planning |
| Forward planning | 2 | 1 | 1 | 2 | 8 | 8 | 3 | 8 | 3 | Loads and Loading Pattern |
| Forward planning | 0 | 1 | 3 | 5 | 10 | 7 | 7 | 3 | 0 | Adjustable Aerodynamics and windows |
| Forward planning | 0 | 0 | 0 | 1 | 0 | 6 | 14 | 11 | 4 | Culture change |
| Forward planning | 0 | 0 | 4 | 3 | 9 | 10 | 8 | 2 | 0 | Management |
| Vehicle idling | 2 | 1 | 7 | 8 | 6 | 6 | 4 | 1 | 1 | Route planning |
| Vehicle idling | 0 | 0 | 3 | 5 | 6 | 8 | 8 | 4 | 2 | Loads and Loading Pattern |

| Attributes | Rating | | | | | | | | | Attributes |
|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |
| Vehicle idling | 0 | 2 | 5 | 11 | 7 | 6 | 2 | 1 | 2 | Adjustable Aerodynamics and windows |
| Vehicle idling | 0 | 0 | 2 | 1 | 6 | 8 | 11 | 5 | 3 | Culture change |
| Vehicle idling | 0 | 1 | 1 | 3 | 9 | 13 | 5 | 3 | 1 | Management |
| Route planning | 0 | 3 | 7 | 10 | 8 | 5 | 2 | 0 | 1 | Loads and Loading Pattern |
| Route planning | 1 | 1 | 5 | 9 | 7 | 6 | 4 | 3 | 0 | Adjustable Aerodynamics and windows |
| Route planning | 1 | 0 | 1 | 0 | 3 | 6 | 15 | 7 | 3 | Culture change |
| Route planning | 1 | 0 | 1 | 1 | 2 | 8 | 12 | 6 | 5 | Management |
| Loads and Loading Pattern | 0 | 2 | 7 | 7 | 7 | 6 | 4 | 2 | 1 | Adjustable Aerodynamics and windows |
| Loads and Loading Pattern | 0 | 0 | 1 | 2 | 5 | 5 | 15 | 6 | 2 | Culture change |
| Loads and Loading Pattern | 1 | 1 | 2 | 4 | 3 | 8 | 12 | 4 | 1 | Management |
| Adjustable Aerodynamics and windows | 0 | 0 | 0 | 2 | 3 | 3 | 19 | 7 | 2 | Culture change |
| Adjustable Aerodynamics and windows | 0 | 0 | 2 | 2 | 3 | 7 | 16 | 4 | 2 | Management |
| Culture change | 1 | 2 | 6 | 6 | 8 | 7 | 5 | 1 | 0 | Management |

# APPENDIX D

## Appendix D-1 Driver Characteristics (trained/treated and control/untreated)

| Driver ID | Gender | Age Group | Years of Experience | Driving Time | Depot | Vehicle Category | Group (2012) |
|---|---|---|---|---|---|---|---|
| 39 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 79 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 85 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 98 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 208 | Male | Under 45 | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 299 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 381 | Male | Under 45 | Under 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 472 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 478 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 10 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 15 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 35 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 42 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 76 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 109 | Male | Under 45 | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 118 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 130 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 132 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 139 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 171 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 210 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 225 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 229 | Male | Under 45 | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |

| Driver ID | Gender | Age Group | Years of Experience | Driving Time | Depot | Vehicle Category | Group (2012) |
|---|---|---|---|---|---|---|---|
| 244 | Male | Under 45 | Under 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 251 | Male | Under 45 | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 261 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 314 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 344 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 365 | Male | Under 45 | Under 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 392 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 433 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 442 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 464 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 492 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy/Medium | Treated |
| 26 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 28 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 51 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 60 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 74 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 88 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 114 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 124 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 128 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 138 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 149 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 164 | Male | Under 45 | Under 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 199 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 201 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |

| Driver ID | Gender | Age Group | Years of Experience | Driving Time | Depot | Vehicle Category | Group (2012) |
|---|---|---|---|---|---|---|---|
| 216 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 234 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 239 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 245 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 255 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 302 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 317 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 318 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 378 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 379 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 389 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 401 | Male | Under 45 | Under 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 428 | Male | 45+ | Under 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 431 | Male | Under 45 | Under 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 444 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 463 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 471 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 479 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 499 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 503 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy/Medium | Untreated |
| 458 | Male | Under 45 | Over 10 | Day | Strensham | Light | Treated |
| 52 | Male | Under 45 | Under 10 | Day | Strensham | Light | Treated |
| 169 | Male | Under 45 | Under 10 | Day | Strensham | Light | Treated |
| 214 | Female | Under 45 | Under 10 | Day | Strensham | Light | Treated |
| 103 | Male | Under 45 | Over 10 | Day | Strensham | Light | Treated |

| Driver ID | Gender | Age Group | Years of Experience | Driving Time | Depot | Vehicle Category | Group (2012) |
|---|---|---|---|---|---|---|---|
| 162 | Male | Under 45 | Over 10 | Day | Strensham | Light | Treated |
| 176 | Male | 45+ | Over 10 | Day | Strensham | Light | Treated |
| 190 | Male | 45+ | Over 10 | Day | Strensham | Light | Treated |
| 195 | Male | 45+ | Over 10 | Day and Night | Strensham | Light | Treated |
| 249 | Male | 45+ | Over 10 | Day and Night | Strensham | Light | Treated |
| 335 | Male | 45+ | Over 10 | Day | Strensham | Light | Treated |
| 398 | Male | Under 45 | Under 10 | Day | Strensham | Light | Treated |
| 409 | Male | Under 45 | Over 10 | Day | Strensham | Light | Treated |
| 418 | Male | 45+ | Over 10 | Day | Doxey and Stafford Park | Light | Untreated |
| 480 | Male | Under 45 | Under 10 | Day | Doxey and Stafford Park | Light | Untreated |
| 488 | Male | Under 45 | Over 10 | Day | Doxey and Stafford Park | Light | Untreated |
| 36 | Male | Under 45 | Over 10 | Day | Doxey and Stafford Park | Light | Untreated |
| 71 | Male | 45+ | Over 10 | Day | Doxey and Stafford Park | Light | Untreated |
| 86 | Male | 45+ | Over 10 | Day | Doxey and Stafford Park | Light | Untreated |
| 145 | Male | Under 45 | Over 10 | Day | Doxey and Stafford Park | Light | Untreated |
| 217 | Male | Under 45 | Over 10 | Day and Night | Doxey and Stafford Park | Light | Untreated |
| 326 | Male | Under 45 | Under 10 | Day | Doxey and Stafford Park | Light | Untreated |
| 343 | Male | Under 45 | Over 10 | Day | Doxey and Stafford Park | Light | Untreated |
| 356 | Female | 45+ | Over 10 | Day | Doxey and Stafford Park | Light | Untreated |
| 448 | Male | 45+ | Over 10 | Day and Night | Doxey and Stafford Park | Light | Untreated |
| 473 | Male | 45+ | Over 10 | Day | Doxey and Stafford Park | Light | Untreated |

## Appendix D-2 Driving style questionnaire (DSQ)

**DRIVING STYLE QUESTIONNAIRE (DSQ)**

Thank you for taking the time to complete this questionnaire. The information that you will provide will help me to carry out a research into road transport energy use efficiency. The information will only be used for the purpose of the research. I believe that the outcomes of my research will benefit the transport sector in the UK in terms of energy use.

Prior to the use of any direct extraction from the questionnaire, where needed, you will be notified for permission, for examples, publication and thesis reports.

**(1) General information**

Respondent ..........................................................................................

Role ..........................................................................................

Company/Institution ..........................................................................................

Date of interview ..........................................................................................

Time Start............................................End....................................

**(2) Researcher Contacts**

**Robert Akena**
College of Engineering and Physical Sciences
School of Civil Engineering
University of Birmingham
Birmingham
B15 2TT
Tel: 07533293096 Email: rpa321@bham.ac.uk

**(3) The questionnaire below requires you to judge the frequency of your own driving errors and violations associated with vehicle fuel consumption. For each item you are asked to indicate how often, if at all, this kind of thing has happened to you. Base your judgements on what you remember of your own driving over the past year.**

| | Never | Hardly ever | Occasionally | Quite Often | Frequently | Nearly All the Time |
|---|---|---|---|---|---|---|
| Do you sometimes fail to drive cautiously? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you dislike people who give you advice about you driving? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you sometimes drive when feeling tired? | 0 | 1 | 2 | 3 | 4 | 5 |
| How often do you forget to check your vehicle tyre pressure? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you sometimes forget to check and familiarise yourself with the vehicle before driving? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you use mobile phone while driving? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you drive fast? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you sometimes fail to apply smooth braking? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you sometimes forget to use block gear changes for example 1-3-5 0r 2-4-6? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you sometimes use the clutch control to balance the car whilst stationary? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you sometimes forget to plan ahead? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do leave the vehicle engine on when it is not needed? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you sometimes forget to plan your journey? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you sometime forget to plan about loading the vehicle? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you forget to carry out necessary aerodynamic adjustments if available to reduce drag? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you drive with windows open especially at high speeds? | 0 | 1 | 2 | 3 | 4 | 5 |
| Have you ever doubted the benefits fuel efficient driving like fuel economy and safety? | 0 | 1 | 2 | 3 | 4 | 5 |
| Do you sometimes fail to get the support you need regarding fuel efficient driving? | 0 | 1 | 2 | 3 | 4 | 5 |

**(4) Do you consider driving in a more fuel efficient way important?**

| | Important | Not Sure | Not important |
|---|---|---|---|
| Tick the appropriate box | | | |

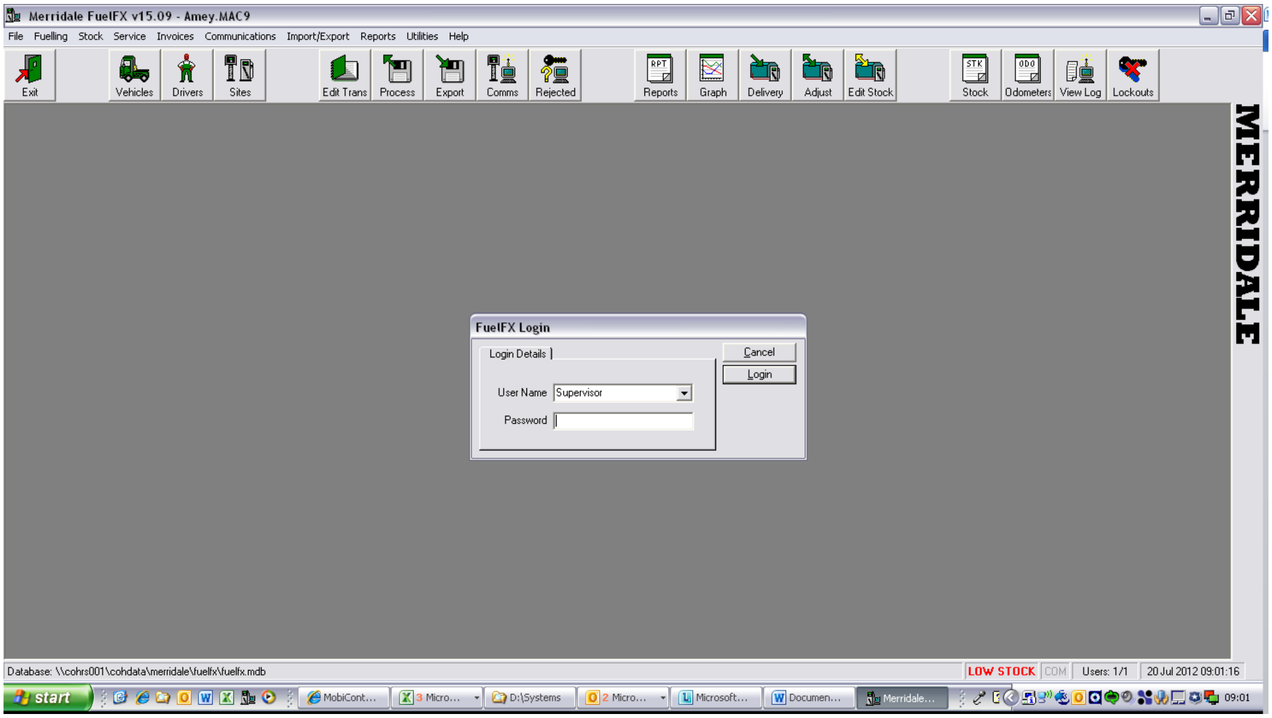
**End of the questionnaire, and thank you**

**Comments**

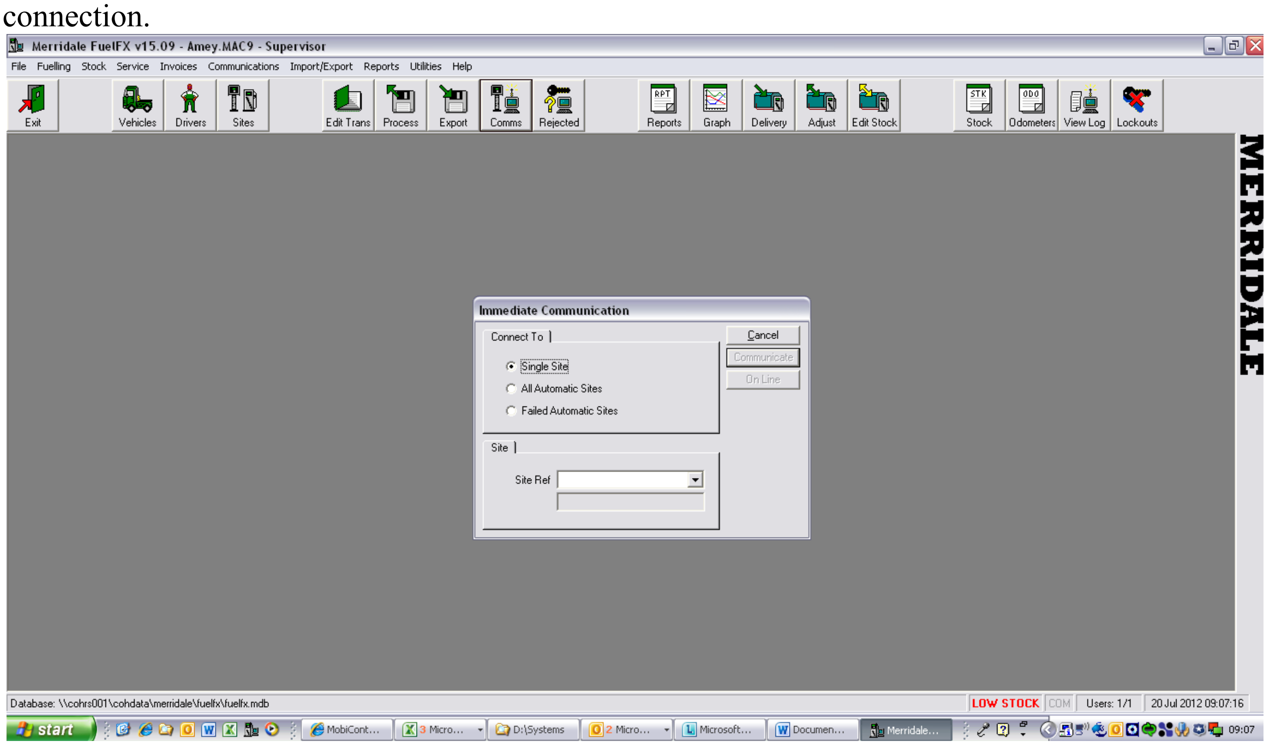
.............................................................................................................................................

**Thank you for taking the time to complete the questionnaire.**

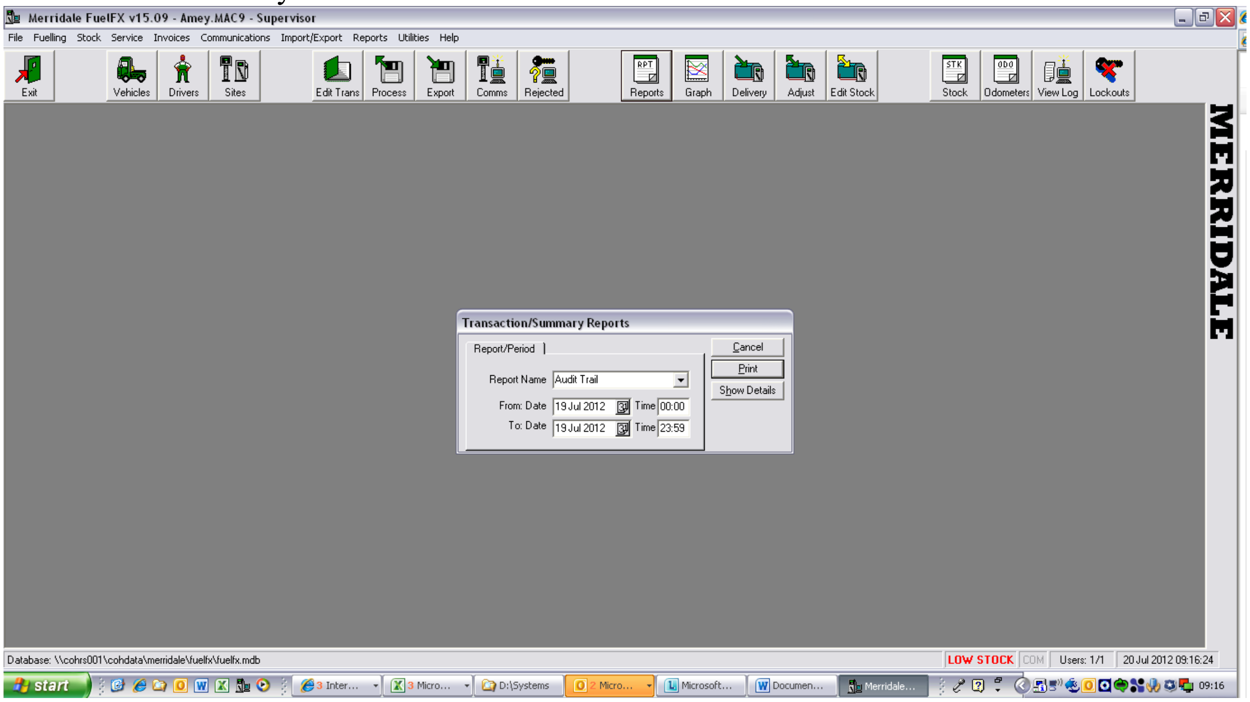
Appendix D-3 Merridale FuelFX v15.09™ User Guide Summary



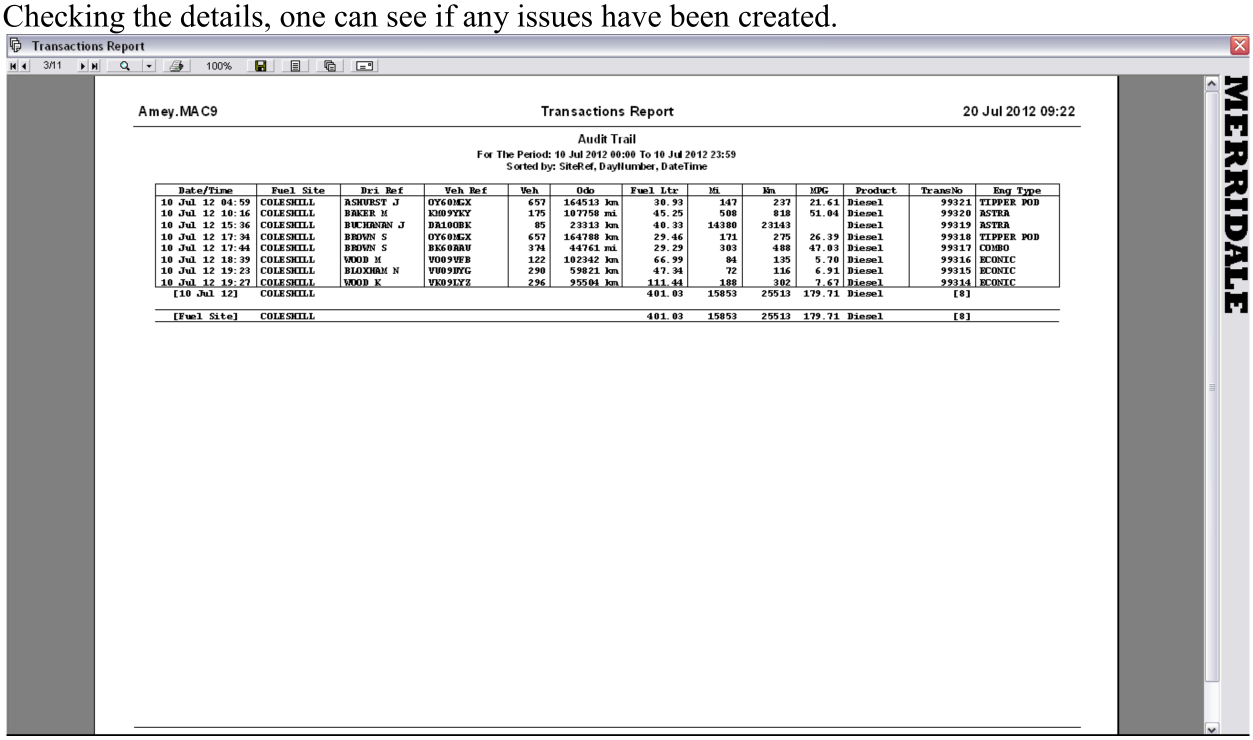

Daily communication checks to every pump to record the transactions since the last connection.



Once communication has been completed Audit checks are carried out to ensure the information entered by the user was correct.




Checking the details, one can see if any issues have been created.



Transactions Report

Amey.MAC9 Transactions Report 20 Jul 2012 09:22

Audit Trail

For The Period: 10 Jul 2012 00:00 To 10 Jul 2012 23:59

Sorted by: SiteRef, DayNumber, DateTime

| Date/Time | Fuel Site | Dri Ref | Veh Ref | Veh | Odo | Fuel Ltr | Mi | Km | MPG | Product | TransNo | Eng Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 Jul 12 04:59 | COLESHILL | ASHURST J | OY60MGX | 657 | 164513 km | 30.93 | 147 | 237 | 21.61 | Diesel | 99321 | TIPPER POD |
| 10 Jul 12 10:16 | COLESHILL | BAKER M | KM09YKY | 175 | 107758 mi | 45.25 | 508 | 818 | 51.04 | Diesel | 99320 | ASTRA |
| 10 Jul 12 15:36 | COLESHILL | BUCHANAN J | DA10OBK | 85 | 23313 km | 40.33 | 14380 | 23143 | | Diesel | 99319 | ASTRA |
| 10 Jul 12 17:34 | COLESHILL | BROWN S | OY60MGX | 657 | 164788 km | 29.46 | 171 | 275 | 26.39 | Diesel | 99318 | TIPPER POD |
| 10 Jul 12 17:44 | COLESHILL | BROWN S | BK60AAU | 374 | 44761 mi | 29.29 | 303 | 488 | 47.03 | Diesel | 99317 | COMBO |
| 10 Jul 12 18:39 | COLESHILL | WOOD M | VO09VFB | 122 | 102342 km | 66.99 | 84 | 135 | 5.70 | Diesel | 99316 | ECONIC |
| 10 Jul 12 19:23 | COLESHILL | BLOXHAM N | VU09DYG | 290 | 59821 km | 47.34 | 72 | 116 | 6.91 | Diesel | 99315 | ECONIC |
| 10 Jul 12 19:27 | COLESHILL | WOOD K | VK09LYZ | 296 | 95504 km | 111.44 | 188 | 302 | 7.67 | Diesel | 99314 | ECONIC |
| [10 Jul 12] | COLESHILL | | | | | 401.03 | 15853 | 25513 | 179.71 | Diesel | [8] | |
| [Fuel Site] | COLESHILL | | | | | 401.03 | 15853 | 25513 | 179.71 | Diesel | [8] | |

One can see if there is any issue with the data entered, for example as highlighted below.

| Dri Ref | Veh Ref | Veh | Odo | Fuel Ltr | Mi | Km | MPG | P |
|---|---|---|---|---|---|---|---|---|
| ASHURST J | OY60MGX | 657 | 164513 km | 30.93 | 147 | 237 | 21.61 | Die |
| BAKER M | KM09YKY | 175 | 107758 mi | 45.25 | 508 | 818 | 51.04 | Die |
| BUCHANAN J | DA10OBK | 85 | 23313 km | 40.33 | 14380 | 23143 | | Die |
| BROWN S | OY60MGX | 657 | 164788 km | 29.46 | 171 | 275 | 26.39 | Die |
| BROWN S | BK60AAU | 374 | 44761 mi | 29.29 | 303 | 488 | 47.03 | Die |
| WOOD M | VO09VFB | 122 | 102342 km | 66.99 | 84 | 135 | 5.70 | Die |
| BLOXHAM N | VU09DYG | 290 | 59821 km | 47.34 | 72 | 116 | 6.91 | Die |
| WOOD K | VK09LYZ | 296 | 95504 km | 111.44 | 188 | 302 | 7.67 | Die |
| | | | | 401.03 | 15853 | 25513 | 179.71 | Die |
| | | | | 401.03 | 15853 | 25513 | 179.71 | Die |

There are two or three ways to deal with this,

1) Check the vehicle history

| Veh ID | Dri Ref | Veh | Fuel Ltr | Odo | Mi | Km | MPG |
|---|---|---|---|---|---|---|---|
| DA10OBK | BUCHANAN J | 85 | 41.48 | 22864 km | 320 | 515 | 35. |
| DA10OBK | RAWMIL J | 85 | | 171 km | ------- | ------- | |
| DA10OBK | RAWMIL J | 85 | 48.62 | 170 km | ------- | ------- | |
| DA10OBK | BUCHANAN J | 85 | 40.33 | 23313 km | 14380 | 23143 | |
| DA10OBK | | 85 | 130.43 | 23313 km | 599 | 964 | 20. |

This shows us that the last user's input details are incorrect, so they would be contacted to ascertain the correct odometer entry and manually update the transaction.

2) The second way is to contact the driver or the depot directly and ask for the odometer to be checked regarding the date on the Vehicle Defect Sheet (a daily record provided by each driver).

3) Merridale™ also acts as a stock reconciliation tool,

; Report

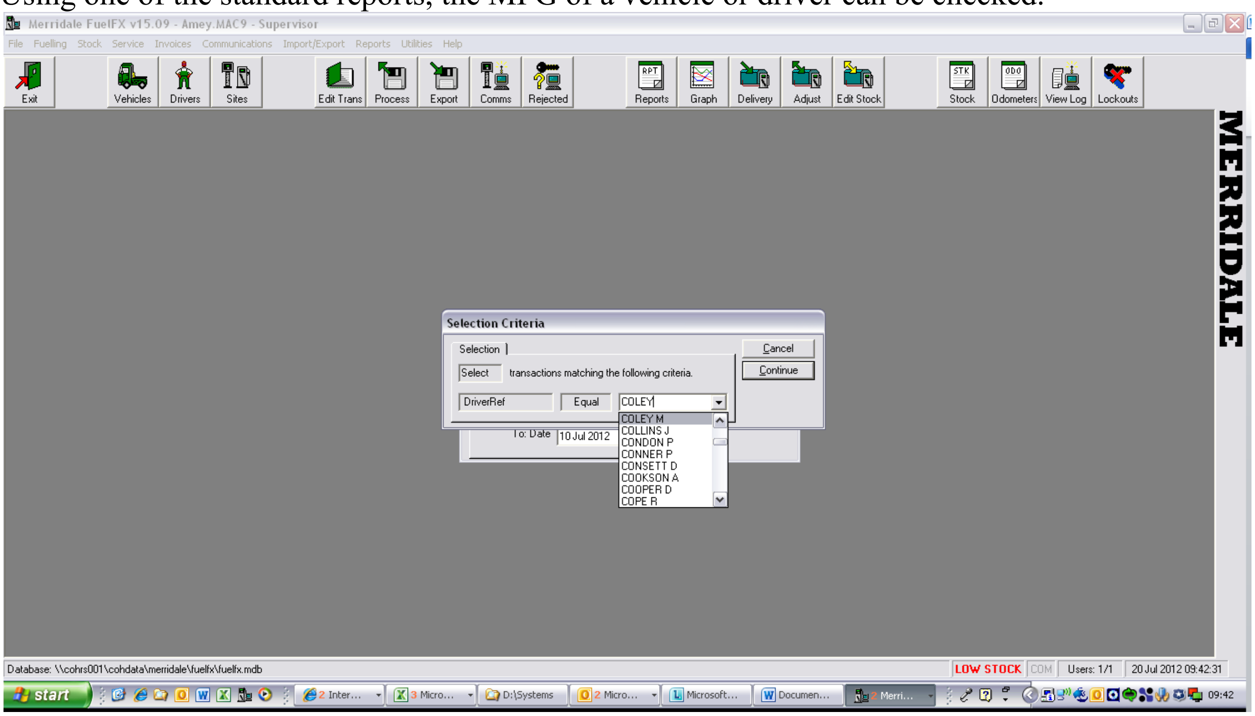
100%

**Amey.MAC9** **Stock Reconciliation Summaries Report** **20 Jul 2012 09:39**

For the period 01 Jun 12 00:00 to 01 Jul 12 23:59

| Site | Tank | Fuel | Throughput | Delivery | Adjustment | Stock | £ Value |
|---|---|---|---|---|---|---|---|
| ANSTY | 1 | Diesel | 2345.40 | 0.00 | 196.38 | 5650.98 | 6698.21 |
| ANSTY | 2 | GasOil | 452.79 | 0.00 | 552.79 | 5900.00 | 3928.50 |
| BESCOT | 1 | Diesel | 10127.96 | 9800.00 | 105.57 | 3423.36 | 3773.23 |
| BESCOT | 2 | GasOil | 511.90 | 0.00 | 173.12 | 5770.67 | 3886.43 |
| BURY COURT | 1 | Diesel | 72.38 | 0.00 | 2726.21 | 8750.00 | 0.00 |
| BURY COURT | 2 | GasOil | 180.00 | 0.00 | -69.92 | 5250.00 | 3299.94 |
| COLESHILL | 1 | Diesel | 10733.51 | 6074.00 | 10647.42 | 14255.13 | 16136.36 |
| COLESHILL | 2 | GasOil | 862.18 | 0.00 | -237.99 | 13827.31 | 0.00 |
| DOXEY | 1 | Diesel | 8226.21 | 6988.00 | 65.24 | 6864.72 | 7566.29 |
| DOXEY | 2 | GasOil | 109.00 | 0.00 | -1191.00 | 6400.00 | 4267.21 |
| HILTON | 1 | Diesel | 3480.18 | 7665.00 | 181.39 | 7625.43 | 8404.75 |
| HILTON | 2 | GasOil | 0.00 | 0.00 | | 7700.00 | 5319.96 |
| IDH | 1 | Diesel | 0.00 | 0.00 | | 0.00 | 0.00 |
| KEELE | 1 | Diesel | 4310.58 | 7000.00 | -183.50 | 7910.47 | 8750.69 |
| KEELE | 2 | GasOil | 0.00 | 0.00 | -100.00 | 2200.00 | 1443.64 |
| LONGBRIDGE | 1 | Diesel | 489.03 | 0.00 | 26.04 | 7610.00 | 8783.15 |
| LONGBRIDGE | 2 | GasOil | 0.00 | 0.00 | | 7290.00 | 4886.25 |
| LYDIATE ASH | 1 | Diesel | 1209.88 | 0.00 | -162.11 | 5700.00 | 6611.01 |
| LYDIATE ASH | 2 | GasOil | 0.00 | 0.00 | -50.00 | 8900.00 | 5794.60 |
| PERRY BARR | 1 | Diesel | 355.26 | 0.00 | -5.72 | 5039.02 | 4473.48 |
| PERRY BARR | 2 | GasOil | 50.15 | 0.00 | -124.79 | 6600.00 | 4545.07 |
| QUINTON | 1 | Diesel | 0.00 | 0.00 | | 0.00 | 0.00 |
| QUINTON | 2 | GasOil | 0.00 | 0.00 | | 0.00 | 0.00 |
| STAFFORD P | 1 | Diesel | 5009.80 | 3000.00 | 1985.53 | 8028.22 | 9065.17 |
| STAFFORD P | 2 | GasOil | 80.18 | 0.00 | -19.82 | 8460.00 | 5756.83 |
| STRENSHAM | 1 | Diesel | 10463.46 | 6000.00 | 3967.96 | 7687.56 | 8597.45 |
| STRENSHAM | 2 | GasOil | 456.29 | 0.00 | -1807.36 | 7100.00 | 4809.94 |
| WARNDON | 1 | Diesel | 6241.18 | 5000.00 | 107.43 | 5079.95 | 5699.77 |
| WARNDON | 2 | GasOil | 59.72 | 0.00 | -3300.00 | 5340.28 | 3566.29 |

Using one of the standard reports, the MPG of a vehicle or driver can be checked.



Transactions Report

1/2 100%

MERRIDALE

Amey.MAC9 Transactions Report 20 Jul 2012 09:46

Single Driver
For The Period: 01 Jan 2012 00:00 To 10 Jul 2012 23:59
Sorted by: DriverRef, VehicleRef, DateTime
Selecting: DriverRef=williams j

| Date/Time | Fuel Site | Dri Ref | Veh Ref | Veh | Odo | Fuel Ltr | Km | Mi | MPG | Product | TransNo | Eng Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 03 Jan 12 15:31 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 63644 mi | 32.01 | 583 | 362 | 51.41 | Diesel | 89288 | ASTRA |
| 05 Jan 12 08:07 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 63896 mi | 22.18 | 406 | 252 | 51.65 | Diesel | 89546 | ASTRA |
| 06 Jan 12 14:06 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 64119 mi | 21.95 | 359 | 223 | 46.19 | Diesel | 89531 | ASTRA |
| 11 Jan 12 14:51 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 64510 mi | 32.45 | 629 | 391 | 54.78 | Diesel | 89703 | ASTRA |
| 13 Jan 12 11:53 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 64757 mi | 22.71 | 398 | 247 | 49.44 | Diesel | 89862 | ASTRA |
| 06 Feb 12 08:28 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 66852 mi | 26.35 | 463 | 288 | 49.69 | Diesel | 91430 | ASTRA |
| 14 Feb 12 07:23 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 67957 mi | 20.06 | 309 | 192 | 43.51 | Diesel | 91829 | ASTRA |
| 20 Feb 12 08:34 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 68415 mi | 23.92 | 414 | 257 | 48.84 | Diesel | 92190 | ASTRA |
| 12 Mar 12 08:26 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 70844 mi | 21.11 | 372 | 231 | 49.75 | Diesel | 93897 | ASTRA |
| 15 Mar 12 08:17 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 71375 mi | 15.69 | 323 | 201 | 58.24 | Diesel | 94017 | ASTRA |
| 21 Mar 12 09:59 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 71786 mi | 34.18 | 661 | 411 | 54.66 | Diesel | 94413 | ASTRA |
| 26 Mar 12 09:05 | LONGBRIDGE | WILLIAMS J | KM09YGC | 120 | 71998 mi | 21.31 | 341 | 212 | 45.23 | Diesel | 94649 | ASTRA |
| 28 Mar 12 08:23 | WARNDON | WILLIAMS J | KM09YGC | 120 | 72425 mi | 31.55 | 687 | 427 | 61.53 | Diesel | 94835 | ASTRA |
| 29 Mar 12 14:57 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 72692 mi | 23.14 | 430 | 267 | 52.45 | Diesel | 94813 | ASTRA |
| 11 Apr 12 09:41 | LONGBRIDGE | WILLIAMS J | KM09YGC | 120 | 73425 mi | 32.72 | 605 | 376 | 52.24 | Diesel | 95349 | ASTRA |
| 13 Apr 12 10:01 | LONGBRIDGE | WILLIAMS J | KM09YGC | 120 | 73780 mi | 32.00 | 571 | 355 | 50.43 | Diesel | 95540 | ASTRA |
| 18 Apr 12 08:18 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 74174 mi | 33.32 | 634 | 394 | 53.76 | Diesel | 95699 | ASTRA |
| 20 Apr 12 07:56 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 74516 mi | 28.02 | 550 | 342 | 55.49 | Diesel | 95826 | ASTRA |
| 27 Apr 12 13:40 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 75022 mi | 21.80 | 381 | 237 | 49.42 | Diesel | 96162 | ASTRA |
| 02 May 12 08:50 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 75284 mi | 22.63 | 422 | 262 | 52.63 | Diesel | 96485 | ASTRA |
| 15 May 12 09:58 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 76202 mi | 20.91 | 378 | 235 | 51.09 | Diesel | 97177 | ASTRA |
| 07 Jun 12 06:03 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 77425 mi | 10.59 | 209 | 130 | 55.81 | Diesel | 97923 | ASTRA |
| 08 Jun 12 08:21 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 77633 mi | 19.49 | 335 | 208 | 48.52 | Diesel | 98024 | ASTRA |
| 25 Jun 12 07:39 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 79495 mi | 21.09 | 373 | 232 | 50.01 | Diesel | 98664 | ASTRA |
| 26 Jun 12 15:34 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 79856 mi | 28.69 | 581 | 361 | 57.20 | Diesel | 98798 | ASTRA |
| 02 Jul 12 10:18 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 80171 mi | 25.57 | 507 | 315 | 56.00 | Diesel | 99002 | ASTRA |
| 04 Jul 12 09:41 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 80393 mi | 19.73 | 357 | 222 | 51.15 | Diesel | 99068 | ASTRA |
| 09 Jul 12 09:18 | STRENSHAM | WILLIAMS J | KM09YGC | 120 | 80690 mi | 26.35 | 478 | 297 | 51.24 | Diesel | 99268 | ASTRA |
| [Veh Ref] | | WILLIAMS J | KM09YGC | 120 | 80690 mi | 691.52 | 12757 | 7927 | 52.11 | Diesel | [28] | ASTRA |
| 12 Jun 12 12:34 | STRENSHAM | WILLIAMS J | KM09YJV | 119 | 72475 mi | 32.53 | 557 | 346 | 48.35 | Diesel | 98152 | ASTRA |
| [Veh Ref] | STRENSHAM | WILLIAMS J | KM09YJV | 119 | 72475 mi | 32.53 | 557 | 346 | 48.35 | Diesel | [1] | ASTRA |
| [Dri Ref] | | WILLIAMS J | | | | 724.05 | 13314 | 8273 | 51.94 | Diesel | [29] | ASTRA |

Transactions Report

1/3 100%

MERRIDALE

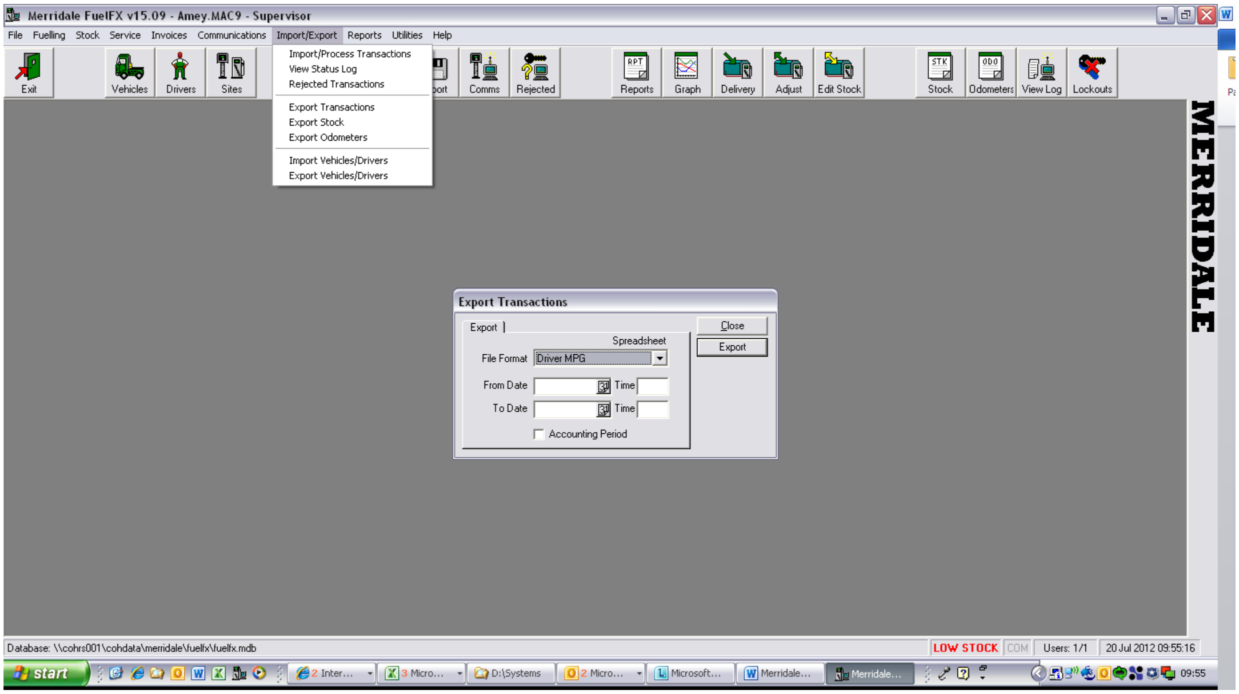
Amey.MAC9 Transactions Report 20 Jul 2012 09:49

Single Vehicle
For The Period: 01 Jan 2012 00:00 To 10 Jul 2012 23:59
Sorted by: VehicleRef, DayNumber, DateTime
Selecting: VehicleRef=km09ygc

| Date/Time | Fuel Site | Veh ID | Dri Ref | Veh | Fuel Ltr | Odo | Mi | Km | MPG | Product | TransNo | Eng Type | £ExVAT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 03 Jan 12 15:31 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 32.01 | 63644 mi | 362 | 583 | 51.41 | Diesel | 89288 | ASTRA | 36.97 |
| 05 Jan 12 08:07 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 22.18 | 63896 mi | 252 | 406 | 51.65 | Diesel | 89546 | ASTRA | 25.62 |
| 06 Jan 12 14:06 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 21.95 | 64119 mi | 223 | 359 | 46.19 | Diesel | 89531 | ASTRA | 25.28 |
| 11 Jan 12 14:51 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 32.45 | 64510 mi | 391 | 629 | 54.78 | Diesel | 89703 | ASTRA | 37.37 |
| 13 Jan 12 11:53 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 22.71 | 64757 mi | 247 | 398 | 49.44 | Diesel | 89862 | ASTRA | 25.82 |
| 18 Jan 12 08:08 | WARNDON | KM09YGC | STEADMAN N | 120 | 24.62 | 65050 mi | 293 | 472 | 54.10 | Diesel | 90141 | ASTRA | 28.44 |
| 19 Jan 12 07:58 | WARNDON | KM09YGC | STEADMAN N | 120 | 16.69 | 65235 mi | 185 | 298 | 50.39 | Diesel | 90195 | ASTRA | 19.28 |
| 20 Jan 12 06:36 | WARNDON | KM09YGC | STEADMAN N | 120 | 9.80 | 65359 mi | 124 | 200 | 57.52 | Diesel | 90247 | ASTRA | 11.32 |
| 23 Jan 12 10:30 | LONGBRIDGE | KM09YGC | STEADMAN N | 120 | 22.17 | 65579 mi | 220 | 354 | 45.11 | Diesel | 90481 | ASTRA | 25.27 |
| 25 Jan 12 07:33 | WARNDON | KM09YGC | STEADMAN N | 120 | 25.54 | 65908 mi | 329 | 529 | 58.56 | Diesel | 90578 | ASTRA | 29.21 |
| 26 Jan 12 14:08 | STRENSHAM | KM09YGC | STEADMAN N | 120 | 29.55 | 66421 mi | 513 | 826 | 78.92 | Diesel | 90714 | ASTRA | 34.42 |
| 01 Feb 12 14:10 | STRENSHAM | KM09YGC | STEADMAN N | 120 | 29.31 | 66564 mi | 143 | 230 | 22.18 | Diesel | 91140 | ASTRA | 34.37 |
| 06 Feb 12 08:28 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 26.35 | 66852 mi | 288 | 463 | 49.69 | Diesel | 91430 | ASTRA | 30.90 |
| 08 Feb 12 09:01 | STRENSHAM | KM09YGC | LECKIE P | 120 | 28.16 | 67160 mi | 308 | 496 | 49.72 | Diesel | 91514 | ASTRA | 32.60 |
| 09 Feb 12 15:43 | WARNDON | KM09YGC | STEADMAN N | 120 | 23.41 | 67435 mi | 275 | 443 | 53.40 | Diesel | 91655 | ASTRA | 26.78 |
| 11 Feb 12 16:56 | STRENSHAM | KM09YGC | DODD J | 120 | 35.32 | 67765 mi | 330 | 531 | 42.47 | Diesel | 91770 | ASTRA | 40.89 |
| 14 Feb 12 07:23 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 20.06 | 67957 mi | 192 | 309 | 43.51 | Diesel | 91829 | ASTRA | 23.05 |
| 14 Feb 12 15:00 | STRENSHAM | KM09YGC | LECKIE P | 120 | 16.77 | 68158 mi | 201 | 323 | 54.49 | Diesel | 91890 | ASTRA | 19.27 |
| 20 Feb 12 08:34 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 23.92 | 68415 mi | 257 | 414 | 48.84 | Diesel | 92190 | ASTRA | 27.49 |
| 21 Feb 12 15:14 | WARNDON | KM09YGC | STEADMAN N | 120 | 23.61 | 68687 mi | 272 | 438 | 52.37 | Diesel | 92592 | ASTRA | 27.01 |
| 23 Feb 12 15:25 | STRENSHAM | KM09YGC | DODD J | 120 | 31.05 | 69054 mi | 367 | 591 | 53.73 | Diesel | 92670 | ASTRA | 35.67 |
| 24 Feb 12 18:37 | STRENSHAM | KM09YGC | WATKINS G | 120 | 20.37 | 69246 mi | 192 | 309 | 42.85 | Diesel | 92998 | ASTRA | 23.40 |
| 26 Feb 12 05:18 | WARNDON | KM09YGC | SHEKELLS C | 120 | 21.88 | 69401 mi | 155 | 249 | 32.20 | Diesel | 93010 | ASTRA | 25.03 |
| 29 Feb 12 09:11 | STRENSHAM | KM09YGC | LECKIE P | 120 | 37.24 | 69781 mi | 380 | 612 | 46.39 | Diesel | 93099 | ASTRA | 42.78 |
| 05 Mar 12 12:18 | STAFFORD P | KM09YGC | DODD J | 120 | 34.57 | 70166 mi | 385 | 620 | 50.63 | Diesel | 93437 | ASTRA | 39.71 |
| 06 Mar 12 15:41 | WARNDON | KM09YGC | STEADMAN N | 120 | 20.31 | 70431 mi | 265 | 426 | 59.32 | Diesel | 93571 | ASTRA | 23.23 |
| 07 Mar 12 15:31 | WARNDON | KM09YGC | STEADMAN N | 120 | 14.65 | 70613 mi | 182 | 293 | 56.48 | Diesel | 93620 | ASTRA | 16.76 |
| 12 Mar 12 08:26 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 21.11 | 70844 mi | 231 | 372 | 49.75 | Diesel | 93897 | ASTRA | 24.83 |
| 14 Mar 12 08:52 | STRENSHAM | KM09YGC | LECKIE P | 120 | 27.18 | 71174 mi | 330 | 531 | 55.20 | Diesel | 93962 | ASTRA | 31.76 |
| 15 Mar 12 08:17 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 15.69 | 71375 mi | 201 | 323 | 58.24 | Diesel | 94017 | ASTRA | 18.33 |
| 21 Mar 12 09:59 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 34.18 | 71786 mi | 411 | 661 | 54.66 | Diesel | 94413 | ASTRA | 39.94 |
| 26 Mar 12 09:05 | LONGBRIDGE | KM09YGC | WILLIAMS J | 120 | 21.31 | 71998 mi | 212 | 341 | 45.23 | Diesel | 94649 | ASTRA | 23.78 |
| 28 Mar 12 08:23 | WARNDON | KM09YGC | WILLIAMS J | 120 | 31.55 | 72425 mi | 427 | 687 | 61.53 | Diesel | 94835 | ASTRA | 37.00 |
| 29 Mar 12 14:57 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 23.14 | 72692 mi | 267 | 430 | 52.45 | Diesel | 94813 | ASTRA | 27.22 |
| 03 Apr 12 15:04 | STRENSHAM | KM09YGC | LECKIE P | 120 | 28.71 | 73049 mi | 357 | 575 | 56.53 | Diesel | 95101 | ASTRA | 34.03 |
| 11 Apr 12 09:41 | LONGBRIDGE | KM09YGC | WILLIAMS J | 120 | 32.72 | 73425 mi | 376 | 605 | 52.24 | Diesel | 95349 | ASTRA | 36.51 |
| 13 Apr 12 10:01 | LONGBRIDGE | KM09YGC | WILLIAMS J | 120 | 32.00 | 73780 mi | 355 | 571 | 50.43 | Diesel | 95540 | ASTRA | 35.71 |
| 18 Apr 12 08:18 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 33.32 | 74174 mi | 394 | 634 | 53.76 | Diesel | 95699 | ASTRA | 39.72 |
| 20 Apr 12 07:56 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 28.02 | 74516 mi | 342 | 550 | 55.49 | Diesel | 95826 | ASTRA | 32.93 |
| 24 Apr 12 15:19 | STRENSHAM | KM09YGC | LECKIE P | 120 | 23.21 | 74785 mi | 269 | 433 | 52.69 | Diesel | 96184 | ASTRA | 27.27 |
| 27 Apr 12 13:40 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 21.80 | 75022 mi | 237 | 381 | 49.42 | Diesel | 96162 | ASTRA | 25.83 |
| 02 May 12 08:50 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 22.63 | 75284 mi | 262 | 422 | 52.63 | Diesel | 96485 | ASTRA | 26.56 |
| 08 May 12 08:22 | WARNDON | KM09YGC | STEADMAN N | 120 | 25.20 | 75594 mi | 310 | 499 | 55.92 | Diesel | 96709 | ASTRA | 29.87 |
| 09 May 12 14:39 | WARNDON | KM09YGC | STEADMAN N | 120 | 29.33 | 75967 mi | 373 | 600 | 57.81 | Diesel | 96821 | ASTRA | 34.87 |
| 15 May 12 09:58 | STRENSHAM | KM09YGC | WILLIAMS J | 120 | 20.91 | 76202 mi | 235 | 378 | 51.09 | Diesel | 97177 | ASTRA | 24.21 |

Merridale FuelFX v15.09 Page 1

The information or data can be exported as CSV to work on in other formats.



## Appendix D-4 Summary of *p* Values for the Normality Tests

### (A) Normality test for the heavy vehicle data set – training group

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | *p* value | Statistic | df | *p* value |
| Aug_2009 | 0.149 | 22 | 0.2 | 0.933 | 22 | 0.141 |
| Sep_2009 | 0.14 | 21 | 0.2 | 0.958 | 21 | 0.471 |
| Oct_2009 | 0.128 | 24 | 0.2 | 0.938 | 24 | 0.15 |
| Nov_2009 | 0.082 | 23 | 0.2 | 0.984 | 23 | 0.963 |
| Dec_2009 | 0.145 | 24 | 0.2 | 0.944 | 24 | 0.202 |
| Jan_2010 | 0.112 | 27 | 0.2 | 0.977 | 27 | 0.795 |
| Feb_2010 | 0.134 | 29 | 0.198 | 0.864 | 29 | 0.002 |
| Mar_2010 | 0.102 | 29 | 0.2 | 0.944 | 29 | 0.129 |
| Apr_2010 | 0.147 | 34 | 0.059 | 0.858 | 34 | 0 |
| May_2010 | 0.185 | 34 | 0.005 | 0.92 | 34 | 0.017 |
| Jun_2010 | 0.112 | 32 | 0.2 | 0.984 | 32 | 0.904 |
| Jul_2010 | 0.105 | 32 | 0.2 | 0.977 | 32 | 0.72 |
| Aug_2010 | 0.088 | 33 | 0.2 | 0.963 | 33 | 0.311 |
| Sep_2010 | 0.11 | 33 | 0.2 | 0.98 | 33 | 0.789 |
| Oct_2010 | 0.16 | 33 | 0.031 | 0.878 | 33 | 0.002 |
| Nov_2010 | 0.076 | 35 | 0.2 | 0.966 | 35 | 0.337 |
| Dec_2010 | 0.104 | 35 | 0.2 | 0.978 | 35 | 0.693 |
| Jan_2011 | 0.155 | 35 | 0.032 | 0.922 | 35 | 0.016 |
| Feb_2011 | 0.14 | 33 | 0.099 | 0.939 | 33 | 0.063 |
| Mar_2011 | 0.094 | 33 | 0.2 | 0.975 | 33 | 0.617 |
| Apr_2011 | 0.151 | 29 | 0.089 | 0.911 | 29 | 0.018 |
| May_2011 | 0.167 | 29 | 0.039 | 0.904 | 29 | 0.012 |
| Jun_2011 | 0.2 | 23 | 0.018 | 0.846 | 23 | 0.002 |
| Jul_2011 | 0.276 | 25 | 0 | 0.735 | 25 | 0 |
| Aug_2011 | 0.133 | 25 | 0.2 | 0.96 | 25 | 0.419 |
| Sep_2011 | 0.115 | 27 | 0.2 | 0.951 | 27 | 0.223 |
| Oct_2011 | 0.166 | 27 | 0.055 | 0.863 | 27 | 0.002 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Nov_2011 | 0.105 | 31 | 0.2 | 0.968 | 31 | 0.475 |
| Dec_2011 | 0.077 | 34 | 0.2 | 0.975 | 34 | 0.619 |
| Jan_2012 | 0.115 | 33 | 0.2 | 0.93 | 33 | 0.035 |
| Feb_2012 | 0.205 | 31 | 0.002 | 0.897 | 31 | 0.006 |
| Mar_2012 | 0.105 | 28 | 0.2 | 0.962 | 28 | 0.393 |
| Apr_2012 | 0.235 | 30 | 0 | 0.878 | 30 | 0.003 |
| May_2012 | 0.152 | 29 | 0.085 | 0.91 | 29 | 0.018 |
| Jun_2012 | 0.134 | 30 | 0.177 | 0.949 | 30 | 0.16 |
| Jul_2012 | 0.101 | 27 | 0.2 | 0.971 | 27 | 0.632 |
| Aug_2012 | 0.145 | 25 | 0.189 | 0.941 | 25 | 0.153 |
| Sep_2012 | 0.125 | 28 | 0.2 | 0.958 | 28 | 0.312 |
| Oct_2012 | 0.11 | 30 | 0.2 | 0.937 | 30 | 0.075 |
| Nov_2012 | 0.104 | 31 | 0.2 | 0.964 | 31 | 0.372 |
| Dec_2012 | 0.119 | 29 | 0.2 | 0.946 | 29 | 0.147 |
| Jan_2013 | 0.12 | 30 | 0.2 | 0.928 | 30 | 0.043 |
| Feb_2013 | 0.119 | 29 | 0.2 | 0.943 | 29 | 0.123 |
| Mar_2013 | 0.154 | 30 | 0.066 | 0.877 | 30 | 0.002 |

(B) Normality test for the heavy vehicle data set – control group

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | $p$ value | Statistic | df | $p$ value |
| Aug_2009 | 0.130 | 18 | 0.200 | 0.955 | 18 | 0.509 |
| Sep_2009 | 0.161 | 16 | 0.200 | 0.911 | 16 | 0.121 |
| Oct_2009 | 0.165 | 17 | 0.200 | 0.912 | 17 | 0.110 |
| Nov_2009 | 0.157 | 18 | 0.200 | 0.907 | 18 | 0.076 |
| Dec_2009 | 0.159 | 18 | 0.200 | 0.845 | 18 | 0.007 |
| Jan_2010 | 0.159 | 21 | 0.178 | 0.957 | 21 | 0.449 |
| Feb_2010 | 0.127 | 24 | 0.200 | 0.933 | 24 | 0.112 |
| Mar_2010 | 0.172 | 28 | 0.034 | 0.929 | 28 | 0.057 |
| Apr_2010 | 0.145 | 28 | 0.137 | 0.954 | 28 | 0.252 |
| May_2010 | 0.155 | 29 | 0.072 | 0.969 | 29 | 0.538 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Jun_2010 | 0.162 | 30 | 0.042 | 0.879 | 30 | 0.003 |
| Jul_2010 | 0.167 | 30 | 0.032 | 0.926 | 30 | 0.038 |
| Aug_2010 | 0.137 | 29 | 0.176 | 0.909 | 29 | 0.016 |
| Sep_2010 | 0.135 | 32 | 0.145 | 0.946 | 32 | 0.108 |
| Oct_2010 | 0.089 | 32 | 0.200 | 0.947 | 32 | 0.117 |
| Nov_2010 | 0.084 | 31 | 0.200 | 0.980 | 31 | 0.799 |
| Dec_2010 | 0.174 | 33 | 0.013 | 0.935 | 33 | 0.048 |
| Jan_2011 | 0.087 | 30 | 0.200 | 0.967 | 30 | 0.472 |
| Feb_2011 | 0.096 | 31 | 0.200 | 0.947 | 31 | 0.126 |
| Mar_2011 | 0.106 | 30 | 0.200 | 0.919 | 30 | 0.026 |
| Apr_2011 | 0.202 | 27 | 0.006 | 0.881 | 27 | 0.005 |
| May_2011 | 0.156 | 27 | 0.089 | 0.965 | 27 | 0.480 |
| Jun_2011 | 0.161 | 27 | 0.071 | 0.946 | 27 | 0.169 |
| Jul_2011 | 0.093 | 25 | 0.200 | 0.971 | 25 | 0.659 |
| Aug_2011 | 0.176 | 24 | 0.054 | 0.938 | 24 | 0.149 |
| Sep_2011 | 0.155 | 31 | 0.057 | 0.933 | 31 | 0.055 |
| Oct_2011 | 0.119 | 33 | 0.200 | 0.976 | 33 | 0.657 |
| Nov_2011 | 0.170 | 30 | 0.027 | 0.924 | 30 | 0.035 |
| Dec_2011 | 0.170 | 31 | 0.022 | 0.948 | 31 | 0.137 |
| Jan_2012 | 0.138 | 31 | 0.136 | 0.931 | 31 | 0.048 |
| Feb_2012 | 0.122 | 33 | 0.200 | 0.937 | 33 | 0.055 |
| Mar_2012 | 0.158 | 33 | 0.035 | 0.839 | 33 | 0.000 |
| Apr_2012 | 0.083 | 31 | 0.200 | 0.974 | 31 | 0.640 |
| May_2012 | 0.123 | 29 | 0.200 | 0.935 | 29 | 0.075 |
| Jun_2012 | 0.119 | 26 | 0.200 | 0.957 | 26 | 0.332 |
| Jul_2012 | 0.148 | 28 | 0.117 | 0.937 | 28 | 0.094 |
| Aug_2012 | 0.181 | 26 | 0.027 | 0.886 | 26 | 0.008 |
| Sep_2012 | 0.131 | 26 | 0.200 | 0.946 | 26 | 0.192 |
| Oct_2012 | 0.148 | 29 | 0.102 | 0.910 | 29 | 0.017 |
| Nov_2012 | 0.151 | 29 | 0.087 | 0.900 | 29 | 0.010 |
| Dec_2012 | 0.167 | 27 | 0.051 | 0.941 | 27 | 0.126 |
| Jan_2013 | 0.168 | 27 | 0.050 | 0.924 | 27 | 0.051 |
| Feb_2013 | 0.094 | 26 | 0.200 | 0.970 | 26 | 0.631 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mar_2013 | 0.108 | 25 | 0.200 | 0.940 | 25 | 0.150 |

(C) Normality test for the medium vehicle data set – training group

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | *p* value | Statistic | df | *p* value |
| Aug_2009 | 0.151 | 18 | 0.2 | 0.908 | 18 | 0.079 |
| Sep_2009 | 0.12 | 17 | 0.2 | 0.974 | 17 | 0.89 |
| Oct_2009 | 0.124 | 18 | 0.2 | 0.936 | 18 | 0.244 |
| Nov_2009 | 0.103 | 16 | 0.2 | 0.981 | 16 | 0.972 |
| Dec_2009 | 0.187 | 14 | 0.197 | 0.908 | 14 | 0.146 |
| Jan_2010 | 0.155 | 15 | 0.2 | 0.968 | 15 | 0.831 |
| Feb_2010 | 0.186 | 23 | 0.038 | 0.833 | 23 | 0.001 |
| Mar_2010 | 0.156 | 22 | 0.175 | 0.957 | 22 | 0.438 |
| Apr_2010 | 0.122 | 25 | 0.2 | 0.952 | 25 | 0.271 |
| May_2010 | 0.155 | 24 | 0.139 | 0.934 | 24 | 0.122 |
| Jun_2010 | 0.135 | 27 | 0.2 | 0.972 | 27 | 0.651 |
| Jul_2010 | 0.129 | 22 | 0.2 | 0.967 | 22 | 0.635 |
| Aug_2010 | 0.121 | 25 | 0.2 | 0.979 | 25 | 0.863 |
| Sep_2010 | 0.135 | 25 | 0.2 | 0.967 | 25 | 0.569 |
| Oct_2010 | 0.168 | 26 | 0.056 | 0.953 | 26 | 0.274 |
| Nov_2010 | 0.189 | 20 | 0.06 | 0.918 | 20 | 0.089 |
| Dec_2010 | 0.141 | 19 | 0.2 | 0.941 | 19 | 0.273 |
| Jan_2011 | 0.102 | 25 | 0.2 | 0.953 | 25 | 0.29 |
| Feb_2011 | 0.083 | 26 | 0.2 | 0.952 | 26 | 0.264 |
| Mar_2011 | 0.097 | 25 | 0.2 | 0.966 | 25 | 0.537 |
| Apr_2011 | 0.15 | 23 | 0.199 | 0.931 | 23 | 0.114 |
| May_2011 | 0.148 | 32 | 0.072 | 0.916 | 32 | 0.016 |
| Jun_2011 | 0.125 | 30 | 0.2 | 0.935 | 30 | 0.067 |
| Jul_2011 | 0.086 | 31 | 0.2 | 0.987 | 31 | 0.965 |
| Aug_2011 | 0.122 | 28 | 0.2 | 0.953 | 28 | 0.229 |
| Sep_2011 | 0.118 | 29 | 0.2 | 0.915 | 29 | 0.023 |
| Oct_2011 | 0.147 | 27 | 0.142 | 0.928 | 27 | 0.062 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Nov_2011 | 0.15 | 28 | 0.109 | 0.94 | 28 | 0.108 |
| Dec_2011 | 0.157 | 27 | 0.086 | 0.958 | 27 | 0.339 |
| Jan_2012 | 0.073 | 27 | 0.2 | 0.979 | 27 | 0.842 |
| Feb_2012 | 0.123 | 28 | 0.2 | 0.896 | 28 | 0.009 |
| Mar_2012 | 0.082 | 31 | 0.2 | 0.965 | 31 | 0.392 |
| Apr_2012 | 0.086 | 29 | 0.2 | 0.97 | 29 | 0.548 |
| May_2012 | 0.092 | 29 | 0.2 | 0.973 | 29 | 0.638 |
| Jun_2012 | 0.16 | 28 | 0.065 | 0.942 | 28 | 0.126 |
| Jul_2012 | 0.166 | 29 | 0.04 | 0.959 | 29 | 0.317 |
| Aug_2012 | 0.094 | 30 | 0.2 | 0.973 | 30 | 0.617 |
| Sep_2012 | 0.11 | 30 | 0.2 | 0.954 | 30 | 0.218 |
| Oct_2012 | 0.1 | 31 | 0.2 | 0.97 | 31 | 0.509 |
| Nov_2012 | 0.1 | 31 | 0.2 | 0.956 | 31 | 0.234 |
| Dec_2012 | 0.101 | 28 | 0.2 | 0.973 | 28 | 0.675 |
| Jan_2013 | 0.088 | 28 | 0.2 | 0.98 | 28 | 0.84 |
| Feb_2013 | 0.095 | 26 | 0.2 | 0.977 | 26 | 0.795 |
| Mar_2013 | 0.155 | 28 | 0.084 | 0.952 | 28 | 0.219 |

(D) Normality test for the medium vehicle data set – control group

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | *p* value | Statistic | df | *p* value |
| Aug_2009 | 0.106 | 17 | 0.2 | 0.988 | 17 | 0.998 |
| Sep_2009 | 0.183 | 14 | 0.2 | 0.915 | 14 | 0.185 |
| Oct_2009 | 0.157 | 16 | 0.2 | 0.937 | 16 | 0.31 |
| Nov_2009 | 0.163 | 19 | 0.2 | 0.966 | 19 | 0.692 |
| Dec_2009 | 0.138 | 15 | 0.2 | 0.973 | 15 | 0.894 |
| Jan_2010 | 0.126 | 20 | 0.2 | 0.96 | 20 | 0.55 |
| Feb_2010 | 0.145 | 23 | 0.2 | 0.947 | 23 | 0.253 |
| Mar_2010 | 0.107 | 25 | 0.2 | 0.931 | 25 | 0.09 |
| Apr_2010 | 0.154 | 21 | 0.2 | 0.923 | 21 | 0.102 |
| May_2010 | 0.108 | 25 | 0.2 | 0.943 | 25 | 0.178 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Jun_2010 | 0.149 | 20 | 0.2 | 0.953 | 20 | 0.421 |
| Jul_2010 | 0.114 | 22 | 0.2 | 0.956 | 22 | 0.411 |
| Aug_2010 | 0.1 | 23 | 0.2 | 0.965 | 23 | 0.576 |
| Sep_2010 | 0.109 | 22 | 0.2 | 0.983 | 22 | 0.955 |
| Oct_2010 | 0.139 | 22 | 0.2 | 0.96 | 22 | 0.488 |
| Nov_2010 | 0.185 | 19 | 0.086 | 0.933 | 19 | 0.197 |
| Dec_2010 | 0.116 | 20 | 0.2 | 0.972 | 20 | 0.806 |
| Jan_2011 | 0.093 | 24 | 0.2 | 0.971 | 24 | 0.689 |
| Feb_2011 | 0.104 | 29 | 0.2 | 0.977 | 29 | 0.761 |
| Mar_2011 | 0.11 | 28 | 0.2 | 0.96 | 28 | 0.357 |
| Apr_2011 | 0.164 | 23 | 0.111 | 0.962 | 23 | 0.499 |
| May_2011 | 0.134 | 29 | 0.197 | 0.912 | 29 | 0.019 |
| Jun_2011 | 0.13 | 31 | 0.196 | 0.969 | 31 | 0.492 |
| Jul_2011 | 0.175 | 27 | 0.033 | 0.904 | 27 | 0.016 |
| Aug_2011 | 0.168 | 26 | 0.058 | 0.91 | 26 | 0.026 |
| Sep_2011 | 0.138 | 28 | 0.187 | 0.949 | 28 | 0.182 |
| Oct_2011 | 0.192 | 27 | 0.012 | 0.933 | 27 | 0.081 |
| Nov_2011 | 0.065 | 31 | 0.2 | 0.988 | 31 | 0.976 |
| Dec_2011 | 0.187 | 25 | 0.024 | 0.9 | 25 | 0.018 |
| Jan_2012 | 0.121 | 29 | 0.2 | 0.953 | 29 | 0.223 |
| Feb_2012 | 0.116 | 25 | 0.2 | 0.963 | 25 | 0.483 |
| Mar_2012 | 0.12 | 25 | 0.2 | 0.975 | 25 | 0.777 |
| Apr_2012 | 0.132 | 25 | 0.2 | 0.953 | 25 | 0.294 |
| May_2012 | 0.094 | 31 | 0.2 | 0.968 | 31 | 0.462 |
| Jun_2012 | 0.127 | 29 | 0.2 | 0.981 | 29 | 0.863 |
| Jul_2012 | 0.135 | 29 | 0.188 | 0.967 | 29 | 0.491 |
| Aug_2012 | 0.102 | 28 | 0.2 | 0.961 | 28 | 0.371 |
| Sep_2012 | 0.196 | 26 | 0.011 | 0.934 | 26 | 0.095 |
| Oct_2012 | 0.136 | 26 | 0.2 | 0.964 | 26 | 0.485 |
| Nov_2012 | 0.083 | 29 | 0.2 | 0.967 | 29 | 0.474 |
| Dec_2012 | 0.1 | 22 | 0.2 | 0.972 | 22 | 0.755 |
| Jan_2013 | 0.198 | 20 | 0.039 | 0.903 | 20 | 0.047 |
| Feb_2013 | 0.149 | 19 | 0.2 | 0.942 | 19 | 0.283 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mar_2013 | 0.126 | 20 | 0.2 | 0.976 | 20 | 0.865 |

(E) Normality test for the light vehicle data set – training group

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | *p* value | Statistic | df | *p* value |
| Aug_2011 | 0.258 | 11 | 0.039 | 0.885 | 11 | 0.119 |
| Sep_2011 | 0.267 | 11 | 0.027 | 0.858 | 11 | 0.054 |
| Oct_2011 | 0.166 | 11 | 0.2 | 0.901 | 11 | 0.189 |
| Nov_2011 | 0.193 | 11 | 0.2 | 0.93 | 11 | 0.414 |
| Dec_2011 | 0.271 | 10 | 0.036 | 0.881 | 10 | 0.133 |
| Jan_2012 | 0.135 | 12 | 0.2 | 0.906 | 12 | 0.191 |
| Feb_2012 | 0.238 | 10 | 0.113 | 0.898 | 10 | 0.206 |
| Mar_2012 | 0.145 | 12 | 0.2 | 0.917 | 12 | 0.258 |
| Apr_2012 | 0.151 | 12 | 0.2 | 0.939 | 12 | 0.482 |
| May_2012 | 0.171 | 12 | 0.2 | 0.879 | 12 | 0.085 |
| Jun_2012 | 0.158 | 12 | 0.2 | 0.941 | 12 | 0.51 |
| Jul_2012 | 0.273 | 11 | 0.021 | 0.78 | 11 | 0.005 |
| Aug_2012 | 0.188 | 13 | 0.2 | 0.909 | 13 | 0.177 |
| Sep_2012 | 0.187 | 13 | 0.2 | 0.841 | 13 | 0.022 |
| Oct_2012 | 0.18 | 11 | 0.2 | 0.935 | 11 | 0.466 |
| Nov_2012 | 0.226 | 13 | 0.067 | 0.934 | 13 | 0.386 |
| Dec_2012 | 0.236 | 11 | 0.089 | 0.871 | 11 | 0.08 |
| Jan_2013 | 0.153 | 8 | 0.2 | 0.946 | 8 | 0.669 |
| Feb_2013 | 0.122 | 7 | 0.2 | 0.993 | 7 | 0.998 |
| Mar_2013 | 0.227 | 7 | 0.2 | 0.916 | 7 | 0.437 |

(F) Normality test for the light vehicle data set – control group

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | *p* value | Statistic | df | *p* value |
| Aug_2011 | 0.206 | 10 | .200* | 0.879 | 10 | 0.127 |
| Sep_2011 | 0.326 | 11 | 0.002 | 0.818 | 11 | 0.016 |
| Oct_2011 | 0.217 | 10 | 0.199 | 0.92 | 10 | 0.36 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Nov_2011 | 0.194 | 10 | .200* | 0.92 | 10 | 0.355 |
| Dec_2011 | 0.188 | 10 | .200* | 0.937 | 10 | 0.515 |
| Jan_2012 | 0.146 | 12 | .200* | 0.906 | 12 | 0.188 |
| Feb_2012 | 0.147 | 9 | .200* | 0.964 | 9 | 0.836 |
| Mar_2012 | 0.175 | 10 | .200* | 0.957 | 10 | 0.751 |
| Apr_2012 | 0.181 | 9 | .200* | 0.979 | 9 | 0.956 |
| May_2012 | 0.179 | 10 | .200* | 0.953 | 10 | 0.7 |
| Jun_2012 | 0.29 | 12 | 0.006 | 0.83 | 12 | 0.021 |
| Jul_2012 | 0.272 | 10 | 0.034 | 0.8 | 10 | 0.015 |
| Aug_2012 | 0.326 | 10 | 0.003 | 0.777 | 10 | 0.008 |
| Sep_2012 | 0.276 | 11 | 0.019 | 0.86 | 11 | 0.058 |
| Oct_2012 | 0.211 | 11 | 0.183 | 0.847 | 11 | 0.039 |
| Nov_2012 | 0.256 | 10 | 0.063 | 0.882 | 10 | 0.136 |
| Dec_2012 | 0.216 | 9 | .200* | 0.908 | 9 | 0.301 |
| Jan_2013 | 0.19 | 9 | .200* | 0.886 | 9 | 0.18 |
| Feb_2013 | 0.234 | 10 | 0.13 | 0.835 | 10 | 0.039 |
| Mar_2013 | 0.323 | 8 | 0.014 | 0.806 | 8 | 0.033 |

## Appendix D-5 Summary of the MPG data

### (A) Additional driver details and annual vehicle-km

| Driver ID | Gender | Age Group | Years of Experience | Driving Time | Depot | Vehicle Category | Treated, 2009 | Treated, 2012 | Control Group | Annual Veh-km, Aug2009-Aug2010 by Veh Cat | Annual Veh-km, Aug2010-Aug2011 by Veh Dat | Annual Veh-km, Aug2011-Aug2012 by Veh Cat | Average Annual veh-km by Veh Dat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Treated | Treated | Treated | 19,694 | 19,920 | 14,561 | 18,058 |
| 79 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Treated | Treated | Treated | 15,947 | 19,283 | 34,869 | 23,366 |
| 85 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Treated | Treated | Treated | 30,597 | 11,592 | 73,042 | 38,410 |
| 98 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Treated | Treated | Treated | 22,897 | 15,041 | 23,020 | 20,319 |
| 208 | Male | Under 45 | Over 10 | Day and Night Shifts | Strensham | Heavy | Treated | Treated | Treated | 10,642 | 11,295 | 2,389 | 8,109 |
| 299 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Treated | Treated | Treated | 6,684 | 15,070 | 13,782 | 11,845 |
| 381 | Male | Under 45 | Under 10 | Day and Night Shifts | Strensham | Heavy | Treated | Treated | Treated | 33,374 | 24,140 | 16,026 | 24,513 |
| 472 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Treated | Treated | Treated | 10,945 | 12,504 | 23,842 | 15,764 |
| 478 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Treated | Treated | Treated | 20,261 | 2,173 | 12,183 | 11,539 |
| 10 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 22,119 | 49,351 | 39,815 | 37,095 |
| 15 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 26,254 | 30,536 | 9,932 | 22,241 |
| 35 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 45,319 | 10,677 | 5,503 | 20,500 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 42 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 10,937 | 15,486 | 12,934 | 13,119 |
| 76 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 8,578 | 12,927 | 18,365 | 13,290 |
| 109 | Male | Under 45 | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 18,258 | 18,947 | 9,148 | 15,451 |
| 118 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 15,253 | 25,260 | 23,561 | 21,358 |
| 130 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 2,956 | 22,338 | 12,250 | 12,515 |
| 132 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 11,958 | 8,718 | 11,134 | 10,603 |
| 139 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 18,929 | 63,912 | 8,245 | 30,362 |
| 171 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 7,610 | 13,818 | 76,853 | 32,760 |
| 210 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 12,328 | 16,958 | 13,376 | 14,221 |
| 225 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 5,683 | 14,309 | 14,227 | 11,406 |
| 229 | Male | Under 45 | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 4,138 | 13,774 | 7,161 | 8,358 |
| 244 | Male | Under 45 | Under 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 9,831 | 11,965 | 67,240 | 29,679 |
| 251 | Male | Under 45 | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 15,915 | 13,385 | 4,243 | 11,181 |
| 261 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 3,433 | 14,099 | 5,509 | 7,680 |
| 314 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 20,106 | 22,218 | 18,839 | 20,388 |
| 344 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 19,194 | 7,766 | 20,465 | 15,808 |
| 365 | Male | Under 45 | Under 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 4,799 | 12,352 | 13,547 | 10,233 |
| 392 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 31,968 | 34,462 | 8,647 | 25,026 |
| 433 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 21,187 | 13,390 | 10,692 | 15,090 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 442 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 11,674 | 46,505 | 7,511 | 21,897 |
| 464 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 31,844 | 22,121 | 20,573 | 24,846 |
| 492 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Heavy | Untreated | Treated | Treated | 3,776 | 19,383 | 14,192 | 12,450 |
| 26 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 4,487 | 18,838 | 5,602 | 9,642 |
| 28 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 1,657 | 1,389 | 12,630 | 5,225 |
| 51 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 1,076 | 6,178 | 3,740 | 3,665 |
| 60 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 10,831 | 37,714 | 7,753 | 18,766 |
| 74 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 11,504 | 16,786 | 13,795 | 14,028 |
| 88 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 4,226 | 11,196 | 16,162 | 10,528 |
| 114 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 15,848 | 16,061 | 68,035 | 33,315 |
| 124 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 14,129 | 22,553 | 11,231 | 15,971 |
| 128 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 34,503 | 7,283 | 19,793 | 20,526 |
| 138 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 4,456 | 79,317 | 20,137 | 34,637 |
| 149 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 23,749 | 12,919 | 12,399 | 16,356 |
| 164 | Male | Under 45 | Under 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 4,443 | 9,726 | 5,489 | 6,553 |
| 199 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 6,679 | 19,572 | 20,741 | 15,664 |
| 201 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 1,895 | 17,824 | 58,172 | 25,964 |
| 216 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 6,564 | 65,823 | 15,899 | 29,429 |
| 234 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 4,130 | 11,305 | 21,247 | 12,227 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 239 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 22,973 | 15,382 | 18,061 | 18,805 |
| 245 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 5,896 | 19,046 | 22,000 | 15,647 |
| 255 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 15,004 | 16,361 | 17,147 | 16,171 |
| 302 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 4,831 | 12,554 | 8,664 | 8,683 |
| 317 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 12,545 | 12,933 | 7,101 | 10,860 |
| 318 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 21,839 | 11,385 | 7,814 | 13,679 |
| 378 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 15,914 | 1,003 | 7,209 | 8,042 |
| 379 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 16,732 | 27,112 | 15,914 | 19,919 |
| 389 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 23,583 | 11,613 | 19,441 | 18,212 |
| 401 | Male | Under 45 | Under 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 32,584 | 72,096 | 3,943 | 36,208 |
| 428 | Male | 45+ | Under 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 11,710 | 26,811 | 17,488 | 18,670 |
| 431 | Male | Under 45 | Under 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 3,246 | 13,211 | 11,051 | 9,169 |
| 444 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 586 | 3,949 | 6,548 | 3,694 |
| 463 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 14,867 | 41,387 | 12,805 | 23,020 |
| 471 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 23,716 | 24,809 | 11,365 | 19,963 |
| 479 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 6,331 | 11,311 | 4,436 | 7,359 |
| 499 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 10,817 | 9,349 | 18,667 | 12,944 |
| 503 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Heavy | Untreated | Untreated | Control | 2,987 | 19,875 | 8,583 | 10,482 |
| 39 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Treated | Treated | Treated | 12,431 | 23,355 | 23,856 | 19,881 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 79 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Treated | Treated | Treated | 26,111 | 78,320 | 81,413 | 61,948 |
| 85 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Treated | Treated | Treated | 17,634 | 34,363 | 16,691 | 22,896 |
| 98 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Treated | Treated | Treated | 27,355 | 21,020 | 22,070 | 23,482 |
| 208 | Male | Under 45 | Over 10 | Day and Night Shifts | Strensham | Medium | Treated | Treated | Treated | 13,713 | 18,464 | 12,359 | 14,845 |
| 299 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Treated | Treated | Treated | 13,745 | 21,926 | 14,947 | 16,873 |
| 381 | Male | Under 45 | Under 10 | Day and Night Shifts | Strensham | Medium | Treated | Treated | Treated | 37,237 | 53,194 | 17,031 | 35,821 |
| 472 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Treated | Treated | Treated | 15,236 | 16,945 | 40,662 | 24,281 |
| 478 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Treated | Treated | Treated | 22,928 | 24,687 | 37,575 | 28,397 |
| 10 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 16,247 | 14,426 | 14,067 | 14,913 |
| 15 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 24,158 | 8,891 | 9,842 | 14,297 |
| 35 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 15,774 | 21,268 | 15,130 | 17,391 |
| 42 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 17,075 | 18,249 | 29,768 | 21,697 |
| 76 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 12,275 | 24,723 | 29,065 | 22,021 |
| 109 | Male | Under 45 | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 16,290 | 14,950 | 18,902 | 16,714 |
| 118 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 15,767 | 16,809 | 25,496 | 19,357 |
| 130 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 8,495 | 23,327 | 16,206 | 16,009 |
| 132 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 16,407 | 17,096 | 19,912 | 17,805 |
| 139 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 21,169 | 17,539 | 19,304 | 19,337 |
| 171 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 9,360 | 19,630 | 18,579 | 15,856 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 210 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 12,563 | 22,100 | 27,500 | 20,721 |
| 225 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 26,179 | 19,645 | 19,070 | 21,631 |
| 229 | Male | Under 45 | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 6,124 | 17,809 | 16,674 | 13,536 |
| 244 | Male | Under 45 | Under 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 11,373 | 15,052 | 14,304 | 13,576 |
| 251 | Male | Under 45 | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 18,844 | 19,882 | 36,519 | 25,082 |
| 261 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 19,835 | 19,764 | 10,558 | 16,719 |
| 314 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 25,325 | 27,379 | 25,728 | 26,144 |
| 344 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 20,627 | 11,141 | 58,046 | 29,938 |
| 365 | Male | Under 45 | Under 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 87,532 | 34,638 | 47,268 | 56,479 |
| 392 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 33,331 | 37,078 | 20,698 | 30,369 |
| 433 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 24,428 | 21,280 | 19,847 | 21,852 |
| 442 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 13,281 | 52,040 | 29,375 | 31,565 |
| 464 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 40,170 | 32,107 | 20,865 | 31,047 |
| 492 | Male | 45+ | Over 10 | Day and Night Shifts | Strensham | Medium | Untreated | Treated | Treated | 5,059 | 27,845 | 23,082 | 18,662 |
| 26 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 45,858 | 23,522 | 11,606 | 26,995 |
| 28 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 13,089 | 16,019 | 18,274 | 15,794 |
| 51 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 4,088 | 17,564 | 34,877 | 18,843 |
| 60 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 13,399 | 43,345 | 18,274 | 25,006 |
| 74 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 18,024 | 9,035 | 21,145 | 16,068 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 88 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 11,884 | 16,701 | 27,644 | 18,743 |
| 114 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 20,254 | 27,989 | 10,939 | 19,727 |
| 124 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 16,187 | 25,372 | 11,424 | 17,661 |
| 128 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 18,906 | 25,779 | 38,037 | 27,574 |
| 138 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 19,517 | 18,654 | 17,908 | 18,693 |
| 149 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 17,305 | 29,158 | 30,748 | 25,737 |
| 164 | Male | Under 45 | Under 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 4,443 | 18,376 | 20,502 | 14,440 |
| 199 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 18,250 | 29,942 | 36,282 | 28,158 |
| 201 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 2,244 | 20,191 | 21,080 | 14,505 |
| 216 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 15,286 | 28,771 | 26,324 | 23,460 |
| 234 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 8,445 | 32,944 | 21,792 | 21,060 |
| 239 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 29,895 | 19,746 | 8,345 | 19,329 |
| 245 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 60,656 | 32,698 | 49,206 | 47,520 |
| 255 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 17,179 | 19,300 | 23,154 | 19,878 |
| 302 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 7,465 | 23,323 | 12,273 | 14,354 |
| 317 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 21,179 | 12,309 | 13,264 | 15,584 |
| 318 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 30,052 | 18,331 | 19,765 | 22,716 |
| 378 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 21,384 | 14,790 | 13,483 | 16,552 |
| 379 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 20,771 | 37,509 | 26,931 | 28,404 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 389 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 27,283 | 17,753 | 29,142 | 24,726 |
| 401 | Male | Under 45 | Under 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 45,448 | 18,167 | 15,284 | 26,300 |
| 428 | Male | 45+ | Under 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 19,347 | 30,817 | 39,130 | 29,765 |
| 431 | Male | Under 45 | Under 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 5,522 | 18,745 | 18,087 | 14,118 |
| 444 | Male | Under 45 | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 1,595 | 10,391 | 8,595 | 6,860 |
| 463 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 18,644 | 22,905 | 12,362 | 17,970 |
| 471 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 27,753 | 24,591 | 13,309 | 21,884 |
| 479 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 7,959 | 19,235 | 10,305 | 12,500 |
| 499 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 11,137 | 18,667 | 24,342 | 18,049 |
| 503 | Male | 45+ | Over 10 | Day and Night Shifts | Doxey and Stafford Park | Medium | Untreated | Untreated | Control | 11,676 | 8,583 | 91,411 | 37,223 |
| 458 | Male | Under 45 | Over 10 | Day | Strensham | Light | Treated | Error | Treated | 5,412 | 7,108 | 1,382 | 4,634 |
| 52 | Male | Under 45 | Under 10 | Day | Strensham | Light | Treated | Treated | Treated | 19,481 | 25,030 | 21,446 | 21,986 |
| 169 | Male | Under 45 | Under 10 | Day | Strensham | Light | Treated | Treated | Treated | 26,349 | 24,480 | 49,630 | 33,486 |
| 214 | Female | Under 45 | Under 10 | Day | Strensham | Light | Treated | Treated | Treated | 27,052 | 25,983 | 31,643 | 28,226 |
| 103 | Male | Under 45 | Over 10 | Day | Strensham | Light | Untreated | treated | Treated | 11,467 | 50,549 | 20,386 | 27,467 |
| 162 | Male | Under 45 | Over 10 | Day | Strensham | Light | Untreated | Treated | Treated | 3,995 | 13,389 | 4,910 | 7,431 |
| 176 | Male | 45+ | Over 10 | Day | Strensham | Light | Untreated | Treated | Treated | 5,529 | 7,891 | 4,564 | 5,995 |
| 190 | Male | 45+ | Over 10 | Day | Strensham | Light | Untreated | Treated | Treated | 14,163 | 7,124 | 8,353 | 9,880 |
| 195 | Male | 45+ | Over 10 | Day and Night | Strensham | Light | Untreated | Treated | Treated | 54,947 | 49,458 | 42,506 | 48,970 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 249 | Male | 45+ | Over 10 | Day and Night | Strensham | Light | Untreated | treated | Treated | 4,689 | 5,041 | 60,607 | 23,446 |
| 335 | Male | 45+ | Over 10 | Day | Strensham | Light | Untreated | Treated | Treated | 25,166 | 37,531 | 31,552 | 31,416 |
| 398 | Male | Under 45 | Under 10 | Day | Strensham | Light | Untreated | Treated | Treated | 20,527 | 33,665 | 9,043 | 21,078 |
| 409 | Male | Under 45 | Over 10 | Day | Strensham | Light | Untreated | Treated | Treated | 8,961 | 8,821 | 90,658 | 36,147 |
| 418 | Male | 45+ | Over 10 | Day | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 8,345 | 7,956 | 16,244 | 10,848 |
| 480 | Male | Under 45 | Under 10 | Day | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 16,745 | 18,907 | 14,691 | 16,781 |
| 488 | Male | Under 45 | Over 10 | Day | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 18,987 | 29,301 | 23,621 | 23,970 |
| 36 | Male | Under 45 | Over 10 | Day | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 33,685 | 18,959 | 37,276 | 29,973 |
| 71 | Male | 45+ | Over 10 | Day | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 22,659 | 11,837 | 9,157 | 14,551 |
| 86 | Male | 45+ | Over 10 | Day | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 9,805 | 18,035 | 11,324 | 13,055 |
| 145 | Male | Under 45 | Over 10 | Day | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 2,156 | 4,156 | 14,870 | 7,061 |
| 217 | Male | Under 45 | Over 10 | Day and Night | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 4,310 | 6,054 | 4,984 | 5,116 |
| 326 | Male | Under 45 | Under 10 | Day | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 27,155 | 12,145 | 14,994 | 18,098 |
| 343 | Male | Under 45 | Over 10 | Day | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 33,906 | 11,229 | 29,495 | 24,877 |
| 356 | Female | 45+ | Over 10 | Day | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 17,085 | 6,978 | 6,512 | 10,192 |
| 448 | Male | 45+ | Over 10 | Day and Night | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 32,567 | 42,830 | 49,784 | 41,727 |
| 473 | Male | 45+ | Over 10 | Day | Doxey and Stafford Park | Light | Untreated | Untreated | Control | 5,644 | 32,568 | 42,611 | 26,941 |

## (B) MPG data for Aug2009-Aug2010

| Driver ID | 2009 | 2009 | 2009 | 2009 | 2009 | 2010 | 2010 | 2010 | 2010 | 2010 | 2010 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | August | September | October | November | December | January | February | March | April | May | June | July |
| | Period1 | Period1 | Period1 | Period1 | Period1 | Period1 | Period1 | Period1 | Period1 | Period1 | Period1 | Period1 |
| 39 | 8.2 | 7.0 | 8.8 | 9.1 | 8.8 | 8.2 | 7.8 | 7.9 | 8.5 | 7.6 | 9.3 | 7.9 |
| 79 | 9.7 | 10.8 | 10.3 | 9.2 | 12.2 | 9.2 | 9.8 | 9.6 | 9.7 | 9.1 | 9.3 | 9.4 |
| 85 | 7.3 | 8.5 | 8.8 | 8.3 | 7.8 | 7.8 | 9.0 | 9.7 | 7.6 | 7.4 | | 10.0 |
| 98 | 9.4 | 8.9 | 8.1 | 8.0 | 8.9 | 7.9 | 8.4 | 9.6 | 8.7 | 8.3 | 8.2 | 7.7 |
| 208 | 9.1 | 9.3 | 9.1 | 9.8 | 9.7 | 9.0 | 8.5 | | 8.9 | 8.7 | | 8.1 |
| 299 | 9.6 | 8.0 | 9.0 | | 7.4 | 8.5 | 9.1 | 8.0 | 8.9 | 8.7 | 8.2 | 8.5 |
| 381 | 7.7 | 8.2 | 8.6 | 7.4 | 6.8 | 7.3 | 7.6 | 7.8 | 8.2 | 7.4 | 7.8 | 6.9 |
| 472 | | 8.1 | 8.8 | 6.8 | 7.0 | 8.1 | 7.5 | 8.3 | 7.8 | 8.0 | 8.5 | 7.9 |
| 478 | 7.8 | 8.1 | 7.0 | 8.1 | 8.5 | | | 8.0 | 8.9 | | | |
| 10 | 9.2 | 9.2 | 9.3 | 9.3 | 7.9 | 7.6 | 9.4 | 10.0 | 9.0 | 8.2 | 7.9 | 9.1 |
| 15 | | | 9.3 | 8.8 | 8.2 | 9.9 | 9.0 | 9.2 | 8.8 | 8.1 | 8.5 | 8.4 |
| 35 | 8.0 | 8.5 | 8.7 | 7.3 | 9.0 | 10.0 | 9.0 | 8.5 | 8.9 | 11.0 | 8.6 | 7.2 |
| 42 | | | | | | 8.7 | 8.6 | 7.4 | 8.7 | 9.6 | 7.4 | 7.9 |
| 76 | | | | | | 8.6 | 8.1 | 8.8 | 8.4 | 8.4 | 9.7 | 9.8 |
| 109 | 8.9 | 8.3 | 7.2 | 7.8 | 8.6 | 8.5 | 9.8 | 9.0 | 9.3 | 8.1 | 8.9 | 9.1 |
| 118 | | | | | | | 7.6 | 7.2 | 7.4 | 8.2 | 8.0 | |
| 130 | | | | | | 8.9 | | 9.8 | 10.4 | 9.1 | 9.3 | 11.1 |
| 132 | | | | | | | | | 8.2 | 9.7 | 8.7 | |
| 139 | 9.1 | 9.8 | 9.0 | 9.2 | 8.2 | 9.0 | 8.5 | 9.0 | 9.2 | 9.9 | 9.3 | 9.5 |
| 171 | | | | | | 8.6 | 7.2 | 9.4 | 8.0 | 5.9 | 7.6 | 7.3 |
| 210 | 8.8 | | 9.6 | 9.9 | 9.0 | 8.3 | 9.8 | 9.5 | 9.5 | 9.7 | 8.9 | 9.2 |
| 225 | | | | | | | 13.3 | | 9.2 | 8.2 | 10.6 | 8.6 |
| 229 | | | | | | | | | | 8.3 | 8.8 | 9.4 |
| 244 | 7.9 | 7.8 | 8.1 | 8.7 | 10.0 | 7.0 | 7.7 | 7.3 | 7.2 | 8.0 | 8.0 | 6.4 |
| 251 | 9.3 | 9.3 | 7.7 | 8.7 | 8.8 | 8.9 | 9.2 | 9.4 | 8.9 | 8.3 | 9.5 | 9.6 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 261 | 9.5 | | 11.6 | 10.2 | 10.2 | | | 11.8 | 12.5 | 10.9 | 8.7 | 9.1 |
| 314 | | | | | | 9.6 | 8.2 | 8.6 | 7.9 | 7.2 | 7.2 | 9.5 |
| 344 | 8.2 | 8.5 | 8.4 | 8.2 | 9.8 | 8.2 | 8.5 | 8.7 | 8.3 | 9.6 | 8.8 | 9.8 |
| 365 | 9.6 | 9.3 | 9.6 | 8.0 | 9.9 | 8.6 | 9.9 | 9.4 | 8.6 | 9.8 | 8.3 | 8.8 |
| 392 | 8.6 | 9.2 | 8.5 | 9.8 | 9.2 | 8.5 | 8.2 | 8.9 | 8.1 | 8.2 | 9.6 | 8.2 |
| 433 | | | | | | | 6.4 | 9.6 | 8.0 | 5.1 | 9.5 | 8.7 |
| 442 | 9.4 | 9.2 | 8.6 | 8.4 | 8.4 | 9.0 | 8.3 | | 8.0 | 3.5 | 9.9 | 9.9 |
| 464 | 8.1 | 8.4 | 7.9 | 8.9 | 8.5 | 9.7 | 9.1 | 8.0 | 9.1 | 12.4 | 8.0 | 8.0 |
| 492 | | | | | | | | | 7.5 | 8.3 | 9.5 | 6.4 |
| 26 | | | | | 11.0 | | | | 11.7 | 11.5 | 9.7 | 12.0 |
| 28 | | | | | | | | 6.9 | 9.2 | 8.9 | 7.9 | |
| 51 | 9.3 | 7.8 | 8.2 | 9.2 | | 11.2 | 12.3 | 6.4 | | | | |
| 60 | | | | | 8.0 | | | 10.8 | 9.0 | 8.7 | 8.4 | 7.9 |
| 74 | 8.7 | 8.2 | 8.6 | 6.9 | 9.2 | 7.1 | 7.7 | 8.0 | 6.1 | 8.4 | 6.1 | 9.7 |
| 88 | | | | | | | | | 7.5 | 8.8 | 6.5 | 8.3 |
| 114 | | | | | | 10.3 | 11.2 | 10.7 | 11.0 | 7.6 | 12.6 | 9.5 |
| 124 | 9.5 | 7.6 | 7.5 | 8.9 | 7.4 | 9.0 | 7.6 | 6.5 | 4.7 | 8.0 | 7.8 | 7.9 |
| 128 | 7.6 | | | | | 7.6 | 7.5 | 7.7 | 6.5 | | | |
| 138 | | | 10.2 | 11.5 | | | | | | 9.4 | 13.2 | |
| 149 | 9.2 | 9.0 | 7.5 | 7.9 | 11.2 | 8.2 | 8.6 | 8.3 | 9.1 | 9.1 | 6.9 | 8.4 |
| 164 | | | | 8.1 | | | | | 5.8 | 7.3 | 8.9 | 6.0 |
| 199 | 7.6 | 10.6 | 10.5 | 11.9 | | 10.7 | 9.4 | 11.4 | 7.1 | 8.7 | 5.9 | 12.8 |
| 201 | | | | | | | | | | 7.5 | | 6.0 |
| 216 | | | | | 8.9 | 7.5 | 8.7 | 10.8 | | 7.6 | 7.9 | 13.9 |
| 234 | | | | | | | | | 12.4 | 10.2 | | 7.6 |
| 239 | 7.6 | 9.1 | 7.7 | 7.9 | 7.8 | 7.9 | 7.3 | 9.3 | 9.7 | 7.5 | 8.0 | 8.1 |
| 245 | | | | | | 7.6 | 7.9 | 8.4 | 7.1 | 6.3 | 7.3 | 6.8 |
| 255 | 6.6 | 7.0 | 7.9 | 6.7 | 7.4 | 6.9 | 6.8 | 7.9 | 7.3 | 7.5 | 6.0 | 7.6 |
| 302 | | | | | | | 7.2 | 7.1 | 7.4 | 7.3 | 7.6 | 5.2 |
| 317 | 8.0 | 7.2 | 7.6 | 8.5 | 8.4 | 9.2 | 7.6 | 8.5 | 6.1 | | 5.9 | 11.5 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 318 | 9.8 | 7.1 | 7.2 | 6.5 | 7.3 | 8.5 | 8.1 | 7.9 | 7.3 | 6.2 | 7.5 | 7.4 |
| 378 | 8.2 | 7.1 | 7.7 | 8.0 | 7.5 | 7.6 | 5.7 | 8.1 | 8.6 | 9.6 | 9.2 | 7.0 |
| 379 | 8.1 | 9.0 | 9.4 | 9.9 | 8.8 | 7.5 | 7.3 | 8.4 | 7.0 | 7.5 | 8.6 | 9.0 |
| 389 | 9.6 | 10.5 | 9.9 | 8.0 | 7.8 | | 10.7 | 8.7 | 8.4 | 8.8 | 7.9 | 8.7 |
| 401 | 7.7 | 9.0 | 9.1 | 9.4 | 8.5 | 9.6 | 9.2 | 9.1 | 10.7 | 9.8 | 8.6 | 7.9 |
| 428 | 8.3 | 8.0 | | 7.9 | 8.4 | 6.2 | 9.4 | 7.6 | 7.0 | 7.3 | 7.2 | 6.7 |
| 431 | | | | | | | | 8.5 | | | 7.7 | 7.5 |
| 444 | | | | | | | | 7.6 | | | | |
| 463 | 10.9 | 11.4 | 10.3 | 8.3 | 9.1 | 9.2 | 9.3 | 6.1 | 14.2 | 9.3 | 7.4 | 11.6 |
| 471 | | | | | 7.4 | 6.0 | 8.2 | 9.1 | 8.0 | | 7.6 | 6.8 |
| 479 | | | | | | 7.4 | 6.8 | 7.6 | 12.2 | 10.8 | 9.7 | 5.5 |
| 499 | 11.2 | | 9.2 | | | | | 11.4 | 10.1 | 9.7 | 10.0 | 9.9 |
| 503 | | | | | | | 7.8 | | | 6.9 | 8.4 | 6.5 |
| 39 | 17.5 | 21.2 | 22.3 | 19.1 | | | 16.9 | 12.9 | | | 13.5 | |
| 79 | 25.7 | 29.1 | 25.4 | 24.2 | 24.9 | 21.7 | | 16.2 | 24.9 | 23.4 | 24.1 | 25.2 |
| 85 | 10.8 | 8.6 | 10.1 | 11.2 | 10.0 | 10.1 | 10.3 | 24.7 | 11.1 | 12.9 | 19.3 | 17.8 |
| 98 | 13.5 | 13.4 | 10.5 | | | | 14.3 | | 14.5 | 17.0 | 22.5 | 20.3 |
| 208 | | | 18.5 | | 25.0 | 16.7 | 20.2 | 18.3 | 18.7 | 16.9 | | |
| 299 | 16.4 | 13.6 | 15.7 | | | | 13.6 | 21.1 | 18.9 | 21.5 | 15.6 | 16.9 |
| 381 | | | 25.8 | 21.0 | | 24.4 | 37.7 | | 15.9 | 17.4 | | |
| 472 | 17.6 | | | 19.3 | 17.6 | | 16.4 | | 23.7 | | 17.2 | 14.1 |
| 478 | 16.4 | 16.1 | 10.6 | 10.0 | 10.0 | 12.0 | 10.0 | 9.8 | 10.1 | 10.3 | 10.2 | 11.2 |
| 10 | 26.2 | 25.4 | 16.4 | 13.8 | 17.5 | 27.8 | | 15.6 | 17.1 | 18.7 | 17.4 | 19.2 |
| 15 | 14.7 | 16.4 | 16.9 | 21.8 | 18.4 | 16.4 | 16.7 | 16.9 | 19.7 | | 19.3 | 18.1 |
| 35 | 27.4 | 17.1 | 18.7 | 13.7 | 16.9 | 19.8 | 20.3 | 18.1 | 15.2 | 18.2 | 19.4 | 12.8 |
| 42 | | | | | | | 25.9 | 21.5 | 25.2 | 29.9 | 27.7 | 21.9 |
| 76 | | | | | | | 18.7 | | 13.3 | | | 17.0 |
| 109 | 20.3 | 22.6 | 17.0 | 15.1 | 20.8 | 18.5 | 17.1 | | 13.2 | | 17.5 | |
| 118 | | | | | | | 11.2 | 17.0 | 16.6 | 14.2 | 11.4 | 17.5 |
| 130 | | | | | | 14.6 | 18.9 | 22.9 | 22.9 | | 24.5 | 20.2 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 132 | | | | | | | | 17.3 | 17.7 | 19.2 | 20.6 | 13.3 |
| 139 | 14.7 | 16.9 | 12.6 | 17.0 | 18.8 | 17.1 | 16.2 | 16.7 | 15.0 | 21.7 | 21.8 | |
| 171 | | | | | | | 17.8 | | | 18.1 | | 18.9 |
| 210 | | | | | | | | | | 19.2 | | |
| 225 | 18.9 | 18.5 | 19.8 | 16.0 | 18.3 | 16.9 | 17.9 | 15.1 | 18.6 | | 21.0 | 20.8 |
| 229 | | | | | | | | | | 17.5 | 13.8 | 17.6 |
| 244 | | | | | | | | | 15.7 | 14.1 | 11.4 | |
| 251 | | 13.7 | | | | | | 19.7 | 16.1 | 21.4 | | |
| 261 | 19.5 | 19.4 | 22.9 | 22.8 | 19.2 | 17.1 | 23.0 | 17.4 | 16.1 | | 18.0 | 16.3 |
| 314 | | | | | | | 16.2 | 17.1 | 15.2 | 14.2 | 14.3 | 16.2 |
| 344 | | | | | | | | | | 16.5 | 19.3 | |
| 365 | 13.4 | 12.8 | 13.8 | 15.7 | 10.0 | 13.0 | 11.5 | 14.4 | 18.6 | 14.4 | 21.8 | |
| 392 | 15.5 | | | 16.8 | | | | | | | | |
| 433 | | | | | | | 16.1 | 9.9 | | 19.0 | 14.2 | 16.6 |
| 442 | 13.4 | 11.6 | 12.1 | | | | | 27.2 | | | 14.4 | |
| 464 | 11.5 | 21.4 | 11.6 | 17.4 | 13.8 | 19.9 | 15.0 | 16.2 | 12.5 | 14.1 | 14.1 | 24.8 |
| 492 | | | | | | | | | | 17.2 | 12.0 | 17.6 |
| 26 | 24.5 | | 22.5 | | | 25.5 | 24.6 | | | | | |
| 28 | 13.3 | 14.4 | | 10.0 | 13.8 | 13.5 | 11.9 | 14.6 | 12.8 | 13.8 | 19.6 | 12.4 |
| 51 | | | | | | | | | 18.3 | 16.9 | | 26.2 |
| 60 | | | | 24.4 | | | 23.5 | 25.7 | | | | |
| 74 | 18.3 | | 16.7 | 17.7 | | 18.3 | 13.1 | 18.0 | | 16.8 | | |
| 88 | 14.4 | | | | | 14.7 | 14.3 | 13.6 | 13.5 | | 19.3 | 10.2 |
| 114 | | | | | | 18.1 | 12.3 | 16.0 | 13.8 | 20.4 | 21.6 | 18.4 |
| 124 | | 21.7 | | 18.2 | 21.7 | 19.9 | | 21.0 | | | 12.2 | |
| 128 | 17.2 | 19.3 | 18.3 | 18.4 | 16.6 | 25.3 | 23.7 | 19.9 | 18.2 | 18.6 | 17.7 | 17.9 |
| 138 | 20.9 | 21.3 | 19.6 | 23.3 | 19.8 | 21.8 | 21.7 | 24.3 | 16.8 | 26.6 | | 26.0 |
| 149 | | | | 14.2 | | 14.3 | 18.7 | 19.0 | | 18.7 | | |
| 164 | | | | | | | | | | | | 20.1 |
| 199 | 15.2 | 14.6 | 16.3 | 16.5 | 16.4 | | 14.2 | 13.4 | | 16.1 | 9.9 | 10.9 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 201 | 16.6 | 19.9 | 18.6 | 18.7 | 12.4 | | | | 22.3 | | | |
| 216 | 18.1 | 17.9 | 18.5 | 12.0 | 24.1 | 19.7 | 16.6 | 20.0 | 19.9 | | 19.0 | 13.9 |
| 234 | | | | | | | | | | 16.8 | 19.9 | 21.1 |
| 239 | 19.4 | 18.6 | 13.5 | 24.0 | 18.0 | 18.3 | 17.2 | 17.1 | | | 15.1 | 18.4 |
| 245 | | | | | | | 28.7 | | 19.6 | 18.6 | 17.4 | |
| 255 | 20.6 | 13.7 | | 15.0 | 14.2 | 13.9 | | 19.3 | | 14.1 | 18.6 | 22.2 |
| 302 | | | | | | | | | 18.7 | 13.9 | | |
| 317 | | | 18.4 | 28.7 | | | 17.2 | 16.6 | | 13.9 | 15.0 | 23.7 |
| 318 | 15.6 | 14.8 | 15.5 | 12.7 | | 17.0 | 17.1 | 14.4 | 13.0 | 18.6 | 14.2 | |
| 378 | | | 17.3 | 21.0 | | | 14.2 | | 14.4 | 13.3 | 15.8 | 13.1 |
| 379 | | | 10.2 | | 18.0 | | | 17.6 | 16.3 | 17.3 | | 23.8 |
| 389 | 22.0 | | 20.0 | | 19.4 | | 20.6 | 17.7 | 19.0 | 20.7 | | |
| 401 | 17.0 | 16.1 | | 13.5 | 17.3 | 11.3 | 23.4 | 19.0 | 14.1 | 22.2 | 22.9 | 25.7 |
| 428 | 11.0 | 20.4 | 20.2 | 18.6 | 16.3 | 18.9 | 18.7 | 17.0 | | 21.7 | | 10.8 |
| 431 | | | | | | 11.9 | 10.5 | 15.4 | 15.1 | 15.1 | | |
| 444 | | | | | | | | | | 14.8 | | 14.4 |
| 463 | 14.5 | 14.7 | 18.2 | 16.0 | 16.8 | 18.8 | | 20.4 | 22.0 | 18.4 | 21.5 | 16.0 |
| 471 | | | | | | 16.0 | 15.7 | 15.9 | 21.1 | 20.1 | 18.5 | 19.5 |
| 479 | | | | | | | | 13.8 | 19.9 | | 20.5 | 12.9 |
| 499 | 16.3 | 16.5 | 16.4 | 15.4 | 18.5 | 18.5 | 14.7 | 13.8 | 15.0 | 20.7 | 20.3 | 7.0 |
| 503 | | | | | | 10.2 | 13.1 | 13.4 | 13.0 | 16.5 | 17.5 | |
| 458 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 52 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 169 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 214 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 103 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 162 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 176 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 190 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 195 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 249 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 335 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 398 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 409 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 418 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 480 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 488 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 36 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 71 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 86 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 145 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 217 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 326 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 343 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 356 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 448 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 473 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

(C) MPG data for Aug2010-Aug2011

| Driver ID | 2010 | 2010 | 2010 | 2010 | 2010 | 2011 | 2011 | 2011 | 2011 | 2011 | 2011 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | August | September | October | November | December | January | February | March | April | May | June | July |
| | Period2 | Period2 | Period2 | Period2 | Period2 | Period2 | Period2 | Period2 | Period2 | Period2 | Period2 | Period2 |
| 39 | 7.7 | 8.3 | 7.3 | 7.1 | 7.8 | 9.0 | 8.2 | 9.1 | 7.0 | 7.2 | 7.9 | 7.7 |
| 79 | 11.7 | 10.4 | 9.9 | 9.7 | 8.9 | 8.1 | 8.4 | 7.6 | 8.1 | 7.9 | 8.2 | |
| 85 | 9.2 | 7.6 | 8.4 | 7.7 | 9.2 | 8.6 | 8.3 | 7.0 | 8.3 | | | |
| 98 | 8.7 | 8.8 | 8.3 | 7.5 | 7.5 | 8.1 | 9.0 | 9.3 | 9.9 | 9.1 | 8.6 | 8.8 |
| 208 | 9.2 | 8.8 | 9.9 | 7.8 | 7.6 | 7.8 | 7.6 | 7.4 | 9.6 | 7.9 | 9.7 | 8.4 |
| 299 | 9.9 | 10.3 | 10.4 | 9.4 | 9.4 | 8.5 | 8.4 | 9.6 | 7.7 | 9.2 | | 9.2 |
| 381 | 7.9 | 8.2 | 7.6 | 8.7 | 10.6 | 8.7 | 9.6 | 11.1 | 8.8 | 8.7 | 8.7 | 8.4 |
| 472 | | 8.5 | 8.5 | 8.8 | 8.5 | 6.0 | 7.7 | 8.0 | 8.0 | 6.8 | 8.8 | 8.9 |
| 478 | 7.8 | | | 7.4 | 7.7 | 8.7 | | | | | | |
| 10 | 9.7 | 9.0 | 9.8 | 8.3 | 8.9 | 8.7 | 7.7 | 8.4 | 6.5 | 7.4 | 6.2 | 7.5 |
| 15 | 9.4 | 10.0 | 8.9 | 9.1 | 9.0 | 9.2 | 9.9 | 9.2 | | 8.9 | 8.6 | 8.2 |
| 35 | | 8.5 | 8.4 | 9.8 | 8.7 | 9.7 | 7.9 | 10.0 | | 5.7 | 7.5 | |
| 42 | 7.5 | 7.1 | 7.9 | 7.6 | 8.2 | 8.7 | 7.2 | 7.5 | 6.6 | | 6.2 | 7.4 |
| 76 | 8.6 | 9.7 | 9.3 | 9.9 | 9.1 | 9.5 | 7.8 | 8.4 | 5.7 | 7.8 | 11.0 | 7.4 |
| 109 | 11.0 | 8.8 | 8.7 | 8.6 | 10.4 | 8.7 | 8.1 | 8.8 | 8.4 | 9.4 | | 9.3 |
| 118 | 9.4 | 7.2 | 9.4 | 7.3 | 8.3 | 8.8 | | 8.7 | 8.8 | 8.4 | 9.0 | |
| 130 | 10.0 | 11.5 | 4.6 | 8.3 | 8.2 | 8.2 | 9.2 | 8.8 | 9.9 | 6.9 | | 6.6 |
| 132 | 8.6 | 8.2 | | 8.1 | 8.8 | 8.4 | 9.2 | 5.8 | 7.8 | 6.5 | 9.3 | 8.9 |
| 139 | 8.8 | 8.7 | 9.4 | 8.9 | 8.9 | 10.3 | 10.0 | 9.2 | 14.8 | 12.8 | | 7.9 |
| 171 | 7.1 | 6.6 | 7.3 | 6.0 | 7.7 | 7.1 | 7.7 | 8.4 | 7.2 | 8.7 | 7.8 | 7.2 |
| 210 | 8.3 | 8.6 | 9.8 | 8.5 | 9.1 | 12.3 | 8.6 | 9.9 | 10.5 | 13.7 | 14.0 | 13.6 |
| 225 | 8.3 | 9.2 | 9.2 | 8.4 | 9.9 | 8.1 | 9.7 | 9.8 | 8.3 | | | |
| 229 | 9.8 | 9.2 | 8.8 | 9.5 | 8.2 | 9.7 | 10.3 | 10.0 | 10.1 | 8.8 | 8.4 | 8.0 |
| 244 | 7.6 | | 8.4 | 7.6 | 7.3 | 8.6 | 7.4 | 6.7 | 7.5 | 8.0 | 7.1 | 7.3 |
| 251 | 9.4 | 9.9 | 8.6 | 8.8 | 8.9 | 8.3 | 9.3 | 9.9 | 12.7 | 12.8 | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 261 | 9.4 | 9.3 | 9.7 | 9.7 | 8.2 | 6.1 | 9.4 | 9.8 | | | | |
| 314 | 9.4 | 7.8 | 8.9 | 8.4 | 9.5 | 8.2 | 7.3 | 6.9 | 7.7 | 10.4 | 7.3 | 7.7 |
| 344 | 9.5 | 9.6 | 9.7 | 9.9 | 9.1 | 9.1 | 7.7 | | 12.7 | | 13.8 | 14.5 |
| 365 | 9.6 | 9.9 | 9.3 | 9.6 | 9.9 | 9.7 | 8.7 | 8.3 | 8.9 | 7.6 | | |
| 392 | 8.3 | 8.9 | 8.3 | 7.2 | 7.0 | 7.5 | 8.1 | 9.1 | | 10.0 | 9.2 | 14.9 |
| 433 | 9.2 | 8.1 | 9.5 | 8.3 | 9.1 | 11.7 | 11.1 | 9.8 | 10.2 | 8.9 | | 11.7 |
| 442 | 8.9 | 8.7 | 8.9 | 8.6 | 8.1 | 9.1 | 8.6 | 8.0 | | 7.3 | | |
| 464 | 8.3 | 8.6 | 9.0 | 7.3 | 7.7 | 7.1 | 7.8 | 7.5 | 7.5 | 10.3 | 9.6 | 7.4 |
| 492 | 8.5 | 8.4 | 6.1 | 9.1 | 9.7 | 8.5 | 8.3 | 6.2 | 10.0 | 8.9 | 8.5 | 8.1 |
| 26 | 8.6 | 8.8 | 8.9 | 11.3 | 9.6 | 10.9 | 8.8 | 10.9 | 11.4 | 11.0 | 11.7 | 10.3 |
| 28 | | | | 8.7 | 7.8 | | | | | | 6.6 | |
| 51 | | | 11.0 | 8.3 | 8.7 | 9.5 | 13.7 | | 12.8 | 10.3 | 9.2 | 11.8 |
| 60 | 8.4 | 8.1 | 9.1 | 7.1 | 7.3 | 11.1 | 6.6 | 6.0 | 5.9 | 6.1 | 7.3 | 8.5 |
| 74 | 7.7 | 7.2 | 7.7 | 8.6 | 7.5 | 6.5 | 8.7 | 6.1 | 7.8 | 4.3 | 6.9 | 5.9 |
| 88 | 9.8 | 9.7 | 8.7 | 8.9 | 8.1 | 8.9 | 8.2 | 8.6 | 7.6 | | | |
| 114 | 12.0 | 11.7 | 6.4 | 10.3 | 7.8 | 6.3 | | 9.0 | 11.0 | | | |
| 124 | 7.4 | 7.4 | 8.1 | 7.2 | 7.8 | 8.2 | 6.0 | 9.7 | 9.2 | 7.4 | 6.8 | 9.4 |
| 128 | | 7.4 | | | 10.3 | | | 8.2 | | 8.2 | 12.2 | |
| 138 | 11.7 | 7.2 | 9.6 | | 7.7 | 8.7 | 7.7 | 6.9 | 8.5 | 13.6 | | 8.3 |
| 149 | 7.9 | 7.9 | 8.6 | 8.4 | 6.7 | 7.1 | 9.5 | 7.7 | 8.7 | 7.6 | 10.4 | 9.7 |
| 164 | 9.3 | 8.6 | 9.2 | 7.9 | | 8.5 | 8.6 | | | | 6.7 | |
| 199 | 11.8 | 9.2 | 9.4 | 6.7 | 8.4 | 9.6 | 9.0 | 9.7 | | 10.6 | 10.7 | 9.9 |
| 201 | 6.6 | 8.8 | 8.3 | 10.1 | 7.7 | 8.8 | 9.7 | 7.0 | | 8.8 | 9.6 | 8.8 |
| 216 | 8.4 | 8.9 | 7.1 | 8.2 | 7.2 | 7.4 | 8.9 | 8.2 | 6.7 | 9.6 | 8.3 | |
| 234 | | 8.9 | 9.6 | | 11.3 | | 7.8 | 14.8 | 7.0 | 12.4 | | 11.9 |
| 239 | 9.0 | 7.7 | 6.9 | 8.1 | 6.6 | 6.9 | 6.8 | 9.3 | 9.1 | 6.3 | 7.4 | 9.2 |
| 245 | 7.1 | 7.5 | 7.1 | 8.0 | 7.2 | 8.9 | 6.9 | 7.8 | 6.9 | 6.6 | 4.8 | 4.8 |
| 255 | 8.7 | 9.8 | 13.1 | 7.7 | 9.4 | 6.4 | 6.0 | 7.3 | 6.9 | 7.0 | 7.4 | 5.6 |
| 302 | 7.6 | 8.9 | 7.6 | 7.5 | 7.5 | 8.2 | 9.3 | 8.0 | 7.6 | 7.4 | 5.8 | |
| 317 | 9.1 | 11.6 | 6.4 | 6.1 | 9.0 | 6.5 | 7.0 | 6.5 | 7.3 | 9.6 | 6.6 | 6.5 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 318 | 7.8 | 9.2 | 7.3 | 7.8 | 7.8 | 6.0 | 9.9 | 8.4 | | | | |
| 378 | 8.1 | | | | | | | | | | | 6.0 |
| 379 | 7.9 | 7.3 | 7.1 | 6.9 | 10.7 | 7.9 | 11.3 | | 7.5 | | 11.6 | 8.1 |
| 389 | 9.7 | 7.2 | 8.6 | 9.2 | 9.0 | 7.4 | 10.7 | 10.1 | 11.7 | 11.1 | | 11.7 |
| 401 | 9.3 | 8.4 | 9.9 | 9.5 | 9.0 | | 9.6 | 7.0 | | 7.5 | 9.8 | 7.0 |
| 428 | 7.7 | 8.0 | 5.9 | 7.3 | 7.9 | 8.4 | 7.0 | 8.8 | 7.8 | 7.2 | 10.2 | 9.2 |
| 431 | 6.8 | 6.1 | 7.4 | 7.8 | 8.4 | 8.9 | 7.8 | 7.4 | 7.6 | 8.6 | 8.2 | 9.1 |
| 444 | | 8.0 | 8.7 | 8.8 | 7.8 | 9.5 | 6.1 | 4.4 | 6.7 | 7.3 | 6.4 | |
| 463 | 7.4 | 8.1 | 7.3 | 7.7 | 8.8 | 8.4 | 6.5 | 9.2 | 9.9 | | 7.0 | |
| 471 | 7.3 | 10.0 | 8.3 | 9.1 | 9.4 | 7.6 | 8.5 | 8.4 | 9.0 | 9.3 | 9.8 | 9.9 |
| 479 | | 8.7 | 9.2 | 8.5 | 9.0 | 7.7 | 8.2 | 6.9 | 7.5 | 6.9 | 7.6 | 8.3 |
| 499 | 10.1 | 10.1 | 10.4 | 9.5 | 7.7 | 9.0 | 10.8 | 10.5 | 13.0 | 11.5 | | 7.0 |
| 503 | 8.6 | 8.4 | 7.6 | 8.4 | 7.9 | 7.3 | 9.1 | 7.0 | 6.7 | 6.8 | 7.1 | 7.7 |
| 39 | 22.2 | 23.3 | 22.1 | | | | 19.7 | 23.1 | 20.2 | 13.3 | 12.3 | 10.1 |
| 79 | 25.7 | 26.7 | 28.3 | 29.1 | 27.3 | 26.5 | 21.7 | 20.7 | 28.8 | 25.4 | 23.6 | 20.7 |
| 85 | 14.0 | 16.6 | 13.5 | 14.4 | 11.1 | 10.2 | 13.1 | 11.3 | 10.7 | 10.7 | 14.3 | 16.0 |
| 98 | 17.3 | 18.8 | 22.3 | | 14.1 | 14.0 | | 14.7 | | 14.4 | 12.6 | 19.1 |
| 208 | | 15.7 | 13.7 | 20.9 | 23.2 | 21.5 | 21.9 | 16.2 | 17.0 | 17.4 | 14.0 | 19.7 |
| 299 | 18.9 | 17.1 | | | | 22.3 | 21.8 | 20.6 | | 25.7 | 21.5 | 21.7 |
| 381 | | 17.8 | 17.5 | | 19.9 | | 12.2 | | | | 20.6 | 17.4 |
| 472 | 14.2 | 11.1 | 10.1 | 15.0 | | 15.0 | 17.4 | 19.5 | | 19.5 | 18.1 | 17.4 |
| 478 | 10.6 | 12.0 | 9.8 | 9.7 | 9.6 | 9.7 | 10.0 | 12.2 | 10.2 | 11.6 | 17.3 | 15.6 |
| 10 | 17.5 | 14.7 | 16.9 | 12.6 | 17.0 | 18.8 | 17.1 | 12.2 | 13.7 | 18.7 | 19.1 | 17.7 |
| 15 | 20.2 | 16.4 | 17.8 | 15.9 | 18.7 | 16.2 | 22.6 | 19.1 | 17.1 | 20.0 | | 18.6 |
| 35 | 19.1 | 20.2 | 17.8 | 15.0 | | 26.7 | 14.9 | 31.0 | | 22.8 | 19.7 | 19.8 |
| 42 | 23.2 | 24.6 | 20.5 | 21.7 | 21.6 | 20.3 | 24.3 | 21.3 | | | 24.6 | 22.3 |
| 76 | 17.1 | | 18.3 | | 17.8 | 18.2 | 15.9 | 18.3 | | 12.4 | 22.7 | 23.3 |
| 109 | 17.5 | 21.8 | 21.3 | 24.8 | 24.6 | 19.2 | 12.8 | 17.8 | 18.9 | 12.6 | 24.5 | 17.6 |
| 118 | 19.0 | 17.0 | 16.5 | 17.1 | 11.7 | 14.2 | 31.5 | 20.7 | 19.6 | 20.1 | 23.7 | 20.3 |
| 130 | 21.1 | 20.6 | 18.1 | 15.8 | | | 29.1 | 9.9 | 18.3 | 20.9 | 21.3 | 20.4 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 132 | 14.5 | 16.9 | | 19.0 | | 10.0 | | 18.0 | 16.2 | 14.3 | 17.2 | 16.9 |
| 139 | 22.7 | 17.0 | 11.5 | | 10.4 | 12.7 | 20.5 | 16.8 | | 13.4 | 15.1 | 15.2 |
| 171 | | | 20.3 | 15.6 | 12.0 | | 12.2 | 13.8 | 14.7 | 24.5 | 15.2 | 15.2 |
| 210 | 16.7 | | 19.1 | | | 18.3 | 18.7 | | | 25.1 | 22.2 | 16.6 |
| 225 | 18.6 | | | | | 14.0 | | 17.4 | 18.5 | 13.8 | 12.5 | 13.6 |
| 229 | | 18.1 | 13.6 | 13.5 | 13.0 | 17.9 | 16.1 | 19.5 | 19.2 | 20.4 | 18.0 | 14.1 |
| 244 | | | 16.4 | 16.3 | | | 11.3 | | 13.9 | 15.1 | 17.2 | 15.9 |
| 251 | | 21.8 | 17.0 | | 20.8 | 14.1 | 20.1 | | | 13.9 | 14.0 | 13.2 |
| 261 | | | | | | | | 16.1 | 17.4 | 14.5 | 14.9 | 15.7 |
| 314 | 17.0 | 14.8 | | 15.7 | | 13.9 | | | 12.9 | 20.5 | | 25.0 |
| 344 | 14.9 | | | | | 16.7 | | | 16.9 | 13.6 | | |
| 365 | 17.3 | 15.0 | 16.7 | 15.7 | 14.3 | 14.7 | | | | 20.0 | | |
| 392 | | 16.1 | | | | | 18.4 | | 23.9 | 22.8 | 23.4 | |
| 433 | 16.9 | 19.9 | 19.8 | 19.4 | 34.4 | 18.0 | 19.2 | 22.3 | 16.7 | 23.0 | 20.6 | 23.1 |
| 442 | | | | | | | | | 18.1 | 18.2 | 13.1 | 13.5 |
| 464 | 23.3 | | 16.9 | 18.4 | 23.0 | 18.6 | 13.9 | 25.1 | 27.4 | 36.6 | 17.5 | 15.6 |
| 492 | 20.0 | 17.4 | 17.2 | | | | 14.1 | 18.2 | 10.9 | 22.5 | 22.4 | 18.8 |
| 26 | | | 23.1 | 22.8 | 20.8 | 21.0 | 24.1 | | | 24.5 | 23.6 | 17.0 |
| 28 | 14.3 | 14.5 | 18.0 | 17.2 | 13.8 | 12.0 | 17.1 | 17.7 | 13.6 | 13.1 | 11.4 | 14.0 |
| 51 | 19.2 | 18.4 | 13.9 | 20.4 | 23.6 | 23.7 | 19.4 | 22.3 | 16.8 | 13.7 | 26.0 | 21.6 |
| 60 | | | | | | 18.8 | 17.3 | 18.0 | 18.0 | 17.9 | 20.6 | 18.3 |
| 74 | | | 18.3 | 13.4 | 17.7 | | | 18.5 | | | 9.5 | 17.9 |
| 88 | 11.0 | 10.8 | 11.3 | | | 14.3 | | 10.2 | | 13.2 | 10.6 | 11.7 |
| 114 | | 20.4 | 11.8 | 15.9 | 19.0 | 17.9 | 22.1 | 22.1 | 15.1 | 16.7 | 18.5 | 19.3 |
| 124 | 18.5 | | | 23.0 | | | | | 23.1 | | 5.6 | 13.9 |
| 128 | 17.7 | 16.8 | 18.4 | 14.6 | 18.1 | 18.8 | 19.9 | 20.4 | 27.4 | 23.7 | | 24.2 |
| 138 | 22.0 | 22.5 | | 17.3 | 21.2 | 25.3 | 23.5 | 20.3 | 23.5 | 24.0 | 29.1 | |
| 149 | | | | | | 17.9 | 15.5 | | 20.0 | 16.3 | 14.0 | 12.5 |
| 164 | 22.3 | | | | | | 12.0 | 12.2 | 14.8 | 13.6 | 12.8 | 14.6 |
| 199 | 19.3 | 17.2 | 17.7 | | 16.3 | 12.7 | 11.4 | 14.5 | | | 14.5 | 18.3 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 201 | 20.7 | | | | | | 14.0 | 14.8 | 9.6 | 15.0 | 14.9 | 15.6 |
| 216 | 16.6 | 14.7 | 16.0 | 18.5 | 15.0 | 12.3 | 18.7 | 16.1 | 17.8 | 17.9 | 16.3 | 18.2 |
| 234 | 18.8 | 16.8 | 16.0 | 15.3 | 14.6 | | 20.1 | 18.2 | 7.6 | 22.2 | 24.5 | 25.4 |
| 239 | 16.7 | 18.4 | | | 11.7 | 17.2 | 16.5 | 17.0 | 18.1 | 18.9 | 24.3 | |
| 245 | 17.4 | | | | 17.3 | 18.1 | 16.5 | 12.3 | 16.3 | 17.9 | 14.4 | |
| 255 | 19.8 | 17.6 | | | | | 19.6 | 19.7 | | 24.2 | | 22.5 |
| 302 | 10.4 | 13.0 | 17.6 | | 19.7 | 15.8 | 16.6 | 13.1 | 17.4 | 13.6 | 14.6 | 15.1 |
| 317 | | | 16.2 | 16.5 | | 17.8 | 22.5 | 21.1 | | 15.0 | 22.5 | 21.8 |
| 318 | 15.0 | | 14.2 | | 12.6 | | 12.5 | 20.4 | 17.0 | 17.2 | 12.2 | 13.0 |
| 378 | 13.3 | 16.2 | 12.2 | 14.5 | 14.1 | 12.5 | 16.8 | 14.7 | 14.0 | 12.3 | 11.6 | 17.8 |
| 379 | | 18.2 | 20.6 | | 14.2 | 16.0 | 18.4 | 17.4 | | 12.3 | 12.1 | 14.6 |
| 389 | | 23.8 | 24.0 | 12.1 | | | 18.6 | 18.5 | | 18.7 | 13.0 | 14.5 |
| 401 | 19.9 | 17.9 | 22.5 | 21.3 | 19.9 | 16.4 | 19.8 | 19.5 | 16.9 | 24.0 | 20.7 | 32.6 |
| 428 | | | | | | | 22.1 | 18.1 | | 16.0 | 22.5 | |
| 431 | | 18.3 | 19.3 | 17.3 | 19.0 | 19.5 | 13.8 | | 12.6 | | 28.4 | 19.9 |
| 444 | 19.6 | 19.3 | 16.1 | 15.4 | | 19.1 | 17.3 | | | 17.9 | | 17.4 |
| 463 | 18.2 | 20.6 | 17.0 | 17.2 | | 22.2 | 16.8 | 17.1 | 20.0 | 22.1 | 26.1 | 17.4 |
| 471 | 15.8 | 19.3 | | 22.4 | | 15.5 | 18.5 | 16.1 | 16.3 | | 18.7 | |
| 479 | 15.2 | 15.4 | 17.1 | 22.2 | 18.5 | 11.0 | | 19.1 | 13.8 | 18.5 | 20.7 | |
| 499 | 14.0 | 12.2 | | | 18.6 | | | 22.1 | | 14.6 | 16.4 | 16.2 |
| 503 | | | 16.3 | | | 14.8 | 15.2 | | 16.6 | 17.1 | 18.2 | |
| 458 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 52 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 169 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 214 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 103 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 162 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 176 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 190 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 195 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 249 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 335 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 398 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 409 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 418 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 480 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 488 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 36 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 71 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 86 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 145 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 217 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 326 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 343 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 356 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 448 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 473 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

## (D) MPG data for Aug2011-Aug2012

| Driver ID | 2011 | 2011 | 2011 | 2011 | 2011 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | August | September | October | November | December | January | February | March | April | May | June | July |
| | Period3 | Period3 | Period3 | Period3 | Period3 | Period3 | Period3 | Period3 | Period3 | Period3 | Period3 | Period3 |
| 39 | 5.8 | 10.3 | 7.6 | 8.0 | 8.9 | 8.4 | 7.5 | 8.1 | 8.2 | 10.4 | 10.6 | 9.0 |
| 79 | 8.3 | | | | | | 10.6 | | | | | |
| 85 | | 8.5 | 8.0 | 10.5 | 9.1 | 10.1 | 8.8 | 10.5 | 12.2 | | 11.9 | 8.6 |
| 98 | 10.1 | 7.3 | 7.2 | 8.5 | 6.4 | 7.1 | | 11.7 | 12.4 | 10.9 | 11.9 | 11.8 |
| 208 | | | | | 10.5 | 9.3 | | 11.9 | 6.5 | 8.1 | 9.0 | 9.9 |
| 299 | 7.4 | 9.3 | 7.9 | 6.3 | 9.1 | 9.8 | 9.5 | 9.4 | 7.6 | 8.6 | 8.6 | 11.8 |
| 381 | | 11.2 | 10.7 | 6.7 | 9.7 | 6.5 | 11.4 | 8.2 | 7.5 | 9.5 | 9.4 | 5.8 |
| 472 | 7.7 | 5.7 | | 8.1 | 10.2 | 7.1 | 12.6 | 6.5 | 8.5 | 8.1 | 7.9 | 7.5 |
| 478 | | 7.4 | | 6.8 | 8.5 | 10.2 | 8.4 | 12.3 | | 9.9 | 8.1 | |
| 10 | 7.5 | 7.9 | 7.8 | 9.4 | 8.3 | 8.7 | 10.2 | 7.9 | 8.3 | 7.4 | 7.9 | |
| 15 | | 9.1 | 9.4 | 9.5 | 7.1 | 8.1 | 8.4 | 10.4 | | 7.3 | 9.0 | |
| 35 | | 9.2 | 6.7 | | 8.8 | 7.5 | 8.2 | 8.2 | 8.0 | 7.3 | | |
| 42 | 6.8 | 6.0 | 7.1 | 8.2 | 7.1 | 7.3 | 6.4 | 7.6 | | 8.8 | 7.6 | 9.0 |
| 76 | 9.0 | 10.5 | 9.6 | 8.8 | 6.5 | 8.0 | 7.6 | 9.4 | 10.2 | 8.1 | 7.8 | 7.8 |
| 109 | 9.5 | | 9.6 | 8.9 | 7.8 | 9.4 | 8.0 | 7.5 | 8.4 | 14.3 | 8.0 | |
| 118 | | | 7.1 | 7.4 | 6.1 | 6.1 | 6.9 | 5.6 | 6.3 | 6.7 | 8.6 | 5.6 |
| 130 | 6.3 | 7.9 | | 7.8 | 5.6 | 7.9 | 8.6 | 8.6 | 8.7 | 7.9 | | |
| 132 | 7.8 | 6.7 | 7.0 | 7.6 | 7.7 | 6.3 | 6.6 | 9.8 | 6.4 | 6.2 | 7.0 | 8.6 |
| 139 | 9.2 | 7.5 | 8.6 | 7.6 | 9.3 | 10.0 | 6.1 | | 7.5 | 8.0 | 10.8 | 11.0 |
| 171 | 7.4 | 7.3 | 6.7 | 6.1 | 9.4 | 8.2 | 8.0 | 10.1 | 7.4 | | 7.6 | 7.3 |
| 210 | 12.1 | 12.5 | 12.9 | 8.9 | 8.6 | 13.9 | 13.1 | | 14.0 | 10.4 | 10.6 | 12.8 |
| 225 | 9.4 | | 8.9 | 7.1 | 7.5 | 7.2 | 12.1 | 6.6 | 7.2 | | 6.9 | 6.2 |
| 229 | 7.5 | | | 7.9 | 7.1 | 9.6 | 7.8 | 8.4 | 8.6 | 6.3 | 9.7 | 7.0 |
| 244 | 7.6 | 7.2 | | 8.9 | 8.2 | 8.4 | 7.3 | 7.0 | 5.8 | 6.3 | 7.0 | 8.9 |
| 251 | | | | | 9.9 | 9.6 | | 9.0 | | 9.5 | 7.3 | 7.6 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 261 | | | 12.2 | 7.4 | 6.3 | 7.9 | 8.1 | | 6.4 | 5.5 | 8.4 | 6.8 |
| 314 | 7.6 | 8.8 | 7.8 | 7.5 | 6.4 | 7.7 | 7.3 | 6.6 | 7.9 | 7.3 | 7.1 | 8.2 |
| 344 | 9.8 | 9.0 | 8.8 | 8.0 | 12.3 | | 13.1 | | 10.8 | 12.5 | 9.3 | 9.1 |
| 365 | 11.3 | 11.6 | 8.7 | 11.1 | 6.8 | 6.8 | 6.9 | 12.4 | 13.2 | | | 9.4 |
| 392 | 8.5 | 8.6 | 8.1 | 9.2 | 7.2 | 6.4 | 5.6 | | 6.0 | | 7.5 | 6.6 |
| 433 | 10.0 | 12.8 | 8.1 | 10.5 | 10.1 | 10.6 | | | 9.9 | 6.3 | | 8.0 |
| 442 | | 9.6 | 7.5 | 8.5 | 7.7 | 12.3 | 8.2 | 10.9 | 7.8 | 6.8 | 5.9 | |
| 464 | 6.8 | 7.4 | 7.2 | 7.9 | 8.7 | 8.4 | 7.9 | 8.2 | 8.5 | 8.2 | 8.1 | 9.6 |
| 492 | 8.1 | 7.1 | 8.8 | 6.1 | 7.7 | 9.3 | 6.0 | 6.8 | 7.3 | 7.3 | 10.0 | 10.3 |
| 26 | 10.7 | 10.8 | 9.9 | 6.7 | 10.9 | 11.2 | 13.3 | 8.9 | 11.7 | 10.4 | 10.5 | 10.9 |
| 28 | | 11.3 | 7.7 | 7.7 | 7.1 | 6.0 | 7.7 | 7.5 | 5.6 | 10.6 | 7.0 | 7.3 |
| 51 | | | 13.8 | | | | | 13.2 | | 8.3 | 9.2 | |
| 60 | 7.0 | 7.7 | 6.2 | 8.5 | 11.9 | 10.8 | 9.1 | 6.8 | 9.1 | 10.0 | | 12.4 |
| 74 | 6.1 | 6.2 | 7.7 | 6.1 | 6.7 | 6.7 | 11.2 | 6.8 | 6.9 | 5.9 | | 5.7 |
| 88 | 10.3 | 7.4 | 8.1 | 6.9 | 6.9 | 12.3 | 7.4 | 7.8 | 12.0 | 10.3 | 10.8 | 10.6 |
| 114 | | 9.1 | 6.4 | 6.5 | 8.8 | 7.5 | 7.8 | 7.5 | 7.7 | 8.0 | 8.6 | 6.9 |
| 124 | 8.0 | 8.0 | 10.6 | 9.0 | 6.3 | | 10.0 | 9.4 | 8.9 | 11.4 | 9.0 | 12.7 |
| 128 | | 10.8 | 9.9 | 10.7 | 9.9 | | 10.3 | 8.6 | 4.4 | 6.0 | 8.9 | 7.4 |
| 138 | 8.1 | 8.3 | 7.6 | 8.3 | 7.6 | 9.6 | 7.9 | 7.9 | 7.7 | 7.1 | 6.1 | 7.5 |
| 149 | | 9.1 | 10.9 | 10.4 | 7.3 | 8.1 | 9.5 | | 12.2 | 9.6 | 10.6 | 9.0 |
| 164 | | 7.1 | | | 6.7 | 6.5 | 6.6 | 6.3 | 6.5 | 6.6 | 6.0 | 7.2 |
| 199 | 8.1 | 8.0 | 7.4 | 7.7 | 5.1 | 6.7 | 5.4 | 7.7 | 5.3 | 5.8 | 5.4 | 4.8 |
| 201 | | 12.6 | 11.2 | | 8.0 | 6.6 | 8.3 | 9.7 | | 8.7 | 8.8 | 10.3 |
| 216 | | 7.7 | 8.0 | 7.9 | 6.6 | 5.8 | 7.9 | 9.0 | | 8.7 | | 8.1 |
| 234 | 11.3 | 12.7 | 11.4 | 9.5 | | 6.4 | 5.0 | 6.2 | 6.9 | 6.0 | 7.3 | 7.1 |
| 239 | 7.4 | 5.8 | 4.6 | 7.1 | 7.5 | 7.7 | 7.6 | 6.8 | 6.4 | 8.4 | 8.3 | 8.9 |
| 245 | 5.7 | 6.0 | 7.3 | 7.1 | 6.0 | 5.6 | 6.3 | 6.5 | 9.9 | 5.8 | 8.6 | 6.9 |
| 255 | 6.6 | 7.2 | 5.4 | 6.7 | 8.0 | 7.1 | 7.9 | 9.4 | 9.6 | 9.7 | 8.2 | |
| 302 | 7.3 | 8.0 | 7.0 | 8.4 | 6.9 | 6.8 | 6.0 | 6.5 | 5.9 | 6.7 | 7.4 | 7.3 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 317 | 8.0 | | | 6.8 | 7.9 | 8.6 | 8.8 | 9.4 | 7.1 | 5.8 | 10.0 | 8.0 |
| 318 | 7.1 | | 10.6 | 8.3 | 7.7 | | 8.7 | 8.9 | | | 8.1 | 7.5 |
| 378 | | | 9.6 | | 8.3 | 7.8 | 10.7 | 12.5 | 7.8 | | | 9.1 |
| 379 | 9.0 | 6.8 | 7.1 | 7.5 | 10.2 | 10.0 | 6.8 | 10.2 | 10.3 | 12.0 | 8.9 | 8.4 |
| 389 | | 11.3 | 10.2 | 9.7 | | 13.1 | 13.4 | 14.8 | 14.4 | 8.8 | | |
| 401 | 8.6 | 8.5 | 7.9 | 7.9 | 9.4 | 9.8 | 8.5 | | 9.0 | | | |
| 428 | 10.8 | 9.1 | 8.9 | 9.0 | 11.1 | 8.3 | 9.4 | 8.1 | 11.2 | 9.8 | 10.8 | 7.4 |
| 431 | 12.1 | 8.5 | 7.0 | 10.5 | 7.2 | 7.5 | 6.0 | 7.1 | 8.0 | 8.9 | 7.1 | 7.2 |
| 444 | 7.7 | 6.4 | 8.4 | | 6.6 | 8.5 | 13.4 | 7.6 | 5.1 | 7.2 | 8.8 | |
| 463 | 8.7 | 9.5 | 8.0 | 7.4 | | 8.7 | 8.7 | 8.4 | 6.3 | | | |
| 471 | 8.2 | 7.9 | 9.9 | 8.3 | 8.1 | 5.7 | 9.5 | 6.7 | 9.7 | 9.8 | 10.1 | 8.8 |
| 479 | 8.5 | 7.0 | 6.1 | 8.5 | 9.9 | 6.8 | 6.9 | 8.2 | 9.5 | | | |
| 499 | | 10.8 | 11.5 | 12.7 | 9.8 | 10.7 | | 8.0 | 8.8 | | | 9.1 |
| 503 | 7.8 | 6.8 | 5.3 | 7.9 | 7.7 | 8.7 | 7.9 | 7.2 | 7.7 | 6.1 | 8.4 | 9.2 |
| 39 | 16.3 | 15.8 | 21.9 | 24.2 | 21.2 | 19.6 | | 20.9 | 19.9 | 19.3 | 19.6 | 20.7 |
| 79 | 21.8 | 23.9 | 25.0 | 22.9 | 21.1 | 22.7 | 19.4 | 23.1 | 23.3 | 24.3 | 22.5 | 21.1 |
| 85 | 17.8 | 12.4 | 15.0 | 14.3 | 14.8 | 14.9 | 29.4 | 25.2 | 19.1 | 18.1 | 18.6 | 18.2 |
| 98 | 19.4 | 12.8 | 12.5 | 11.5 | 14.8 | 17.2 | 18.3 | 16.1 | 17.6 | | | 12.7 |
| 208 | 17.2 | 22.2 | 12.1 | 13.8 | 15.4 | 18.5 | 13.1 | 21.0 | | 14.8 | 13.8 | |
| 299 | 18.0 | 12.3 | 22.1 | 15.3 | 19.3 | | 18.2 | 18.7 | 19.7 | 11.6 | 12.7 | 21.9 |
| 381 | 15.0 | 12.9 | 17.4 | 18.0 | | 13.5 | | 15.9 | 14.7 | 15.0 | 14.0 | 16.5 |
| 472 | | 14.5 | | | | | | 13.1 | | | | 14.1 |
| 478 | 17.0 | 12.2 | 16.3 | 10.8 | 20.1 | 22.6 | 22.7 | 23.5 | 22.3 | 16.1 | 19.8 | 16.2 |
| 10 | 14.8 | 17.8 | 19.6 | 16.3 | 14.3 | 16.8 | 18.3 | 18.4 | 18.3 | 20.8 | 19.1 | 16.6 |
| 15 | | 19.0 | | 13.3 | | | 18.4 | 16.4 | 12.3 | | 18.1 | 20.0 |
| 35 | 20.5 | 18.5 | 21.9 | 16.1 | 18.5 | | 13.8 | 17.6 | 14.5 | 13.6 | 20.6 | 22.5 |
| 42 | 23.0 | 22.0 | 25.5 | 23.9 | 20.4 | 20.3 | 20.7 | 13.3 | 17.6 | 20.6 | 19.3 | 18.7 |
| 76 | 23.2 | 20.6 | 16.4 | | 18.0 | 14.2 | 13.1 | 15.6 | 14.7 | 18.6 | 16.9 | 16.2 |
| 109 | 14.1 | 20.7 | 17.8 | 19.5 | 19.2 | 21.1 | 20.2 | 13.6 | 17.0 | 16.7 | 16.6 | 16.5 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 118 | 20.6 | 20.1 | 16.2 | 17.9 | 15.1 | 12.8 | 15.3 | 17.3 | 18.2 | 21.5 | 20.1 | 22.9 |
| 130 | 17.3 | 19.3 | 17.1 | 16.3 | 19.5 | 15.1 | 20.1 | 19.3 | 18.8 | 17.8 | 19.2 | 16.8 |
| 132 | 16.1 | 13.9 | | | 12.5 | 12.1 | 12.3 | | 15.3 | 19.2 | 18.1 | 16.0 |
| 139 | 14.5 | 11.6 | 13.4 | 13.7 | 15.5 | 15.6 | 13.0 | | | 15.6 | | 16.8 |
| 171 | 12.1 | | 12.3 | | 17.3 | 14.6 | 15.4 | 18.1 | 16.4 | 16.2 | 19.5 | 18.1 |
| 210 | | | 15.1 | 16.0 | 21.4 | 20.5 | 14.0 | 15.1 | 15.0 | 20.4 | 19.2 | 18.1 |
| 225 | 15.1 | 16.6 | 19.2 | 18.4 | | | 13.6 | | 12.7 | 11.7 | 13.6 | |
| 229 | 15.8 | 12.4 | 21.3 | 17.9 | | 18.7 | 16.4 | 19.3 | 18.9 | 14.4 | 14.5 | 16.2 |
| 244 | 19.5 | 30.7 | 15.4 | 23.4 | 23.3 | 20.9 | 19.4 | 13.7 | 16.3 | 22.0 | 17.1 | 14.7 |
| 251 | 14.0 | | 14.0 | 13.4 | 13.2 | 19.0 | 13.5 | 17.0 | 16.9 | 14.6 | 17.2 | 13.0 |
| 261 | 16.3 | 16.7 | | 16.0 | | 16.1 | | 13.4 | | | | 15.0 |
| 314 | | | | 21.8 | 21.7 | 17.4 | | 18.5 | | 14.2 | | 19.4 |
| 344 | | 12.0 | 14.6 | 15.5 | 15.3 | 16.0 | 17.4 | 15.8 | 14.4 | 13.2 | 15.3 | 15.4 |
| 365 | | 18.9 | 15.5 | | 17.3 | 16.5 | 16.2 | 14.6 | 18.1 | 17.0 | | |
| 392 | 15.7 | 19.4 | | 22.2 | 17.4 | 11.5 | 13.3 | 12.2 | 18.0 | 20.4 | 14.2 | 13.1 |
| 433 | 23.9 | 19.5 | 22.2 | 17.5 | 14.1 | | 16.7 | 16.7 | 14.5 | 23.7 | 19.7 | |
| 442 | 14.3 | 13.8 | 12.9 | 22.8 | | 17.6 | | 16.9 | 12.0 | 11.1 | 16.2 | 16.0 |
| 464 | 18.1 | | | | 18.7 | 19.6 | 19.7 | 20.3 | 19.6 | | 20.1 | 20.2 |
| 492 | 18.2 | 17.1 | 14.4 | 15.0 | 13.7 | | 19.1 | 18.1 | 22.8 | 15.3 | 12.1 | |
| 26 | 14.4 | 16.5 | 18.7 | 19.5 | | 20.3 | 12.5 | 21.1 | 13.8 | 18.9 | | 13.9 |
| 28 | 18.5 | | 18.5 | 18.9 | 17.2 | 16.0 | 13.4 | 13.9 | 18.6 | 13.7 | 20.4 | |
| 51 | | 18.6 | 17.0 | 19.9 | 22.1 | 13.4 | 22.5 | 18.7 | 17.7 | 18.2 | 18.1 | 19.0 |
| 60 | 15.1 | 17.3 | 14.6 | 18.9 | 14.3 | 14.7 | | 22.8 | 21.7 | | 21.8 | 13.7 |
| 74 | 19.8 | 19.3 | | 20.3 | 22.6 | 17.7 | | | 19.4 | 24.3 | | 19.8 |
| 88 | 13.1 | 13.4 | | 14.8 | 14.1 | 15.1 | 14.7 | 18.0 | 20.0 | 17.7 | 19.7 | 15.3 |
| 114 | 16.4 | 13.6 | 16.0 | 21.1 | 22.5 | 22.9 | | 11.6 | 15.2 | 17.5 | 16.1 | 17.0 |
| 124 | 22.7 | 14.9 | 18.1 | 17.1 | | | 16.5 | | 16.6 | 16.8 | 19.0 | 21.7 |
| 128 | 22.9 | 22.5 | | | | 20.3 | | | | | 18.2 | 13.5 |
| 138 | 22.6 | 22.3 | | 23.5 | | | | 16.1 | | 18.2 | 11.8 | 16.7 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 149 | 13.9 | 13.3 | 17.1 | 15.3 | 13.8 | 16.8 | 16.7 | 13.7 | 14.6 | 15.4 | 13.8 | 10.3 |
| 164 | 14.2 | 14.6 | 16.3 | 16.5 | 16.4 | 15.4 | 18.5 | 18.5 | 15.4 | 13.5 | 17.9 | 25.4 |
| 199 | 23.6 | 19.9 | 18.6 | 18.7 | 12.4 | 22.3 | 18.2 | 16.3 | 18.4 | 17.7 | 18.5 | 21.4 |
| 201 | 14.1 | 17.9 | 17.5 | 12.0 | 24.1 | 20.3 | 19.8 | 16.1 | 19.0 | 11.2 | 16.8 | 14.2 |
| 216 | 14.6 | 15.6 | 15.7 | 16.1 | 14.8 | 13.6 | | 11.6 | 14.9 | 14.2 | 15.8 | 15.3 |
| 234 | 24.3 | 19.5 | 21.5 | 17.6 | | | | | | 22.7 | 21.4 | |
| 239 | | 19.1 | 10.7 | | | 19.3 | 14.0 | | 14.0 | 14.3 | | 17.0 |
| 245 | | 14.4 | | 17.7 | 16.5 | 17.5 | 21.7 | 18.9 | 19.7 | 19.0 | 18.2 | 17.0 |
| 255 | | 18.3 | 17.3 | 19.4 | 20.5 | | 22.1 | | | 12.8 | 13.9 | 23.1 |
| 302 | 15.8 | | 17.4 | 17.2 | | 19.3 | 19.2 | 15.8 | 18.3 | 23.8 | 20.3 | 14.2 |
| 317 | 21.8 | | | 11.3 | 21.1 | 21.5 | 20.1 | 20.6 | | 21.8 | | 24.3 |
| 318 | 12.3 | 18.6 | 18.5 | 13.9 | 12.4 | 19.2 | 11.9 | 17.0 | | 21.4 | 19.7 | |
| 378 | 12.6 | | 13.9 | 16.1 | 12.9 | 12.2 | | | | 15.3 | 14.3 | 17.4 |
| 379 | 11.4 | 12.4 | 14.1 | 12.6 | 13.4 | 11.5 | 11.0 | 20.1 | 17.4 | 16.0 | 13.0 | 15.3 |
| 389 | 14.8 | 14.8 | 15.0 | 15.1 | 15.8 | 13.6 | 18.5 | 17.9 | 15.2 | 15.5 | 14.7 | |
| 401 | 12.8 | 21.0 | 24.2 | 22.8 | 22.0 | 22.7 | 22.0 | 17.7 | 14.6 | 11.5 | 10.6 | 16.9 |
| 428 | | 18.2 | 14.8 | 20.1 | 23.1 | 21.0 | 20.1 | 13.5 | 18.4 | 13.8 | 14.7 | 15.8 |
| 431 | 23.0 | | 22.7 | 15.4 | 16.5 | 11.5 | 16.5 | 19.6 | 18.0 | | 20.1 | 10.1 |
| 444 | 18.7 | 17.7 | | 17.4 | 16.2 | 19.6 | 18.2 | 17.8 | 19.4 | 11.4 | 17.9 | 22.9 |
| 463 | 18.1 | 19.8 | 18.2 | 15.7 | 14.9 | 17.9 | 16.4 | 16.9 | 16.0 | 19.8 | | |
| 471 | | | 16.3 | | | | | 17.5 | | 19.1 | 20.4 | 18.9 |
| 479 | | 13.1 | 13.6 | 15.2 | 17.3 | 14.3 | 16.6 | 16.0 | 16.0 | 17.6 | 15.2 | 20.3 |
| 499 | 19.2 | 14.2 | 15.0 | 18.1 | | 13.9 | 14.8 | | | 16.6 | 16.0 | 14.6 |
| 503 | | 19.2 | 26.3 | 18.1 | 16.3 | 18.2 | 19.1 | | 18.3 | 26.1 | 23.4 | 22.1 |
| 458 | 46.2 | 45.1 | 36.1 | 46.1 | 47.4 | 46.7 | 47.5 | 51.2 | 50.3 | 49.3 | 48.1 | 47.9 |
| 52 | 50.2 | 48.7 | 48.4 | 47.1 | 47.6 | 45.0 | 45.5 | 46.7 | | | 40.4 | 45.6 |
| 169 | 46.1 | 44.3 | 47.3 | 48.0 | 46.8 | 41.8 | 46.5 | 49.8 | 45.5 | 51.5 | 51.3 | |
| 214 | 48.8 | 46.7 | 51.5 | 49.9 | 49.7 | 50.7 | 47.3 | 53.6 | 52.3 | 51.9 | 52.0 | 53.5 |
| 103 | 30.2 | 45.2 | 45.3 | 41.5 | 33.0 | 40.9 | 42.5 | 40.5 | 41.3 | 41.7 | 53.5 | 46.9 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 162 | 40.5 | 46.0 | 44.0 | 41.7 | 41.4 | 50.3 | 46.6 | 42.9 | 38.0 | 46.3 | 43.4 | 43.8 |
| 176 | 30.3 | 32.0 | 38.3 | 41.4 | 47.4 | 45.0 | 45.8 | 45.2 | 45.6 | 44.1 | 45.0 | 46.1 |
| 190 | | 28.9 | | | | 28.1 | | 28.4 | 28.2 | 29.4 | 29.5 | 28.5 |
| 195 | 50.9 | 53.5 | 52.4 | 50.8 | 53.4 | 52.5 | 54.9 | 53.4 | 54.3 | 51.3 | 51.4 | 48.1 |
| 249 | | | | | | | | 34.1 | 35.2 | 38.0 | 35.8 | |
| 335 | 45.7 | 43.0 | 36.3 | 40.2 | 42.8 | 43.0 | 42.5 | 41.2 | 43.3 | 41.6 | 38.1 | 43.2 |
| 398 | 45.2 | 49.9 | 39.3 | 44.2 | 48.5 | 38.9 | | | 49.8 | 48.2 | 44.1 | 45.9 |
| 409 | 56.2 | | 51.6 | 52.5 | | 49.5 | 34.9 | 52.4 | 53.6 | 49.4 | | 49.7 |
| 418 | 42.0 | 49.0 | 47.7 | 47.0 | | 46.6 | 40.1 | 40.4 | 36.7 | 36.3 | 37.8 | 39.6 |
| 480 | 47.1 | 46.6 | 47.3 | 49.0 | 49.9 | 47.0 | | | | | | |
| 488 | 49.6 | 45.7 | 49.6 | 42.6 | 47.4 | 45.9 | 45.4 | 47.1 | 53.4 | 51.9 | 48.9 | 49.4 |
| 36 | | | | | | 31.9 | | | | 55.2 | 52.4 | 50.8 |
| 71 | 50.7 | 51.4 | | 48.9 | 40.9 | 42.0 | 43.3 | 43.3 | 46.4 | 44.3 | 47.0 | 47.9 |
| 86 | 40.2 | 36.8 | 41.2 | 40.6 | 43.1 | 40.4 | 44.9 | 41.9 | 44.1 | 31.6 | 34.6 | 33.6 |
| 145 | 47.7 | 45.5 | 51.4 | 50.5 | 56.5 | 50.8 | 44.7 | 50.6 | | 37.5 | 47.7 | 32.9 |
| 217 | 43.1 | | | | 44.3 | 42.7 | | 49.7 | | 47.5 | 49.4 | 51.5 |
| 326 | 51.9 | 47.5 | 48.3 | | 49.7 | 49.2 | 48.2 | 47.2 | 44.3 | | 48.4 | 46.4 |
| 343 | 31.2 | 30.9 | 34.3 | 42.0 | 49.1 | 44.4 | 48.8 | | 45.9 | 38.1 | 28.3 | |
| 356 | | 28.5 | 36.6 | 42.2 | | | | 42.1 | 40.2 | | 44.0 | |
| 448 | 50.4 | 50.4 | 53.2 | 52.0 | 49.4 | 49.5 | 46.7 | 43.2 | 49.3 | 47.5 | 50.3 | 50.4 |
| 473 | | 46.7 | 44.8 | 44.5 | 33.0 | 43.4 | 43.3 | 36.0 | 47.4 | 49.4 | 47.6 | 48.6 |

## (E) MPG data for Aug2012-Mar2013

| Driver ID | 2012 | 2012 | 2012 | 2012 | 2012 | 2013 | 2013 | 2013 |
|---|---|---|---|---|---|---|---|---|
| | August | September | October | November | December | January | February | March |
| | Period4 | Period4 | Period4 | Period4 | Period4 | Period4 | Period4 | Period4 |
| 39 | 8.5 | 10.4 | 8.8 | 9.6 | 8.5 | 9.8 | 5.0 | 10.1 |
| 79 | | | 8.5 | 10.8 | 8.4 | 8.7 | 7.4 | 8.1 |
| 85 | 10.0 | 11.9 | 9.7 | 7.8 | | 10.2 | | 7.6 |
| 98 | | 11.5 | 8.7 | 10.0 | | | | 9.0 |
| 208 | 9.9 | 10.2 | | 9.1 | 10.8 | 12.7 | 12.0 | 14.3 |
| 299 | 11.0 | 10.7 | 11.1 | 7.2 | 6.7 | 6.1 | 9.4 | 9.5 |
| 381 | 7.6 | 8.1 | | 7.3 | 6.2 | 11.3 | 12.7 | 7.2 |
| 472 | 8.2 | 9.8 | 9.1 | 6.9 | 7.3 | 7.3 | 8.8 | 9.2 |
| 478 | 7.9 | 8.0 | 8.7 | 6.7 | 7.2 | 6.1 | | 7.6 |
| 10 | 8.0 | 9.6 | 8.5 | 8.4 | 9.0 | 9.5 | 9.1 | 8.6 |
| 15 | | | 8.4 | 7.5 | 8.2 | | 7.5 | 9.6 |
| 35 | | | | | | | | |
| 42 | 9.6 | 10.5 | 9.7 | 8.1 | 7.6 | 7.0 | 7.3 | 7.4 |
| 76 | 8.2 | 9.9 | 9.2 | 10.0 | 12.0 | 10.0 | 12.4 | 8.4 |
| 109 | 8.9 | 8.2 | 9.8 | 8.7 | 10.2 | 7.8 | 7.2 | 7.5 |
| 118 | 7.3 | 8.8 | 7.2 | 6.0 | 8.0 | 7.0 | | 7.3 |
| 130 | | | 9.8 | 5.7 | 7.2 | 6.3 | 7.9 | 6.4 |
| 132 | 8.6 | 8.3 | 8.9 | 10.7 | 9.5 | 12.0 | 6.0 | |
| 139 | 10.3 | 8.9 | 7.2 | 11.5 | 9.5 | 8.1 | 10.7 | 10.9 |
| 171 | | 7.5 | 7.9 | | | 6.0 | 6.2 | 9.1 |
| 210 | 11.7 | | 10.3 | | | 11.0 | 11.6 | |
| 225 | 6.9 | 9.8 | 6.4 | 6.8 | 11.9 | | 9.1 | 10.1 |
| 229 | 7.9 | 8.7 | 7.5 | 8.1 | 9.7 | 13.8 | 7.3 | 5.7 |
| 244 | 9.0 | 8.0 | 7.6 | 7.1 | 8.4 | 9.3 | 5.9 | 8.0 |
| 251 | | 8.2 | 8.0 | 9.5 | 9.9 | 7.3 | 11.7 | 9.4 |

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|---|---|---|---|---|---|---|---|---|
| 261 | | 7.1 | | 8.1 | 6.4 | 7.4 | 9.5 | |
| 314 | 8.7 | 7.9 | 7.8 | 7.0 | 6.0 | 7.4 | 8.2 | 8.8 |
| 344 | | | 6.2 | | | 8.2 | 7.6 | 7.8 |
| 365 | 11.4 | 10.0 | 9.5 | 8.5 | 6.9 | 9.0 | 13.3 | 14.1 |
| 392 | | 7.6 | | 7.3 | 7.8 | | | |
| 433 | 9.5 | 8.5 | 7.7 | 8.6 | 7.3 | 8.3 | 7.0 | 6.5 |
| 442 | 7.7 | 9.4 | 13.3 | 8.5 | 9.4 | 6.0 | 8.6 | 8.7 |
| 464 | 8.3 | | 8.0 | 7.4 | 7.1 | 7.3 | 5.4 | 6.7 |
| 492 | 8.2 | 7.6 | 7.1 | 6.7 | 6.5 | 7.7 | 6.6 | 9.0 |
| 26 | 10.2 | 10.0 | 13.0 | 12.0 | 11.4 | | | 10.3 |
| 28 | 8.0 | 8.0 | 9.9 | 8.5 | 8.9 | 7.5 | 8.5 | 12.5 |
| 51 | 8.4 | 7.9 | 6.0 | 8.8 | 6.7 | 7.8 | 7.3 | 6.9 |
| 60 | 9.4 | 10.6 | 7.9 | 8.9 | | 6.9 | 10.3 | 5.4 |
| 74 | 7.0 | 6.8 | 7.6 | 6.3 | 7.0 | 7.6 | 6.9 | 7.2 |
| 88 | 8.7 | 11.2 | 8.1 | 9.5 | | 10.6 | 6.8 | |
| 114 | 7.9 | | 6.2 | | 9.8 | | | |
| 124 | | | 7.0 | 12.0 | 7.3 | 10.2 | 8.2 | 6.7 |
| 128 | 11.5 | 12.1 | 11.1 | 8.9 | 8.2 | 7.5 | 8.0 | 8.1 |
| 138 | 8.1 | 7.3 | 9.2 | 9.9 | 8.2 | | 9.1 | |
| 149 | 7.4 | 7.1 | | 6.6 | | | 5.4 | |
| 164 | 6.1 | 6.4 | 8.4 | 7.5 | 6.8 | 7.0 | 7.7 | |
| 199 | 7.0 | 7.6 | 8.2 | 7.2 | 6.5 | 8.6 | 8.0 | 7.7 |
| 201 | 6.8 | | 5.4 | 7.7 | 8.7 | | | 9.0 |
| 216 | | 9.0 | 7.6 | | 7.5 | 6.8 | 8.1 | 8.0 |
| 234 | 8.9 | 6.4 | 6.4 | 7.4 | 7.5 | | | |
| 239 | | 7.6 | 7.5 | 7.2 | 7.0 | 5.9 | 7.0 | 6.1 |
| 245 | 7.3 | 6.2 | 6.3 | 8.4 | 7.1 | 7.8 | 8.7 | 7.5 |
| 255 | 13.2 | 9.3 | | 7.0 | 9.3 | 6.4 | 11.4 | 6.7 |
| 302 | 8.8 | 8.2 | 8.8 | 6.3 | 8.5 | 7.6 | 8.9 | 6.8 |
| 317 | 7.3 | | 6.6 | 6.9 | 5.9 | 9.4 | 7.2 | 7.3 |

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|---|---|---|---|---|---|---|---|---|
| 318 | 8.8 | | 7.7 | 7.0 | 8.7 | 8.7 | 5.7 | 8.4 |
| 378 | 7.8 | 7.4 | | 7.6 | 7.5 | 8.1 | 11.9 | 10.3 |
| 379 | 8.7 | 7.8 | | 9.4 | 11.3 | 8.8 | 10.8 | 8.9 |
| 389 | | | 12.0 | 9.6 | 10.2 | | | |
| 401 | | | | | | 9.8 | | |
| 428 | 7.8 | 10.1 | 12.8 | | | 12.1 | | 9.6 |
| 431 | 7.9 | 6.8 | 7.0 | 7.2 | 7.5 | 6.9 | 7.3 | 7.1 |
| 444 | 7.4 | 8.2 | 7.3 | 6.7 | 9.6 | 7.2 | | 10.2 |
| 463 | | | | | | | | |
| 471 | | 9.1 | 11.7 | 10.9 | | 8.2 | 8.9 | 13.2 |
| 479 | | | 9.0 | 7.2 | 7.4 | 7.2 | 9.8 | |
| 499 | | 10.7 | 6.5 | | | 11.0 | 9.3 | 9.7 |
| 503 | 9.9 | 8.6 | 9.0 | 8.0 | 8.0 | 7.7 | 7.4 | 8.9 |
| 39 | 21.1 | 21.1 | 21.9 | 21.8 | 20.1 | 22.0 | 20.7 | 19.3 |
| 79 | 24.7 | 22.8 | 24.0 | 22.9 | 20.2 | 20.4 | 19.8 | 18.5 |
| 85 | 19.3 | 23.9 | 16.5 | 19.1 | 19.1 | 19.4 | | 18.4 |
| 98 | 13.8 | 15.6 | 16.6 | 16.2 | 15.3 | 20.5 | 16.0 | 15.9 |
| 208 | | | 18.7 | | | 13.0 | 16.6 | 14.7 |
| 299 | 14.8 | 22.1 | 21.7 | 20.2 | 17.8 | | | 17.9 |
| 381 | 16.2 | 14.5 | 14.4 | 13.9 | 16.4 | 14.8 | 16.4 | 13.9 |
| 472 | 15.0 | 11.8 | 12.3 | 27.7 | 16.3 | 17.4 | 18.4 | 16.2 |
| 478 | 20.9 | | 14.7 | 12.3 | 15.1 | 23.4 | | 13.0 |
| 10 | 17.8 | 19.9 | 17.4 | 17.9 | 18.7 | 15.3 | 14.5 | 16.8 |
| 15 | 22.1 | 21.7 | 20.8 | 23.9 | 19.1 | 18.3 | 20.4 | 17.6 |
| 35 | 23.8 | | | | | | | |
| 42 | 18.6 | 15.4 | 19.4 | 21.1 | 21.8 | 17.4 | 17.7 | 17.8 |
| 76 | | 20.5 | 17.6 | 19.9 | 17.7 | 10.2 | 17.6 | |
| 109 | 16.8 | 21.5 | 19.1 | 13.2 | 22.0 | 17.3 | 17.0 | 15.4 |
| 118 | 22.3 | 19.6 | 20.6 | 20.5 | 19.3 | 16.1 | 18.3 | 15.9 |
| 130 | 16.9 | 22.1 | 18.9 | 17.2 | 18.0 | 16.4 | 17.0 | 19.1 |

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|---|---|---|---|---|---|---|---|---|
| 132 | 19.0 | 11.1 | 18.6 | 16.1 | 15.2 | 16.0 | 13.1 | |
| 139 | 13.6 | | 14.5 | 15.0 | 14.9 | 14.0 | 15.8 | 19.3 |
| 171 | 20.4 | 17.5 | | 19.7 | 21.1 | 19.0 | 20.3 | 19.0 |
| 210 | 13.2 | 16.1 | 17.0 | 19.7 | 17.2 | 15.7 | 15.3 | 18.0 |
| 225 | 17.9 | 14.9 | 17.8 | 19.9 | | | | 21.8 |
| 229 | 18.7 | 16.0 | 12.6 | 13.1 | | 10.6 | 15.7 | 18.0 |
| 244 | 19.6 | 18.9 | 17.3 | 18.0 | 17.7 | 17.7 | 18.0 | 19.0 |
| 251 | 17.6 | 17.4 | 21.4 | | 14.5 | 15.0 | 21.7 | |
| 261 | | 13.1 | | 12.3 | 20.7 | | | |
| 314 | 18.5 | 21.2 | 20.6 | 21.0 | 23.1 | 16.4 | 16.0 | 18.5 |
| 344 | 16.1 | 13.6 | 12.7 | 14.2 | 13.9 | 15.2 | 14.2 | 14.4 |
| 365 | 17.3 | 13.7 | 15.2 | 15.0 | | | | 20.3 |
| 392 | 16.9 | 14.7 | 14.5 | 13.8 | 15.5 | | | 10.2 |
| 433 | 23.8 | 18.0 | 20.3 | 18.1 | 19.4 | 21.0 | 20.3 | 19.8 |
| 442 | 17.7 | 19.2 | 19.0 | 12.5 | | 18.5 | 14.0 | 15.5 |
| 464 | | 20.2 | 21.7 | 21.0 | 17.2 | 17.5 | 17.6 | 20.1 |
| 492 | 19.0 | 21.2 | 18.8 | 18.1 | 18.8 | 22.4 | 18.7 | |
| 26 | 14.2 | 15.1 | 15.3 | 22.1 | 16.8 | | | 20.8 |
| 28 | | | | 17.8 | 21.4 | | 17.3 | 17.6 |
| 51 | 15.7 | 15.6 | 22.6 | 22.1 | 14.1 | 17.5 | 15.4 | 15.8 |
| 60 | 14.4 | 16.8 | 15.9 | 18.8 | 17.2 | | | |
| 74 | 19.5 | | 14.8 | 14.8 | 14.4 | | | |
| 88 | 15.8 | 15.2 | 14.6 | 14.7 | 18.5 | 18.7 | 17.2 | 17.1 |
| 114 | 16.0 | 16.0 | 16.5 | 16.2 | | | | |
| 124 | 20.1 | | 21.6 | | 18.3 | 17.3 | 17.5 | 21.4 |
| 128 | | 12.6 | 17.5 | | | 15.8 | | |
| 138 | 18.6 | 16.5 | 16.0 | 14.2 | | | | |
| 149 | 14.9 | 14.8 | 16.4 | 17.1 | 13.6 | 13.2 | 16.5 | 17.9 |
| 164 | 15.2 | 16.4 | | 16.0 | 14.6 | | | |
| 199 | 21.0 | 20.9 | | | | 18.1 | 19.3 | 19.4 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 201 | 15.4 | 15.5 | 17.9 | 14.6 | | | | |
| 216 | 18.1 | 16.2 | 18.1 | 15.6 | 13.1 | 10.5 | 12.5 | 11.8 |
| 234 | 10.3 | 16.8 | 16.5 | 18.7 | | | | 17.9 |
| 239 | | 16.4 | 18.6 | 22.2 | 20.1 | 18.2 | 16.1 | 14.3 |
| 245 | 18.3 | 20.3 | 18.2 | 10.6 | 20.0 | 18.4 | 17.8 | 17.6 |
| 255 | | | | 20.3 | 23.2 | | | 22.0 |
| 302 | 18.0 | 19.8 | 21.4 | 15.4 | 15.0 | 20.0 | 17.5 | 13.9 |
| 317 | 21.1 | 20.9 | 21.6 | 22.6 | 15.8 | 20.8 | 21.0 | 22.8 |
| 318 | 19.1 | 20.6 | | 13.3 | 16.7 | | 17.9 | |
| 378 | 15.4 | | 11.7 | 13.4 | | 13.4 | | |
| 379 | 16.2 | 22.0 | 12.5 | 18.0 | 17.2 | 19.0 | 18.0 | 15.5 |
| 389 | 18.0 | 22.1 | | 20.9 | | | | |
| 401 | 16.9 | 21.9 | 20.4 | 17.5 | 18.1 | 18.6 | 19.6 | 19.3 |
| 428 | 14.2 | 16.4 | 18.8 | 17.0 | 18.9 | 16.2 | 15.4 | 14.4 |
| 431 | 13.3 | 18.0 | 15.2 | | 20.9 | 21.0 | 20.9 | |
| 444 | 19.8 | 14.2 | 20.9 | 21.6 | 15.6 | 10.8 | 12.8 | |
| 463 | | | | | | | | |
| 471 | 16.9 | | | 18.3 | | 17.3 | | 16.2 |
| 479 | 20.5 | 18.2 | 16.0 | 17.4 | 16.3 | 16.5 | 16.9 | 13.6 |
| 499 | | | 13.0 | 13.9 | | | | |
| 503 | 20.7 | 18.7 | 15.9 | 19.0 | | 17.6 | 17.1 | 17.5 |
| 458 | 50.0 | 50.2 | 45.3 | 46.4 | 48.1 | 51.0 | | |
| 52 | 49.7 | 48.9 | 45.5 | 46.8 | 44.5 | 45.8 | 45.4 | 48.2 |
| 169 | 50.2 | 51.2 | 51.1 | 50.7 | 48.8 | | | 45.6 |
| 214 | 54.7 | 50.8 | 51.8 | 54.3 | 52.0 | 50.8 | 49.3 | 52.4 |
| 103 | 44.2 | 45.8 | 43.4 | 48.8 | 47.5 | 41.9 | | |
| 162 | 44.6 | 45.6 | 46.6 | 49.0 | 48.6 | 48.6 | 46.8 | |
| 176 | 45.1 | 43.1 | | 39.0 | | | 42.6 | 44.3 |
| 190 | 29.4 | 29.7 | | 29.5 | 28.7 | | | |
| 195 | 48.5 | 46.7 | 46.8 | 46.4 | 43.2 | 46.2 | 44.5 | 41.1 |

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|---|---|---|---|---|---|---|---|---|
| 249 | 39.2 | 38.8 | 36.0 | 36.4 | 36.0 | | | |
| 335 | 40.3 | 41.5 | 39.7 | 37.3 | 39.0 | 43.5 | 40.7 | 44.0 |
| 398 | 48.5 | 50.3 | 48.2 | 50.2 | 48.3 | | | |
| 409 | 52.7 | 51.3 | 50.2 | 42.6 | | 48.3 | 43.9 | 44.4 |
| 418 | 36.9 | 35.7 | 28.6 | 37.1 | | 41.2 | 42.8 | 40.4 |
| 480 | | | | | | | | |
| 488 | 49.0 | 50.8 | 51.5 | 50.2 | 49.4 | 48.7 | 46.9 | 46.5 |
| 36 | 51.1 | 49.4 | 46.1 | | 48.4 | 48.1 | 44.2 | |
| 71 | 45.7 | 44.0 | 43.9 | 41.8 | 43.5 | 46.4 | 43.0 | 41.7 |
| 86 | 31.2 | 38.8 | 34.6 | 36.9 | 34.2 | | 34.8 | |
| 145 | | | 51.5 | 47.2 | 51.0 | 49.2 | 47.9 | 46.3 |
| 217 | 47.6 | 46.5 | | 48.2 | | 45.9 | | 45.9 |
| 326 | 45.9 | 47.0 | 51.1 | 48.8 | | 46.7 | 49.7 | 48.0 |
| 343 | | 47.3 | 51.9 | | 40.8 | | 48.9 | |
| 356 | 47.9 | 32.2 | 36.7 | 31.5 | 37.5 | | | |
| 448 | 47.8 | 46.5 | 53.3 | 52.2 | 47.4 | 45.3 | 47.1 | 46.8 |
| 473 | 49.8 | 49.3 | 48.8 | 49.8 | 51.4 | 47.4 | 48.5 | 47.5 |

## Appendix D-6 Data obtained by using the driving style questionnaire (DSQ)

| Driver ID | Attitude Towards Driving for Fuel Economy | | Do you sometimes fail to drive cautiously? | | Do you dislike people who give you advice about you driving? | | Do you sometimes drive when feeling tired? | | How often do you forget to check your vehicle tyre pressure? | | Do you drive fast? | | Do you sometimes fail to apply smooth braking? | | Do you sometimes forget to use block gear changes for example 1-3-5 0r 2-4-6? | | Do you sometimes use the clutch control to balance the car whilst stationary? | | Do you sometimes forget to plan ahead? | | Do leave the vehicle engine on when it is not needed? | | Do you sometimes forget to plan your journey? | | Do you sometime forget to plan about loading the vehicle? | | Do you forget to carry out necessary aerodynamic adjustments if available to reduce drag? | | Have you ever doubted the benefits fuel efficient driving like fuel economy and safety? | | Do you sometimes fail to get the support you need regarding fuel efficient driving? | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before | After | Before1 | After1 | Before2 | After2 | Before3 | After3 | Before4 | After4 | Before5 | After5 | Before6 | After6 | Before7 | After7 | Before8 | After8 | Before9 | After9 | Before10 | After10 | Before11 | After11 | Before12 | After12 | Before13 | After13 | Before14 | After14 | Before15 | After15 |
| 39 | Important | Important | 1 | 1 | 0 | 1 | 2 | 0 | 2 | 1 | 1 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 2 | 1 |
| 79 | Important | Important | 3 | 3 | 2 | 2 | 3 | 2 | 3 | 3 | 2 | 1 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 0 | 3 | 3 | 2 | 2 | 2 | 3 |
| 85 | Important | Important | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 2 | 3 | 2 |
| 98 | Important | Important | 4 | 2 | 3 | 3 | 2 | 2 | 3 | 2 | 4 | 2 | 4 | 4 | 2 | 2 | 3 | 2 | 4 | 2 | 3 | 3 | 3 | 4 | 4 | 2 | 3 | 2 | 4 | 4 | 4 | 4 |
| 208 | Important | Important | 3 | 4 | 3 | 4 | 4 | 3 | 0 | 0 | 4 | 3 | 5 | 3 | 4 | 4 | 3 | 3 | 3 | 3 | 5 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 5 | 5 | 5 | 2 |
| 299 | Important | Important | 3 | 1 | 3 | 2 | 3 | 2 | 3 | 2 | 2 | 2 | 3 | 4 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 3 | 4 | 2 | 2 | 1 | 4 | 3 | 4 | 3 | 4 | 4 |
| 381 | Important | Important | 4 | 2 | 4 | 3 | 4 | 3 | 5 | 2 | 2 | 2 | 4 | 4 | 4 | 3 | 2 | 4 | 2 | 0 | 4 | 2 | 3 | 4 | 4 | 2 | 4 | 3 | 4 | 2 | 4 | 4 |
| 472 | Unsure | Importa | 3 | 3 | 3 | 2 | 3 | 2 | 2 | 3 | 4 | 4 | 2 | 2 | 2 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 2 | 4 | 2 | 2 | 5 | 2 | 4 | 4 | 3 | 3 |

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| | | nt | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 478 | Important | Important | 4 | 3 | 5 | 2 | 2 | 0 | 3 | 0 | 4 | 5 | 4 | 3 | 3 | 4 | 3 | 3 | 2 | 3 | 4 | 2 | 2 | 4 | 5 | 4 | 3 | 4 | 4 | 3 | 2 | 3 |
| 10 | Important | Important | 4 | 3 | 2 | 0 | 2 | 4 | 3 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 2 | 3 | 2 | 4 | 2 | 3 | 2 | 2 | 3 | 3 | 4 | 3 | 4 | 4 | 5 | 3 |
| 15 | Unsure | Unsure | 0 | 2 | 2 | 3 | 3 | 2 | 2 | 3 | 2 | 1 | 4 | 2 | 2 | 3 | 2 | 4 | 2 | 2 | 3 | 3 | 3 | 4 | 2 | 1 | 2 | 3 | 2 | 4 | 3 | 4 |
| 35 | Important | Important | 3 | 4 | 4 | 0 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 2 | 4 | 2 | 2 | 2 | 5 | 3 | 4 | 3 | 3 | 3 | 3 | 0 | 4 | 2 | 4 | 4 | 4 | 2 |
| 42 | Important | Important | 2 | 2 | 4 | 2 | 4 | 3 | 4 | 3 | 3 | 3 | 5 | 3 | 2 | 4 | 3 | 0 | 4 | 0 | 2 | 3 | 5 | 2 | 2 | 0 | 4 | 3 | 3 | 3 | 3 | 4 |
| 76 | Important | Important | 4 | 3 | 2 | 3 | 4 | 3 | 3 | 3 | 2 | 4 | 3 | 4 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 3 | 3 | 3 | 2 | 3 |
| 109 | Unsure | Important | 4 | 2 | 5 | 5 | 4 | 3 | 3 | 4 | 4 | 0 | 5 | 4 | 3 | 4 | 4 | 2 | 4 | 3 | 4 | 2 | 3 | 3 | 2 | 1 | 4 | 4 | 2 | 4 | 4 | 4 |
| 118 | Important | Important | 5 | 5 | 2 | 4 | 2 | 4 | 3 | 3 | 4 | 4 | 4 | 2 | 3 | 2 | 3 | 2 | 3 | 3 | 4 | 2 | 3 | 3 | 3 | 1 | 2 | 4 | 4 | 3 | 4 | 4 |
| 130 | Important | Important | 3 | 2 | 4 | 2 | 2 | 3 | 2 | 4 | 4 | 5 | 2 | 4 | 5 | 0 | 4 | 3 | 4 | 3 | 4 | 3 | 3 | 3 | 4 | 3 | 2 | 2 | 5 | 2 | 2 | 3 |
| 132 | Important | Important | 2 | 3 | 2 | 3 | 3 | 3 | 4 | 4 | 2 | 3 | 5 | 3 | 4 | 3 | 4 | 2 | 4 | 4 | 4 | 3 | 4 | 2 | 2 | 1 | 3 | 3 | 2 | 5 | 2 | 2 |
| 139 | Important | Important | 4 | 4 | 4 | 3 | 4 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 3 | 3 | 4 | 3 | 4 | 5 | 3 | 1 | 4 | 3 | 3 | 2 | 4 | 2 |
| 171 | Unsure | Unsure | 1 | 0 | 2 | 3 | 2 | 3 | 5 | 4 | 2 | 4 | 2 | 3 | 2 | 2 | 2 | 0 | 2 | 0 | 2 | 3 | 2 | 4 | 5 | 4 | 4 | 3 | 3 | 4 | 5 | 2 |
| 210 | Unsure | Important | 4 | 3 | 2 | 3 | 2 | 2 | 3 | 4 | 3 | 3 | 2 | 2 | 4 | 2 | 2 | 1 | 3 | 2 | 2 | 4 | 4 | 2 | 4 | 3 | 3 | 2 | 2 | 4 | 2 | 2 |
| 225 | Important | Important | 4 | 0 | 2 | 4 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 2 | 3 | 2 | 2 | 2 | 2 | 1 | 2 | 4 | 4 | 2 | 4 | 3 | 2 | 2 | 3 | 1 | 3 | 3 |
| 229 | Unsure | Unsure | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 244 | Unimportant | Important | 2 | 4 | 4 | 2 | 3 | 4 | 4 | 4 | 3 | 3 | 2 | 4 | 2 | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 4 | 3 | 2 | 2 | 2 | 3 | 4 | 3 | 3 | 4 |
| 251 | Important | Important | 2 | 2 | 3 | 4 | 2 | 3 | 3 | 3 | 4 | 2 | 3 | 3 | 2 | 4 | 3 | 2 | 2 | 2 | 3 | 3 | 2 | 0 | 2 | 3 | 2 | 1 | 3 | 2 | 2 | 4 |
| 261 | Important | Important | 4 | 4 | 3 | 2 | 2 | 3 | 2 | 2 | 4 | 3 | 5 | 4 | 2 | 4 | 3 | 3 | 3 | 2 | 3 | 4 | 2 | 4 | 3 | 2 | 3 | 4 | 3 | 2 | 2 | 3 |
| 314 | Unsure | Unimportant | 3 | 1 | 3 | 3 | 4 | 3 | 4 | 4 | 2 | 4 | 3 | 2 | 3 | 2 | 2 | 4 | 3 | 2 | 4 | 3 | 4 | 4 | 3 | 2 | 4 | 3 | 2 | 3 | 4 | 4 |
| 344 | Unsure | Important | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 4 | 3 | 2 | 3 | 2 | 4 | 3 | 2 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 4 | 4 | 3 | 3 |
| 365 | Important | Important | 2 | 2 | 4 | 2 | 2 | 4 | 3 | 3 | 2 | 3 | 4 | 2 | 2 | 4 | 4 | 2 | 3 | 0 | 4 | 4 | 4 | 3 | 4 | 1 | 3 | 1 | 3 | 3 | 3 | 2 |

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| 392 | Important | Important | 4 | 3 | 2 | 4 | 4 | 2 | 2 | 2 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 2 | 4 | 0 | 4 | 4 | 4 | 3 | 3 | 3 | 4 | 2 | 2 | 3 | 3 | 4 |
| 433 | Important | Important | 4 | 2 | 2 | 1 | 2 | 2 | 3 | 2 | 2 | 1 | 2 | 2 | 0 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 3 | 2 | 3 | 2 |
| 442 | Important | Important | 3 | 1 | 4 | 4 | 5 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 2 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 2 | 2 | 2 | 4 | 3 | 4 | 3 | 3 |
| 464 | Important | Important | 3 | 0 | 3 | 3 | 3 | 4 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 4 | 4 | 3 | 2 | 1 | 3 | 3 | 2 | 3 | 2 | 3 | 4 | 3 | 4 | 4 | 3 | 2 |
| 492 | Important | Important | 4 | 2 | 2 | 1 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 2 | 3 | 4 | 3 | 2 | 3 | 3 | 2 | 2 | 2 | 5 | 4 | 3 | 3 | 3 | 3 | 3 | 4 |
| 26 | | Unsure | 4 | | 4 | | 4 | | 2 | | 4 | | 4 | | 3 | | 4 | | 3 | | 4 | | 4 | | 3 | | 3 | | 4 | | 3 | |
| 28 | | Important | 2 | | 3 | | 3 | | 2 | | 5 | | 4 | | 4 | | 2 | | 2 | | 2 | | 3 | | 2 | | 2 | | 2 | | 2 | |
| 51 | | Unsure | 4 | | 2 | | 3 | | 2 | | 2 | | 2 | | 4 | | 4 | | 3 | | 4 | | 4 | | 2 | | 3 | | 4 | | 2 | |
| 60 | | Important | 2 | | 4 | | 4 | | 3 | | 2 | | 2 | | 3 | | 3 | | 4 | | 2 | | 4 | | 3 | | 2 | | 2 | | 3 | |
| 74 | | Unsure | 5 | | 3 | | 4 | | 3 | | 4 | | 2 | | 3 | | 4 | | 3 | | 2 | | 3 | | 4 | | 3 | | 2 | | 4 | |
| 88 | | Important | 4 | | 4 | | 3 | | 2 | | 4 | | 2 | | 2 | | 3 | | 2 | | 3 | | 4 | | 4 | | 4 | | 2 | | 4 | |
| 114 | | Important | 4 | | 3 | | 2 | | 2 | | 4 | | 4 | | 3 | | 3 | | 3 | | 2 | | 3 | | 4 | | 2 | | 4 | | 4 | |
| 124 | | Important | 0 | | 0 | | 2 | | 1 | | 3 | | 1 | | 0 | | 0 | | 1 | | 0 | | 1 | | 2 | | 2 | | 2 | | 1 | |
| 128 | | Unsure | 2 | | 3 | | 2 | | 3 | | 3 | | 3 | | 4 | | 4 | | 3 | | 3 | | 4 | | 3 | | 4 | | 2 | | 4 | |
| 138 | | Unsure | 2 | | 2 | | 3 | | 2 | | 3 | | 3 | | 2 | | 2 | | 4 | | 2 | | 4 | | 3 | | 3 | | 4 | | 3 | |
| 149 | | Important | 4 | | 5 | | 2 | | 2 | | 3 | | 2 | | 4 | | 4 | | 2 | | 4 | | 5 | | 4 | | 4 | | 4 | | 2 | |
| 164 | | Important | 3 | | 4 | | 2 | | 4 | | 2 | | 4 | | 4 | | 4 | | 3 | | 3 | | 3 | | 2 | | 2 | | 3 | | 2 | |
| 199 | | Unsure | 3 | | 3 | | 2 | | 3 | | 3 | | 4 | | 3 | | 2 | | 2 | | 3 | | 3 | | 3 | | 4 | | 2 | | 2 | |
| 201 | | Important | 3 | | 2 | | 2 | | 3 | | 3 | | 0 | | 4 | | 3 | | 0 | | 3 | | 4 | | 2 | | 4 | | 4 | | 2 | |
| 216 | | Important | 4 | | 3 | | 4 | | 3 | | 2 | | 2 | | 4 | | 2 | | 3 | | 4 | | 4 | | 3 | | 3 | | 2 | | 2 | |
| 234 | | Unimportant | 3 | | 4 | | 3 | | 3 | | 3 | | 3 | | 3 | | 3 | | 3 | | 3 | | 3 | | 2 | | 2 | | 2 | | 3 | |
| 239 | | Important | 2 | | 1 | | 2 | | 4 | | 2 | | 4 | | 2 | | 3 | | 4 | | 4 | | 2 | | 3 | | 3 | | 3 | | 4 | |
| 245 | | Important | 5 | | 3 | | 3 | | 4 | | 4 | | 5 | | 5 | | 5 | | 3 | | 3 | | 2 | | 2 | | 4 | | 3 | | 4 | |

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| 255 | | Unimportant | 3 | | 3 | | 2 | | 2 | | 2 | | 3 | | 2 | | 3 | | 2 | | 4 | | 2 | | 4 | | 4 | | 3 | | 2 | |
| 302 | | Important | 1 | | 0 | | 3 | | 4 | | 4 | | 4 | | 4 | | 3 | | 2 | | 0 | | 1 | | 2 | | 4 | | 3 | | 3 | |
| 317 | | Important | 3 | | 3 | | 3 | | 3 | | 2 | | 3 | | 3 | | 2 | | 2 | | 3 | | 0 | | 3 | | 0 | | 0 | | 3 | |
| 318 | | Important | 4 | | 4 | | 4 | | 3 | | 2 | | 4 | | 4 | | 4 | | 4 | | 2 | | 4 | | 3 | | 4 | | 3 | | 2 | |
| 378 | | Unsure | 5 | | 5 | | 4 | | 4 | | 4 | | 3 | | 4 | | 3 | | 3 | | 4 | | 4 | | 4 | | 3 | | 2 | | 4 | |
| 379 | | Important | 4 | | 2 | | 2 | | 3 | | 2 | | 4 | | 4 | | 3 | | 3 | | 2 | | 3 | | 4 | | 2 | | 3 | | 2 | |
| 389 | | Important | 0 | | 2 | | 4 | | 2 | | 2 | | 4 | | 3 | | 4 | | 3 | | 3 | | 3 | | 4 | | 4 | | 4 | | 4 | |
| 401 | | Important | 5 | | 4 | | 4 | | 3 | | 2 | | 4 | | 4 | | 2 | | 2 | | 4 | | 3 | | 3 | | 2 | | 3 | | 4 | |
| 428 | | Unsure | 3 | | 3 | | 3 | | 4 | | 3 | | 3 | | 2 | | 3 | | 2 | | 3 | | 3 | | 4 | | 3 | | 4 | | 4 | |
| 431 | | Important | 4 | | 4 | | 4 | | 3 | | 3 | | 3 | | 2 | | 2 | | 3 | | 3 | | 4 | | 3 | | 4 | | 3 | | 2 | |
| 444 | | Important | 4 | | 3 | | 2 | | 3 | | 2 | | 4 | | 2 | | 3 | | 2 | | 3 | | 3 | | 4 | | 2 | | 4 | | 4 | |
| 463 | | Unsure | 2 | | 2 | | 3 | | 2 | | 3 | | 2 | | 4 | | 4 | | 3 | | 3 | | 4 | | 2 | | 2 | | 4 | | 4 | |
| 471 | | Important | 2 | | 2 | | 3 | | 3 | | 3 | | 3 | | 2 | | 4 | | 2 | | 4 | | 4 | | 2 | | 3 | | 4 | | 2 | |
| 479 | | Important | 1 | | 2 | | 3 | | 3 | | 2 | | 4 | | 2 | | 4 | | 3 | | 3 | | 3 | | 2 | | 2 | | 4 | | 4 | |
| 499 | | Unsure | 3 | | 2 | | 4 | | 2 | | 3 | | 2 | | 2 | | 3 | | 3 | | 2 | | 3 | | 2 | | 2 | | 2 | | 4 | |
| 503 | | Important | 0 | | 2 | | 3 | | 3 | | 3 | | 2 | | 4 | | 2 | | 3 | | 3 | | 3 | | 2 | | 0 | | 0 | | 2 | |
| 458 | Unsure | Important | 3 | 4 | 3 | 2 | 4 | 4 | 3 | 2 | 2 | 2 | 2 | 4 | 3 | 4 | 2 | 3 | 2 | 4 | 3 | 3 | 4 | 3 | 3 | 2 | 4 | 3 | 2 | 4 | 2 | 2 |
| 52 | Important | Important | 2 | 3 | 3 | 3 | 4 | 3 | 2 | 2 | 2 | 3 | 4 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 3 | 2 | 4 | 3 | 4 | 2 | 4 | 4 | 3 |
| 169 | Unsure | Important | 5 | 2 | 3 | 2 | 4 | 2 | 2 | 2 | 4 | 2 | 4 | 4 | 2 | 1 | 2 | 1 | 4 | 1 | 2 | 3 | 4 | 0 | 3 | 4 | 3 | 2 | 2 | 2 | 3 | 4 |
| 214 | Unsure | Unsure | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 3 | 1 | 3 |
| 103 | Important | Important | 3 | 3 | 4 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 2 | 2 | 4 | 4 | 3 | 3 | 4 | 3 | 2 | 4 | 4 | 4 | 4 | 2 | 3 | 4 | 2 | 4 |
| 162 | Unsure | Important | 3 | 2 | 3 | 2 | 4 | 2 | 4 | 4 | 4 | 2 | 2 | 3 | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 2 | 3 | 3 | 4 | 2 | 4 | 2 | 4 | 4 | 3 | 2 |
| 176 | Importa | Importa | 3 | 4 | 2 | 2 | 4 | 3 | 4 | 4 | 3 | 2 | 3 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 4 | 4 | 2 | 3 | 2 | 4 | 2 | 3 | 4 | 3 | 4 | 2 |

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| 190 | Importa nt | Importa nt | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 2 | 1 | 4 | 0 | 2 | 2 | 3 | 3 | 2 | 1 | 3 | 2 | 3 | 2 |
| 195 | Unsure | Importa nt | 2 | 2 | 3 | 4 | 4 | 3 | 3 | 3 | 3 | 4 | 2 | 2 | 4 | 3 | 2 | 1 | 4 | 3 | 4 | 4 | 2 | 4 | 3 | 4 | 3 | 4 | 4 | 2 | 2 | 2 |
| 249 | Unsure | Importa nt | 3 | 4 | 4 | 2 | 3 | 4 | 4 | 2 | 4 | 4 | 2 | 2 | 3 | 4 | 2 | 1 | 4 | 2 | 2 | 2 | 3 | 2 | 4 | 3 | 4 | 2 | 2 | 2 | 5 | 4 |
| 335 | Importa nt | Importa nt | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 3 | 5 | 4 | 3 | 2 | 2 | 2 | 2 | 3 | 4 | 3 | 4 | 3 | 4 | 4 | 2 | 4 | 4 | 3 |
| 398 | Importa nt | Importa nt | 1 | 2 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 2 |
| 409 | Importa nt | Importa nt | 4 | 2 | 3 | 3 | 4 | 4 | 2 | 4 | 3 | 2 | 2 | 4 | 3 | 2 | 3 | 4 | 2 | 3 | 3 | 4 | 4 | 2 | 3 | 3 | 4 | 2 | 2 | 4 | 4 | 3 |
| 418 | | Unsure | 4 | | 2 | | 4 | | 2 | | 3 | | 2 | | 2 | | 2 | | 3 | | 2 | | 2 | | 2 | | 2 | | 3 | | 4 | |
| 480 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 488 | | Importa nt | 3 | | 3 | | 4 | | 2 | | 2 | | 4 | | 3 | | 3 | | 3 | | 3 | | 2 | | 4 | | 4 | | 4 | | 2 | |
| 36 | | Importa nt | 3 | | 0 | | 2 | | 4 | | 4 | | 4 | | 4 | | 3 | | 4 | | 3 | | 4 | | 2 | | 4 | | 2 | | 3 | |
| 71 | | Importa nt | 2 | | 2 | | 3 | | 2 | | 2 | | 3 | | 2 | | 2 | | 3 | | 4 | | 2 | | 4 | | 4 | | 2 | | 3 | |
| 86 | | Importa nt | 4 | | 2 | | 4 | | 3 | | 2 | | 4 | | 3 | | 2 | | 3 | | 3 | | 2 | | 2 | | 2 | | 2 | | 4 | |
| 145 | | Unsure | 2 | | 2 | | 3 | | 4 | | 2 | | 2 | | 2 | | 4 | | 3 | | 3 | | 3 | | 3 | | 3 | | 4 | | 2 | |
| 217 | | Unsure | 0 | | 2 | | 3 | | 4 | | 4 | | 4 | | 3 | | 3 | | 4 | | 4 | | 3 | | 4 | | 2 | | 4 | | 3 | |
| 326 | | Unsure | 2 | | 4 | | 3 | | 4 | | 4 | | 2 | | 4 | | 3 | | 4 | | 4 | | 2 | | 4 | | 4 | | 4 | | 2 | |
| 343 | | Importa nt | 4 | | 3 | | 0 | | 3 | | 3 | | 4 | | 3 | | 3 | | 2 | | 2 | | 2 | | 4 | | 4 | | 3 | | 2 | |
| 356 | | Importa nt | 3 | | 0 | | 1 | | 1 | | 1 | | 1 | | 1 | | 2 | | 2 | | 2 | | 1 | | 0 | | 0 | | 1 | | 1 | |
| 448 | | Importa nt | 4 | | 4 | | 3 | | 3 | | 3 | | 4 | | 4 | | 2 | | 3 | | 3 | | 4 | | 3 | | 4 | | 2 | | 3 | |
| 473 | | Importa nt | 2 | | 4 | | 3 | | 2 | | 4 | | 2 | | 4 | | 2 | | 2 | | 3 | | 4 | | 2 | | 4 | | 4 | | 2 | |

# APPENDIX E

Appendix E-1 Summary of the independent t-Tests carried out on the training and control groups annual vehicle-km

(A) Heavy Vehicle

| Group Statistics | | | | | |
|---|---|---|---|---|---|
| | Group | N | Mean | Std. Deviation | Std. Error Mean |
| VehKm_Aug2009_Jul2010_Heavy | Training | 34 | 16326.117 | 10144.350 | 1739.741 |
| | Control | 34 | 11657 | 9076.302 | 1556.573 |
| VehKm_Aug2010_Jul2011_ Heavy | Training | 34 | 19578.676 | 12595.893 | 2160.177 |
| | Control | 34 | 20725.617 | 18579.236 | 3186.312 |
| VehKm_Aug2011_Jul2012_ Heavy | Training | 34 | 19637.529 | 18493.467 | 3171.603 |
| | Control | 34 | 15619.470 | 13338.556 | 2287.543 |

| Independent Samples Test | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Levene's Test for Equality of Variances | | t-Test for Equality of Means | | | | | | |
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | | Lower | Upper |
| VehKm_Aug2009_Jul2010_ Heavy | **Equal variances assumed** | **0.282** | **0.597** | **2.000** | **66** | **0.050** | **4669.111** | **2334.442** | **8.253** | **9329.982** |
| | Equal variances not assumed | | | 2.000 | 65.200 | 0.050 | 4669.117 | 2334.442 | 7.184 | 9331.050 |
| VehKm_Aug2010_Jul2011_ Heavy | **Equal variances assumed** | **1.883** | **0.175** | **-0.298** | **66** | **0.767** | **-1146.941** | **3849.540** | **-8832.796** | **6538.913** |
| | Equal variances not assumed | | | -0.298 | 58 | 0.767 | -1146.941 | 3849.540 | -8852.507 | 6558.625 |
| VehKm_Aug2011_Jul2012_ Heavy | **Equal variances assumed** | **2.031** | **0.159** | **1.028** | **66** | **0.308** | **4018.059** | **3910.489** | **-3789.484** | **11825.602** |
| | Equal variances not assumed | | | 1.028 | 60 | 0.308 | 4018.059 | 3910.489 | -3804.026 | 11840.144 |

## (B) Medium Vehicle

| Group Statistics | | | | | |
|---|---|---|---|---|---|
| | Group | N | Mean | Std. Deviation | Std. Error Mean |
| VehKm_Aug2009_Jul2010_Medium | Training | 34 | 20708.176 | 14330.4924 | 2457.6591 |
| | Control | 34 | 18591.882 | 12768.2915 | 2189.7439 |
| VehKm_Aug2010_Jul2011_ Medium | Training | 34 | 24910.058 | 13586.1386 | 2330.0035 |
| | Control | 34 | 22094.764 | 7917.9216 | 1357.9123 |
| VehKm_Aug2011_Jul2012_ Medium | Training | 34 | 25070.853 | 14490.424 | 2485.087 |
| | Control | 34 | 23389.529 | 15563.050 | 2669.041 |

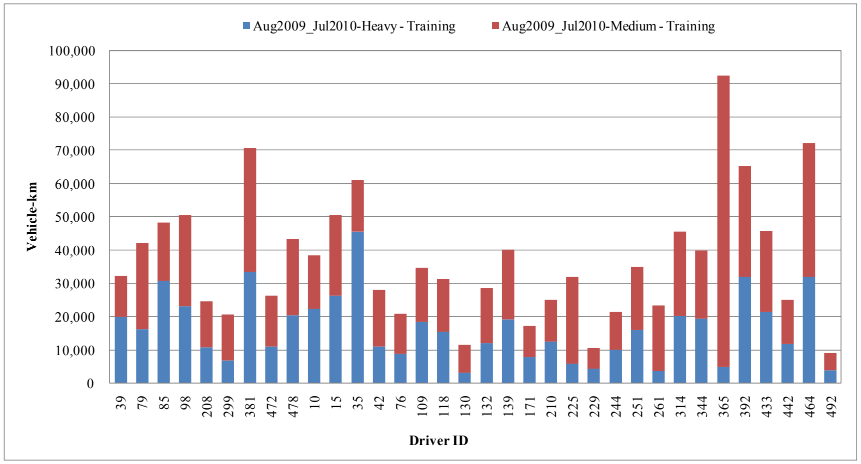
| Independent Samples Test | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Levene's Test for Equality of Variances | | t-Test for Equality of Means | | | | | | |
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | | Lower | Upper |
| VehKm_Aug2009_Jul2010_ Medium | **Equal variances assumed** | **0.000** | **0.988** | **0.643** | **66.000** | **0.523** | **2116.294** | **3291.666** | **-4455.730** | **8688.318** |
| | Equal variances not assumed | | | 0.643 | 65.140 | 0.523 | 2116.294 | 3291.666 | -4457.350 | 8689.938 |
| VehKm_Aug2010_Jul2011_ Medium | **Equal variances assumed** | **1.982** | **0.164** | **1.044** | **66.000** | **0.300** | **2815.294** | **2696.821** | **-2569.082** | **8199.671** |
| | Equal variances not assumed | | | 1.044 | 53.098 | 0.301 | 2815.294 | 2696.821 | -2593.610 | 8224.198 |
| VehKm_Aug2011_Jul2012_ Medium | **Equal variances assumed** | **0.016** | **0.899** | **0.461** | **66** | **0.646** | **1681.324** | **3646.840** | **-5599.827** | **8962.474** |
| | Equal variances not assumed | | | 0.461 | 65.666 | 0.646 | 1681.324 | 3646.840 | -5600.517 | 8963.164 |

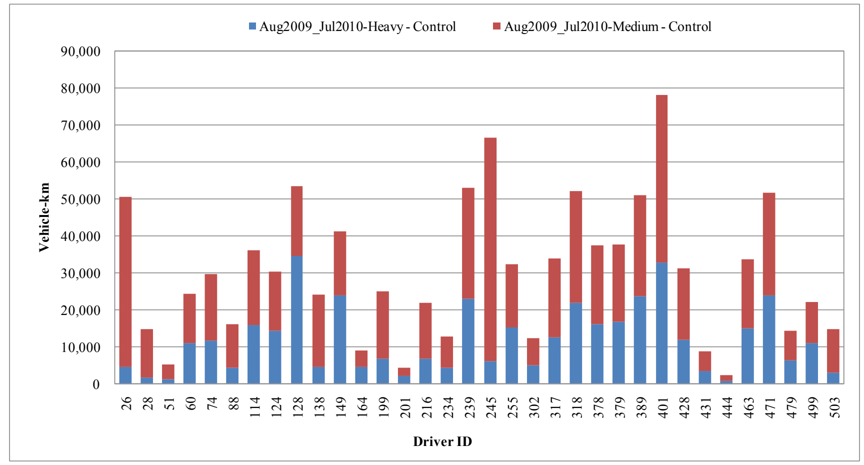
## (C) Light Vehicle

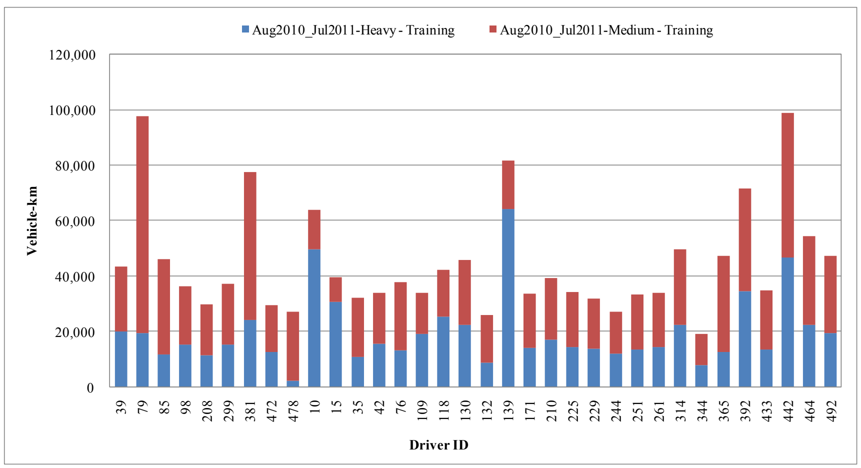
| Group Statistics | | | | | |
|---|---|---|---|---|---|
| | Group | N | Mean | Std. Deviation | Std. Error Mean |
| VehKm_Aug2009_Jul2010_Light | Training | 13 | 17518.307 | 14142.2891 | 3922.3652 |
| | Control | 13 | 17926.846 | 11443.8882 | 3173.9635 |
| VehKm_Aug2010_Jul2011_Light | Training | 13 | 22774.615 | 16194.7535 | 4491.6165 |
| | Control | 13 | 16996.538 | 11618.8110 | 3222.4783 |
| VehKm_Aug2011_Jul2012_Light | Training | 13 | 28975.384 | 26328.4622 | 7302.2016 |
| | Control | 13 | 21197.153 | 14362.4495 | 3983.4268 |

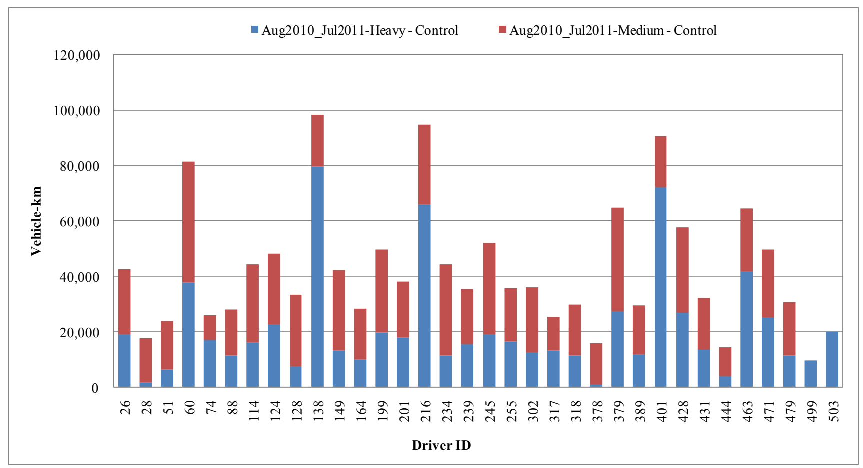
| Independent Samples Test | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Levene's Test for Equality of Variances | | t-Test for Equality of Means | | | | | | |
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | | Lower | Upper |
| VehKm_Aug2009_Jul2010_Light | **Equal variances assumed** | **0.132** | **0.719** | **-0.081** | **24.000** | **0.936** | **-408.538** | **5045.691** | **-10822.332** | **10005.255** |
| | Equal variances not assumed | | | -0.081 | 22.999 | 0.936 | -408.538 | 5045.691 | -10846.366 | 10029.289 |
| VehKm_Aug2010_Jul2011_Light | **Equal variances assumed** | **2.219** | **0.149** | **1.045** | **24.000** | **0.306** | **5778.077** | **5528.018** | **-5631.192** | **17187.346** |
| | Equal variances not assumed | | | 1.045 | 21.766 | 0.307 | 5778.077 | 5528.018 | -5693.482 | 17249.636 |
| VehKm_Aug2011_Jul2012_Light | **Equal variances assumed** | **3.249** | **0.084** | **0.935** | **24.000** | **0.359** | **7778.231** | **8318.043** | **-9389.366** | **24945.827** |
| | Equal variances not assumed | | | 0.935 | 18.561 | 0.362 | 7778.231 | 8318.043 | -9659.548 | 25216.010 |

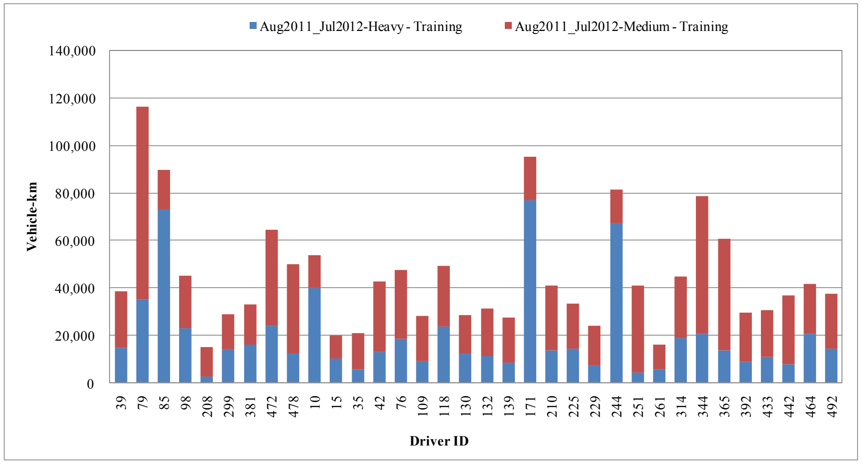
## Appendix E-2 Proportion of annual vehicle-km between heavy and medium vehicles for the multi-vehicle drivers (heavy/medium)

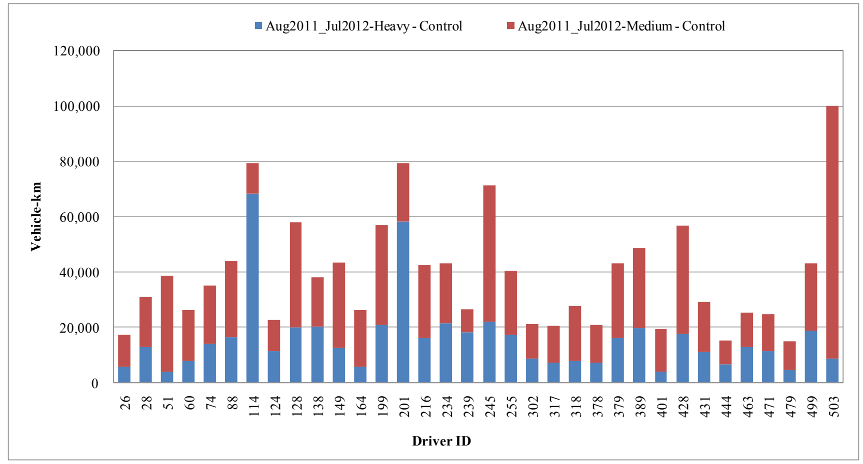



Aug2011_Jul2012-Heavy - Training
Aug2011_Jul2012-Medium - Training
Vehicle-km
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
39 79 85 98 208 299 381 472 478 10 15 35 42 76 109 118 130 132 139 171 210 225 229 244 251 261 314 344 365 392 433 442 464 492
Driver ID


Aug2011_Jul2012-Heavy - Control
Aug2011_Jul2012-Medium - Control
Vehicle-km
120,000
100,000
80,000
60,000
40,000
20,000
0
26 28 51 60 74 88 114 124 128 138 149 164 199 201 216 234 239 245 255 302 317 318 378 379 389 401 428 431 444 463 471 479 499 503
Driver ID

# Appendix E-3 Paired t-Test results regarding comparison of MPG before and after the large-scale training within the training group

## (A) Heavy Vehicle

**Paired Samples Statistics**

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | MPG_Before_Month1 | 8.39 | 18 | 1.62 | 0.38 |
| | MPG_After_Month1 | 9.05 | 18 | 1.30 | 0.31 |
| Pair 2 | MPG_Before_Month2 | 8.60 | 21 | 1.89 | 0.41 |
| | MPG_After_Month2 | 11.16 | 21 | 9.06 | 1.98 |
| Pair 3 | MPG_Before_Month3 | 8.22 | 23 | 1.36 | 0.28 |
| | MPG_After_Month3 | 10.42 | 23 | 8.39 | 1.75 |
| Pair 4 | MPG_Before_Month4 | 8.23 | 27 | 1.25 | 0.24 |
| | MPG_After_Month4 | 8.01 | 27 | 1.40 | 0.27 |
| Pair 5 | MPG_Before_Month5 | 8.03 | 28 | 1.35 | 0.26 |
| | MPG_After_Month5 | 9.77 | 28 | 7.73 | 1.46 |
| Pair 6 | MPG_Before_Month6 | 8.81 | 27 | 1.78 | 0.34 |
| | MPG_After_Month6 | 8.58 | 27 | 2.17 | 0.42 |
| Pair 7 | MPG_Before_Month7 | 8.77 | 25 | 2.20 | 0.44 |
| | MPG_After_Month7 | 8.43 | 25 | 2.28 | 0.46 |
| Pair 8 | MPG_Before_Month8 | 8.90 | 26 | 1.94 | 0.38 |
| | MPG_After_Month8 | 10.04 | 26 | 6.75 | 1.32 |

**Paired Samples Correlations**

| | | N | Correlation | Sig. |
|---|---|---|---|---|
| Pair 1 | MPG_Before_Month1 & MPG_After_Month1 | 18 | 0.52 | 0.03 |
| Pair 2 | MPG_Before_Month2 & MPG_After_Month2 | 21 | 0.08 | 0.74 |
| Pair 3 | MPG_Before_Month3 & MPG_After_Month3 | 23 | -0.22 | 0.30 |

| | | | | |
|---|---|---|---|---|
| Pair 4 | MPG_Before_Month4 & MPG_After_Month4 | 27 | 0.24 | 0.22 |
| Pair 5 | MPG_Before_Month5 & MPG_After_Month5 | 28 | 0.12 | 0.53 |
| Pair 6 | MPG_Before_Month6 & MPG_After_Month6 | 27 | 0.00 | 0.99 |
| Pair 7 | MPG_Before_Month7 & MPG_After_Month7 | 25 | 0.27 | 0.19 |
| Pair 8 | MPG_Before_Month8 & MPG_After_Month8 | 26 | 0.22 | 0.29 |

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | MPG_Before_Month1 & MPG_After_Month1 | -0.66 | 1.45 | 0.34 | -1.38 | 0.07 | -1.91 | 17 | 0.07 |
| Pair 2 | MPG_Before_Month2 & MPG_After_Month2 | -2.57 | 9.11 | 1.99 | -6.71 | 1.58 | -1.29 | 20 | 0.21 |
| Pair 3 | MPG_Before_Month3 & MPG_After_Month3 | -2.20 | 8.79 | 1.83 | -6.00 | 1.60 | -1.20 | 22 | 0.24 |
| Pair 4 | MPG_Before_Month4 & MPG_After_Month4 | 0.22 | 1.64 | 0.32 | -0.43 | 0.87 | 0.71 | 26 | 0.49 |
| Pair 5 | MPG_Before_Month5 & MPG_After_Month5 | -1.74 | 7.68 | 1.45 | -4.72 | 1.24 | -1.20 | 27 | 0.24 |
| Pair 6 | MPG_Before_Month6 & MPG_After_Month6 | 0.23 | 2.80 | 0.54 | -0.88 | 1.33 | 0.42 | 26 | 0.68 |
| Pair 7 | MPG_Before_Month7 & MPG_After_Month7 | 0.34 | 2.71 | 0.54 | -0.77 | 1.46 | 0.64 | 24 | 0.53 |
| Pair 8 | MPG_Before_Month8 & MPG_After_Month8 | -1.14 | 6.61 | 1.30 | -3.81 | 1.53 | -0.88 | 25 | 0.39 |

## (B) Medium Vehicle

| Paired Samples Statistics | | | | | |
|---|---|---|---|---|---|
| | | Mean | N | Std. Deviation | Std. Error Mean |
| Pair 1 | MPG_Before_Month1 | 17.28 | 24 | 3.07 | 0.63 |
| | MPG_After_Month1 | 18.80 | 24 | 2.95 | 0.60 |
| Pair 2 | MPG_Before_Month2 | 17.45 | 26 | 4.34 | 0.85 |
| | MPG_After_Month2 | 19.12 | 26 | 7.37 | 1.45 |
| Pair 3 | MPG_Before_Month3 | 17.49 | 26 | 3.85 | 0.76 |
| | MPG_After_Month3 | 19.09 | 26 | 6.58 | 1.29 |
| Pair 4 | MPG_Before_Month4 | 17.71 | 26 | 3.85 | 0.75 |
| | MPG_After_Month4 | 18.70 | 26 | 7.32 | 1.44 |
| Pair 5 | MPG_Before_Month5 | 17.62 | 25 | 3.09 | 0.62 |
| | MPG_After_Month5 | 19.28 | 25 | 6.55 | 1.31 |
| Pair 6 | MPG_Before_Month6 | 17.50 | 25 | 3.00 | 0.60 |
| | MPG_After_Month6 | 16.37 | 25 | 3.63 | 0.73 |
| Pair 7 | MPG_Before_Month7 | 16.85 | 21 | 2.81 | 0.61 |
| | MPG_After_Month7 | 17.41 | 21 | 2.27 | 0.50 |
| Pair 8 | MPG_Before_Month8 | 17.58 | 26 | 3.39 | 0.66 |
| | MPG_After_Month8 | 17.05 | 26 | 2.43 | 0.48 |

| Paired Samples Correlations | | | | |
|---|---|---|---|---|
| | | N | Correlation | Sig. |
| Pair 1 | MPG_Before_Month1 & MPG_After_Month1 | 24 | 0.50 | 0.01 |
| Pair 2 | MPG_Before_Month2 & MPG_After_Month2 | 26 | 0.17 | 0.40 |
| Pair 3 | MPG_Before_Month3 & MPG_After_Month3 | 26 | 0.38 | 0.06 |
| Pair 4 | MPG_Before_Month4 & MPG_After_Month4 | 26 | 0.03 | 0.90 |

| | | | | |
|---|---|---|---|---|
| Pair 5 | MPG_Before_Month5 & MPG_After_Month5 | 25 | 0.21 | 0.31 |
| Pair 6 | MPG_Before_Month6 & MPG_After_Month6 | 25 | 0.38 | 0.06 |
| Pair 7 | MPG_Before_Month7 & MPG_After_Month7 | 21 | 0.16 | 0.48 |
| Pair 8 | MPG_Before_Month8 & MPG_After_Month8 | 26 | 0.22 | 0.29 |

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | MPG_Before_Month1 & MPG_After_Month1 | -1.52 | 3.00 | 0.61 | -2.78 | -0.25 | -2.48 | 23 | 0.02 |
| Pair 2 | MPG_Before_Month2 & MPG_After_Month2 | -1.68 | 7.88 | 1.55 | -4.86 | 1.51 | -1.09 | 25 | 0.29 |
| Pair 3 | MPG_Before_Month3 & MPG_After_Month3 | -1.60 | 6.24 | 1.22 | -4.12 | 0.92 | -1.30 | 25 | 0.20 |
| Pair 4 | MPG_Before_Month4 & MPG_After_Month4 | -0.98 | 8.18 | 1.60 | -4.29 | 2.32 | -0.61 | 25 | 0.55 |
| Pair 5 | MPG_Before_Month5 & MPG_After_Month5 | -1.66 | 6.62 | 1.32 | -4.39 | 1.07 | -1.25 | 24 | 0.22 |
| Pair 6 | MPG_Before_Month6 & MPG_After_Month6 | 1.13 | 3.71 | 0.74 | -0.41 | 2.66 | 1.52 | 24 | 0.14 |
| Pair 7 | MPG_Before_Month7 & MPG_After_Month7 | -0.56 | 3.31 | 0.72 | -2.07 | 0.95 | -0.78 | 20 | 0.45 |
| Pair 8 | MPG_Before_Month8 & MPG_After_Month8 | 0.53 | 3.72 | 0.73 | -0.97 | 2.03 | 0.73 | 25 | 0.47 |

## (C) Light Vehicle

**Paired Samples Statistics**

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | MPG_Before_Month1 | 44.57 | 11 | 8.11 | 2.45 |
| | MPG_After_Month1 | 48.05 | 11 | 4.16 | 1.25 |
| Pair 2 | MPG_Before_Month2 | 43.94 | 11 | 7.31 | 2.20 |
| | MPG_After_Month2 | 45.80 | 11 | 6.24 | 1.88 |
| Pair 3 | MPG_Before_Month3 | 45.22 | 10 | 6.20 | 1.96 |
| | MPG_After_Month3 | 46.86 | 10 | 3.70 | 1.17 |
| Pair 4 | MPG_Before_Month4 | 45.76 | 11 | 4.26 | 1.29 |
| | MPG_After_Month4 | 46.50 | 11 | 5.10 | 1.54 |
| Pair 5 | MPG_Before_Month5 | 45.62 | 9 | 5.91 | 1.97 |
| | MPG_After_Month5 | 46.67 | 9 | 3.83 | 1.28 |
| Pair 6 | MPG_Before_Month6 | 47.33 | 8 | 4.10 | 1.45 |
| | MPG_After_Month6 | 47.01 | 8 | 3.27 | 1.16 |
| Pair 7 | MPG_Before_Month7 | 45.36 | 7 | 5.97 | 2.26 |
| | MPG_After_Month7 | 44.74 | 7 | 2.80 | 1.06 |
| Pair 8 | MPG_Before_Month8 | 48.90 | 7 | 4.71 | 1.78 |
| | MPG_After_Month8 | 45.71 | 7 | 3.63 | 1.37 |

**Paired Samples Correlations**

| | | N | Correlation | Sig. |
|---|---|---|---|---|
| Pair 1 | MPG_Before_Month1 & MPG_After_Month1 | 11 | 0.60 | 0.05 |
| Pair 2 | MPG_Before_Month2 & MPG_After_Month2 | 11 | 0.77 | 0.01 |
| Pair 3 | MPG_Before_Month3 & MPG_After_Month3 | 10 | 0.61 | 0.06 |
| Pair 4 | MPG_Before_Month4 & MPG_After_Month4 | 11 | 0.34 | 0.31 |
| Pair 5 | MPG_Before_Month5 & MPG_After_Month5 | 9 | 0.02 | 0.96 |

| | | | | |
|---|---|---|---|---|
| Pair 6 | MPG_Before_Month6 & MPG_After_Month6 | 8 | 0.69 | 0.06 |
| Pair 7 | MPG_Before_Month7 & MPG_After_Month7 | 7 | 0.29 | 0.54 |
| Pair 8 | MPG_Before_Month8 & MPG_After_Month8 | 7 | 0.19 | 0.69 |

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | MPG_Before_Month1 & MPG_After_Month1 | -3.47 | 6.51 | 1.96 | -7.84 | 0.90 | -1.77 | 10 | 0.11 |
| Pair 2 | MPG_Before_Month2 & MPG_After_Month2 | -1.86 | 4.75 | 1.43 | -5.05 | 1.33 | -1.30 | 10 | 0.22 |
| Pair 3 | MPG_Before_Month3 & MPG_After_Month3 | -1.64 | 4.89 | 1.55 | -5.14 | 1.86 | -1.06 | 9 | 0.32 |
| Pair 4 | MPG_Before_Month4 & MPG_After_Month4 | -0.74 | 5.43 | 1.64 | -4.39 | 2.91 | -0.45 | 10 | 0.66 |
| Pair 5 | MPG_Before_Month5 & MPG_After_Month5 | -1.04 | 6.98 | 2.33 | -6.41 | 4.32 | -0.45 | 8 | 0.67 |
| Pair 6 | MPG_Before_Month6 & MPG_After_Month6 | 0.31 | 3.01 | 1.07 | -2.21 | 2.83 | 0.29 | 7 | 0.78 |
| Pair 7 | MPG_Before_Month7 & MPG_After_Month7 | 0.61 | 5.83 | 2.20 | -4.78 | 6.01 | 0.28 | 6 | 0.79 |
| Pair 8 | MPG_Before_Month8 & MPG_After_Month8 | 3.19 | 5.39 | 2.04 | -1.80 | 8.17 | 1.56 | 6 | 0.17 |

Appendix E-4 Statistics for the comparison ranks for the Mann-Whitney and Wilcoxon signed-rank tests applied to heavy/medium and light vehicle drivers

## (A) Summary of Mann-Whitney test

### (A-1) Heavy/Medium Vehicle – ranks before the training

| Attribute | Group | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| Do you sometimes fail to drive cautiously? | Training | 34 | 34.75 | 1181.5 |
| | Control | 34 | 34.25 | 1164.5 |
| | Total | 68 | | |
| Do you dislike people who give you advice about you driving? | Training | 34 | 34.35 | 1168 |
| | Control | 34 | 34.65 | 1178 |
| | Total | 68 | | |
| Do you sometimes drive when feeling tired? | Training | 34 | 33.43 | 1136.5 |
| | Control | 34 | 35.57 | 1209.5 |
| | Total | 68 | | |
| How often do you forget to check your vehicle tyre pressure? | Training | 34 | 36.38 | 1237 |
| | Control | 34 | 32.62 | 1109 |
| | Total | 68 | | |
| Do you drive fast? | Training | 34 | 34.79 | 1183 |
| | Control | 34 | 34.21 | 1163 |
| | Total | 68 | | |
| Do you sometimes fail to apply smooth braking? | Training | 34 | 36.65 | 1246 |
| | Control | 34 | 32.35 | 1100 |
| | Total | 68 | | |
| Do you sometimes forget to use block gear changes for example 1-3-5 0r 2-4-6? | Training | 34 | 31.78 | 1080.5 |
| | Control | 34 | 37.22 | 1265.5 |
| | Total | 68 | | |

| | | | | |
|---|---|---|---|---|
| Do you sometimes use the clutch control to balance the car whilst stationary? | Training | 34 | 31.59 | 1074 |
| | Control | 34 | 37.41 | 1272 |
| | Total | 68 | | |
| Do you sometimes forget to plan ahead? | Training | 34 | 35.46 | 1205.5 |
| | Control | 34 | 33.54 | 1140.5 |
| | Total | 68 | | |
| Do leave the vehicle engine on when it is not needed? | Training | 34 | 35.85 | 1219 |
| | Control | 34 | 33.15 | 1127 |
| | Total | 68 | | |
| Do you sometimes forget to plan your journey? | Training | 34 | 31.63 | 1075.5 |
| | Control | 34 | 37.37 | 1270.5 |
| | Total | 68 | | |
| Do you sometime forget to plan about loading the vehicle? | Training | 34 | 34.16 | 1161.50 |
| | Control | 34 | 34.84 | 1184.50 |
| | Total | 68 | | |
| Do you forget to carry out necessary aerodynamic adjustments if available to reduce drag? | Training | 34 | 35.6 | 1210.5 |
| | Control | 34 | 33.4 | 1135.5 |
| | Total | 68 | | |
| Have you ever doubted the benefits fuel efficient driving like fuel economy and safety? | Training | 34 | 36.37 | 1236.5 |
| | Control | 34 | 32.63 | 1109.5 |
| | Total | 68 | | |
| Do you sometimes fail to get the support you need regarding fuel efficient driving? | Training | 34 | 35.34 | 1201.5 |
| | Control | 34 | 33.66 | 1144.5 |
| | Total | 68 | | |

## (A-2) Heavy/Medium Vehicle – ranks after the training

| Attribute | Group | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| Do you sometimes fail to drive cautiously? | Training | 34 | 29.97 | 1019.00 |
| | Control | 34 | 39.03 | 1327.00 |
| | Total | 68 | | |
| Do you dislike people who give you advice about you driving? | Training | 34 | 32.37 | 1100.50 |
| | Control | 34 | 36.63 | 1245.50 |
| | Total | 68 | | |
| Do you sometimes drive when feeling tired? | Training | 34 | 31.62 | 1075.00 |
| | Control | 34 | 37.38 | 1271.00 |
| | Total | 68 | | |
| How often do you forget to check your vehicle tyre pressure? | Training | 34 | 35.62 | 1211.00 |
| | Control | 34 | 33.38 | 1135.00 |
| | Total | 68 | | |
| Do you drive fast? | Training | 34 | 34.44 | 1171.00 |
| | Control | 34 | 34.56 | 1175.00 |
| | Total | 68 | | |
| Do you sometimes fail to apply smooth braking? | Training | 34 | 32.50 | 1105.00 |
| | Control | 34 | 36.50 | 1241.00 |
| | Total | 68 | | |
| Do you sometimes forget to use block gear changes for example 1-3-5 0r 2-4-6? | Training | 34 | 31.50 | 1071.00 |
| | Control | 34 | 37.50 | 1275.00 |
| | Total | 68 | | |
| Do you sometimes use the clutch control to balance the car whilst stationary? | Training | 34 | 28.25 | 960.50 |
| | Control | 34 | 40.75 | 1385.50 |
| | Total | 68 | | |
| Do you sometimes forget to plan ahead? | Training | 34 | 30.75 | 1045.50 |
| | Control | 34 | 38.25 | 1300.50 |
| | Total | 68 | | |
| Do leave the vehicle engine on when it is not needed? | Training | 34 | 33.25 | 1130.50 |
| | Control | 34 | 35.75 | 1215.50 |

| | | | | |
|---|---|---|---|---|
| | Total | 68 | | |
| Do you sometimes forget to plan your journey? | Training | 34 | 31.12 | 1058.00 |
| | Control | 34 | 37.88 | 1288.00 |
| | Total | 68 | | |
| Do you sometime forget to plan about loading the vehicle? | Training | 34 | 26.13 | 888.50 |
| | Control | 34 | 42.87 | 1457.50 |
| | Total | 68 | | |
| Do you forget to carry out necessary aerodynamic adjustments if available to reduce drag? | Training | 34 | 32.69 | 1111.50 |
| | Control | 34 | 36.31 | 1234.50 |
| | Total | 68 | | |
| Have you ever doubted the benefits fuel efficient driving like fuel economy and safety? | Training | 34 | 35.59 | 1210.00 |
| | Control | 34 | 33.41 | 1136.00 |
| | Total | 68 | | |
| Do you sometimes fail to get the support you need regarding fuel efficient driving? | Training | 34 | 34.25 | 1164.50 |
| | Control | 34 | 34.75 | 1181.50 |
| | Total | 68 | | |

## (A-3) Light Vehicle – ranks before the training

| Attribute | Group | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| Do you sometimes fail to drive cautiously? | Training | 13 | 12.62 | 164 |
| | Control | 12 | 13.42 | 161 |
| | Total | 25 | | |
| Do you dislike people who give you advice about you driving? | Training | 13 | 13.65 | 177.5 |
| | Control | 12 | 12.29 | 147.5 |
| | Total | 25 | | |
| Do you sometimes drive when feeling tired? | Training | 13 | 14.73 | 191.5 |
| | Control | 12 | 11.12 | 133.5 |
| | Total | 25 | | |
| How often do you forget to check your vehicle tyre pressure? | Training | 13 | 12.58 | 163.5 |

| | | | | |
|---|---|---|---|---|
| | Control | 12 | 13.46 | 161.5 |
| | Total | 25 | | |
| Do you drive fast? | Training | 13 | 13.04 | 169.5 |
| | Control | 12 | 12.96 | 155.5 |
| | Total | 25 | | |
| Do you sometimes fail to apply smooth braking? | Training | 13 | 11.46 | 149 |
| | Control | 12 | 14.67 | 176 |
| | Total | 25 | | |
| Do you sometimes forget to use block gear changes for example 1-3-5 0r 2-4-6? | Training | 13 | 12.27 | 159.5 |
| | Control | 12 | 13.79 | 165.5 |
| | Total | 25 | | |
| Do you sometimes use the clutch control to balance the car whilst stationary? | Training | 13 | 12.54 | 163 |
| | Control | 12 | 13.5 | 162 |
| | Total | 25 | | |
| Do you sometimes forget to plan ahead? | Training | 13 | 12.19 | 158.5 |
| | Control | 12 | 13.88 | 166.5 |
| | Total | 25 | | |
| Do leave the vehicle engine on when it is not needed? | Training | 13 | 12.77 | 166 |
| | Control | 12 | 13.25 | 159 |
| | Total | 25 | | |
| Do you sometimes forget to plan your journey? | Training | 13 | 13.85 | 180 |
| | Control | 12 | 12.08 | 145 |
| | Total | 25 | | |
| Do you sometime forget to plan about loading the vehicle? | Training | 13 | 13.15 | 171 |
| | Control | 12 | 12.83 | 154 |
| | Total | 25 | | |
| Do you forget to carry out necessary aerodynamic adjustments if available to reduce drag? | Training | 13 | 12.62 | 164 |
| | Control | 12 | 13.42 | 161 |
| | Total | 25 | | |
| Have you ever doubted the benefits fuel efficient driving like fuel economy and safety? | Training | 13 | 11.58 | 150.5 |
| | Control | 12 | 14.54 | 174.5 |
| | Total | 25 | | |

| | | | | |
|---|---|---|---|---|
| Do you sometimes fail to get the support you need regarding fuel efficient driving? | Training | 13 | 14.04 | 182.5 |
| | Control | 12 | 11.88 | 142.5 |
| | Total | 25 | | |

## (A-4) Light Vehicle – ranks after the training

| Attribute | Group | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| Do you sometimes fail to drive cautiously? | Training | 13 | 12.23 | 159.00 |
| | Control | 12 | 13.83 | 166.00 |
| | Total | 25 | | |
| Do you dislike people who give you advice about you driving? | Training | 13 | 12.31 | 160.00 |
| | Control | 12 | 13.75 | 165.00 |
| | Total | 25 | | |
| Do you sometimes drive when feeling tired? | Training | 13 | 12.81 | 166.50 |
| | Control | 12 | 13.21 | 158.50 |
| | Total | 25 | | |
| How often do you forget to check your vehicle tyre pressure? | Training | 13 | 12.04 | 156.50 |
| | Control | 12 | 14.04 | 168.50 |
| | Total | 25 | | |
| Do you drive fast? | Training | 13 | 11.73 | 152.50 |
| | Control | 12 | 14.38 | 172.50 |
| | Total | 25 | | |
| Do you sometimes fail to apply smooth braking? | Training | 13 | 12.04 | 156.50 |
| | Control | 12 | 14.04 | 168.50 |
| | Total | 25 | | |
| Do you sometimes forget to use block gear changes for example 1-3-5 0r 2-4-6? | Training | 13 | 11.96 | 155.50 |
| | Control | 12 | 14.12 | 169.50 |
| | Total | 25 | | |
| Do you sometimes use the clutch control to balance the car whilst stationary? | Training | 13 | 12.08 | 157.00 |
| | Control | 12 | 14.00 | 168.00 |

| | | | | |
|---|---|---|---|---|
| | Total | 25 | | |
| Do you sometimes forget to plan ahead? | Training | 13 | 11.15 | 145.00 |
| | Control | 12 | 15.00 | 180.00 |
| | Total | 25 | | |
| Do leave the vehicle engine on when it is not needed? | Training | 13 | 12.31 | 160.00 |
| | Control | 12 | 13.75 | 165.00 |
| | Total | 25 | | |
| Do you sometimes forget to plan your journey? | Training | 13 | 13.54 | 176.00 |
| | Control | 12 | 12.42 | 149.00 |
| | Total | 25 | | |
| Do you sometime forget to plan about loading the vehicle? | Training | 13 | 13.65 | 177.50 |
| | Control | 12 | 12.29 | 147.50 |
| | Total | 25 | | |
| Do you forget to carry out necessary aerodynamic adjustments if available to reduce drag? | Training | 13 | 10.85 | 141.00 |
| | Control | 12 | 15.33 | 184.00 |
| | Total | 25 | | |
| Have you ever doubted the benefits fuel efficient driving like fuel economy and safety? | Training | 13 | 13.27 | 172.50 |
| | Control | 12 | 12.71 | 152.50 |
| | Total | 25 | | |
| Do you sometimes fail to get the support you need regarding fuel efficient driving? | Training | 13 | 13.62 | 177.00 |
| | Control | 12 | 12.33 | 148.00 |
| | Total | 25 | | |

# (B) Summary of Wilcoxon Signed Rank test

## (B-1) Heavy/Medium Vehicle -ranks

| Comparison of the Attribute Score Before and After the Training | Ranks Details | Ranks Statistics | | |
|---|---|---|---|---|
| | | N | Mean Rank | Sum of Ranks |
| After1 - Before1 | Negative Ranks | 17a | 12.09 | 205.5 |
| | Positive Ranks | 5b | 9.5 | 47.5 |
| | Ties | 12c | | |
| | Total | 34 | | |
| After2 - Before2 | Negative Ranks | 14a | 14.46 | 202.5 |
| | Positive Ranks | 11b | 11.14 | 122.5 |
| | Ties | 9c | | |
| | Total | 34 | | |
| After3 - Before3 | Negative Ranks | 17a | 13.97 | 237.5 |
| | Positive Ranks | 10b | 14.05 | 140.5 |
| | Ties | 7c | | |
| | Total | 34 | | |
| After4 - Before4 | Negative Ranks | 9a | 8.89 | 80 |
| | Positive Ranks | 7b | 8 | 56 |
| | Ties | 18c | | |
| | Total | 34 | | |
| After5 - Before5 | Negative Ranks | 12a | 11.38 | 136.5 |
| | Positive Ranks | 10b | 11.65 | 116.5 |
| | Ties | 12c | | |
| | Total | 34 | | |
| After6 - Before6 | Negative Ranks | 16a | 12.19 | 195 |
| | Positive Ranks | 6b | 9.67 | 58 |
| | Ties | 12c | | |
| | Total | 34 | | |
| After7 - Before7 | Negative Ranks | 12a | 11.75 | 141 |
| | Positive Ranks | 12b | 13.25 | 159 |
| | Ties | 10c | | |
| | Total | 34 | | |
| After8 - Before8 | Negative Ranks | 17a | 11.18 | 190 |
| | Positive Ranks | 6b | 14.33 | 86 |

| | | | | |
|---|---|---|---|---|
| | Ties | 11c | | |
| | Total | 34 | | |
| After9 - Before9 | Negative Ranks | 17a | 12.12 | 206 |
| | Positive Ranks | 5b | 9.4 | 47 |
| | Ties | 12c | | |
| | Total | 34 | | |
| After10 - Before10 | Negative Ranks | 13a | 11.54 | 150 |
| | Positive Ranks | 8b | 10.12 | 81 |
| | Ties | 13c | | |
| | Total | 34 | | |
| After11 - Before11 | Negative Ranks | 9a | 10.72 | 96.5 |
| | Positive Ranks | 9b | 8.28 | 74.5 |
| | Ties | 16c | | |
| | Total | 34 | | |
| After12 - Before12 | Negative Ranks | 24a | 14.625 | 351 |
| | Positive Ranks | 3b | 9 | 27 |
| | Ties | 7c | | |
| | Total | 34 | | |
| After13 - Before13 | Negative Ranks | 17a | 13 | 221 |
| | Positive Ranks | 8b | 13 | 104 |
| | Ties | 9c | | |
| | Total | 34 | | |
| After14 - Before14 | Negative Ranks | 13a | 9.96 | 129.5 |
| | Positive Ranks | 8b | 12.69 | 101.5 |
| | Ties | 13c | | |
| | Total | 34 | | |
| After15 - Before15 | Negative Ranks | 10a | 13.35 | 133.5 |
| | Positive Ranks | 11b | 8.86 | 97.5 |
| | Ties | 13c | | |
| | Total | 34 | | |
| a. After2 < Before2 | | | | |
| b. After2 > Before2 | | | | |
| c. After2 = Before2 | | | | |

## (B-2) Light Vehicle - ranks

| Comparison of the Attribute Score Before and After the Training | Ranks Details | Ranks Statistics | | |
|---|---|---|---|---|
| | | N | Mean Rank | Sum of Ranks |
| After1 - Before1 | Negative Ranks | 4a | 7 | 28 |
| | Positive Ranks | 6b | 4.5 | 27 |
| | Ties | 3c | | |
| | Total | 13 | | |
| After2 - Before2 | Negative Ranks | 5a | 4.4 | 22 |
| | Positive Ranks | 2b | 3 | 6 |
| | Ties | 6c | | |
| | Total | 13 | | |
| After3 - Before3 | Negative Ranks | 6a | 4.83 | 29 |
| | Positive Ranks | 2b | 3.5 | 7 |
| | Ties | 5c | | |
| | Total | 13 | | |
| After4 - Before4 | Negative Ranks | 3a | 2.17 | 6.5 |
| | Positive Ranks | 1b | 3.5 | 3.5 |
| | Ties | 9c | | |
| | Total | 13 | | |
| After5 - Before5 | Negative Ranks | 6a | 5.75 | 34.5 |
| | Positive Ranks | 3b | 3.5 | 10.5 |
| | Ties | 4c | | |
| | Total | 13 | | |
| After6 - Before6 | Negative Ranks | 4a | 4 | 16 |
| | Positive Ranks | 4b | 5 | 20 |
| | Ties | 5c | | |
| | Total | 13 | | |
| After7 - Before7 | Negative Ranks | 5a | 4 | 20 |
| | Positive Ranks | 2b | 4 | 8 |
| | Ties | 6c | | |
| | Total | 13 | | |
| After8 - Before8 | Negative Ranks | 6a | 5.83 | 35 |
| | Positive Ranks | 4b | 5 | 20 |
| | Ties | 3c | | |
| | Total | 13 | | |

| | | | | |
|---|---|---|---|---|
| After9 - Before9 | Negative Ranks | 6a | 5.08 | 30.5 |
| | Positive Ranks | 3b | 4.83 | 14.5 |
| | Ties | 4c | | |
| | Total | 13 | | |
| After10 - Before10 | Negative Ranks | 4a | 5.5 | 22 |
| | Positive Ranks | 4b | 3.5 | 14 |
| | Ties | 5c | | |
| | Total | 13 | | |
| After11 - Before11 | Negative Ranks | 6a | 6 | 36 |
| | Positive Ranks | 5b | 6 | 30 |
| | Ties | 2c | | |
| | Total | 13 | | |
| After12 - Before12 | Negative Ranks | 4a | 4.62 | 18.5 |
| | Positive Ranks | 5b | 5.3 | 26.5 |
| | Ties | 4c | | |
| | Total | 13 | | |
| After13 - Before13 | Negative Ranks | 8a | 6.75 | 54 |
| | Positive Ranks | 3b | 4 | 12 |
| | Ties | 2c | | |
| | Total | 13 | | |
| After14 - Before14 | Negative Ranks | 3a | 3.5 | 10.5 |
| | Positive Ranks | 6b | 5.75 | 34.5 |
| | Ties | 4c | | |
| | Total | 13 | | |
| After15 - Before15 | Negative Ranks | 7a | 5.29 | 37 |
| | Positive Ranks | 4b | 7.25 | 29 |
| | Ties | 2c | | |
| | Total | 13 | | |
| a. After2 < Before2 | | | | |
| b. After2 > Before2 | | | | |
| c. After2 = Before2 | | | | |

## Appendix E-5 Independent t-Test results regarding comparison of MPG before and after the large-scale training

### (A) Heavy Vehicle

| Period | Levene's Test for Equality of Variances | | | t-Test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Assumption | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | | Lower | Upper |
| MPG Befor Month1 | Equal variances assumed | 0.00 | 0.97 | 0.00 | 45.00 | 1.00 | 0.00 | 0.47 | -0.94 | 0.94 |
| | Equal variances not assumed | | | 0.00 | 44.43 | 1.00 | 0.00 | 0.47 | -0.94 | 0.94 |
| MPG Befor Month2 | Equal variances assumed | 0.02 | 0.88 | 0.32 | 54.00 | 0.75 | 0.16 | 0.51 | -0.86 | 1.18 |
| | Equal variances not assumed | | | 0.32 | 53.14 | 0.75 | 0.16 | 0.51 | -0.86 | 1.18 |
| MPG Befor Month3 | Equal variances assumed | 4.13 | 0.05 | -0.05 | 56.00 | 0.96 | -0.03 | 0.50 | -1.03 | 0.98 |
| | Equal variances not assumed | | | -0.05 | 55.51 | 0.96 | -0.03 | 0.49 | -1.00 | 0.95 |
| MPG Befor Month4 | Equal variances assumed | 0.34 | 0.56 | -0.26 | 57.00 | 0.80 | -0.09 | 0.36 | -0.81 | 0.62 |
| | Equal variances not assumed | | | -0.26 | 54.84 | 0.80 | -0.09 | 0.36 | -0.81 | 0.63 |
| MPG Befor Month5 | Equal variances assumed | 0.11 | 0.74 | 0.33 | 61.00 | 0.75 | 0.13 | 0.40 | -0.66 | 0.92 |
| | Equal variances not assumed | | | 0.33 | 58.98 | 0.75 | 0.13 | 0.40 | -0.67 | 0.93 |
| MPG Befor Month6 | Equal variances assumed | 0.78 | 0.38 | 0.80 | 60.00 | 0.43 | 0.38 | 0.47 | -0.57 | 1.33 |
| | Equal variances not assumed | | | 0.80 | 57.72 | 0.43 | 0.38 | 0.48 | -0.57 | 1.33 |
| MPG Befor Month7 | Equal variances assumed | 0.00 | 0.96 | 0.03 | 60.00 | 0.98 | 0.01 | 0.54 | -1.07 | 1.10 |
| | Equal variances not assumed | | | 0.03 | 59.90 | 0.98 | 0.01 | 0.54 | -1.07 | 1.10 |
| MPG Befor Month8 | Equal variances assumed | 0.21 | 0.65 | 0.88 | 57.00 | 0.38 | 0.45 | 0.51 | -0.57 | 1.47 |
| | Equal variances not assumed | | | 0.88 | 56.08 | 0.38 | 0.45 | 0.51 | -0.57 | 1.47 |
| MPG After | Equal variances assumed | 1.18 | 0.28 | 1.49 | 48.00 | 0.14 | 1.07 | 0.72 | -0.37 | 2.52 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month1 | Equal variances not assumed | | | 1.49 | 34.43 | 0.14 | 1.07 | 0.72 | -0.39 | 2.53 |
| MPG After Month2 | Equal variances assumed | 1.33 | 0.25 | 1.33 | 51.00 | 0.19 | 2.13 | 1.61 | -1.10 | 5.36 |
| | Equal variances not assumed | | | 1.40 | 29.53 | 0.17 | 2.13 | 1.53 | -0.98 | 5.25 |
| MPG After Month3 | Equal variances assumed | 0.90 | 0.35 | 1.11 | 56.00 | 0.27 | 1.60 | 1.44 | -1.30 | 4.49 |
| | Equal variances not assumed | | | 1.14 | 33.97 | 0.26 | 1.60 | 1.40 | -1.25 | 4.44 |
| MPG After Month4 | Equal variances assumed | 1.57 | 0.22 | 0.88 | 57.00 | 0.38 | 1.31 | 1.48 | -1.66 | 4.27 |
| | Equal variances not assumed | | | 0.93 | 32.82 | 0.36 | 1.31 | 1.41 | -1.57 | 4.18 |
| MPG After Month5 | Equal variances assumed | 2.05 | 0.16 | 1.02 | 53.00 | 0.31 | 1.55 | 1.51 | -1.49 | 4.58 |
| | Equal variances not assumed | | | 1.08 | 30.18 | 0.29 | 1.55 | 1.44 | -1.39 | 4.48 |
| MPG After Month6 | Equal variances assumed | 3.03 | 0.09 | 0.74 | 53.00 | 0.46 | 0.37 | 0.50 | -0.63 | 1.37 |
| | Equal variances not assumed | | | 0.76 | 50.84 | 0.45 | 0.37 | 0.49 | -0.61 | 1.35 |
| MPG After Month7 | Equal variances assumed | 0.19 | 0.66 | -0.23 | 52.00 | 0.82 | -0.16 | 0.69 | -1.54 | 1.23 |
| | Equal variances not assumed | | | -0.22 | 49.60 | 0.82 | -0.16 | 0.69 | -1.55 | 1.24 |
| MPG After Month8 | Equal variances assumed | 1.62 | 0.21 | 0.71 | 60.00 | 0.48 | 1.27 | 1.80 | -2.33 | 4.87 |
| | Equal variances not assumed | | | 0.74 | 44.64 | 0.46 | 1.27 | 1.72 | -2.19 | 4.74 |

## (B) Medium Vehicle

| Period | Levene's Test for Equality of Variances | | | t-Test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Assumption | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | | Lower | Upper |
| MPG Befor Month1 | Equal variances assumed | 5.89 | 0.02 | 0.15 | 52.00 | 0.88 | 0.15 | 0.98 | -1.82 | 2.12 |
| | Equal variances not assumed | | | 0.15 | 45.96 | 0.88 | 0.15 | 0.99 | -1.85 | 2.15 |
| MPG Befor | Equal variances assumed | 3.59 | 0.06 | 0.09 | 55.00 | 0.93 | 0.08 | 1.00 | -1.92 | 2.09 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month2 | Equal variances not assumed | | | 0.09 | 48.35 | 0.93 | 0.08 | 0.99 | -1.91 | 2.08 |
| MPG Befor Month3 | Equal variances assumed | 1.91 | 0.17 | -0.02 | 52.00 | 0.99 | -0.02 | 0.99 | -2.01 | 1.97 |
| | Equal variances not assumed | | | -0.02 | 50.84 | 0.99 | -0.02 | 0.99 | -2.01 | 1.97 |
| MPG Befor Month4 | Equal variances assumed | 2.92 | 0.09 | 0.13 | 57.00 | 0.89 | 0.12 | 0.88 | -1.65 | 1.89 |
| | Equal variances not assumed | | | 0.13 | 49.86 | 0.90 | 0.12 | 0.90 | -1.68 | 1.92 |
| MPG Befor Month5 | Equal variances assumed | 1.52 | 0.22 | 0.21 | 50.00 | 0.84 | 0.19 | 0.94 | -1.69 | 2.08 |
| | Equal variances not assumed | | | 0.21 | 46.00 | 0.84 | 0.19 | 0.95 | -1.71 | 2.10 |
| MPG Befor Month6 | Equal variances assumed | 0.85 | 0.36 | -0.08 | 54.00 | 0.93 | -0.07 | 0.88 | -1.84 | 1.69 |
| | Equal variances not assumed | | | -0.08 | 53.93 | 0.93 | -0.07 | 0.88 | -1.83 | 1.69 |
| MPG Befor Month7 | Equal variances assumed | 0.14 | 0.71 | -0.23 | 51.00 | 0.82 | -0.22 | 0.97 | -2.18 | 1.73 |
| | Equal variances not assumed | | | -0.23 | 50.98 | 0.82 | -0.22 | 0.97 | -2.16 | 1.72 |
| MPG Befor Month8 | Equal variances assumed | 0.50 | 0.48 | 0.33 | 54.00 | 0.74 | 0.27 | 0.81 | -1.36 | 1.90 |
| | Equal variances not assumed | | | 0.34 | 53.64 | 0.74 | 0.27 | 0.80 | -1.34 | 1.88 |
| MPG After Month1 | Equal variances assumed | 0.08 | 0.78 | 1.85 | 56.00 | 0.07 | 1.39 | 0.75 | -0.11 | 2.89 |
| | Equal variances not assumed | | | 1.86 | 55.86 | 0.07 | 1.39 | 0.75 | -0.11 | 2.89 |
| MPG After Month2 | Equal variances assumed | 2.48 | 0.12 | 1.00 | 55.00 | 0.32 | 1.41 | 1.42 | -1.43 | 4.24 |
| | Equal variances not assumed | | | 1.06 | 40.49 | 0.30 | 1.41 | 1.33 | -1.27 | 4.09 |
| MPG After Month3 | Equal variances assumed | 0.80 | 0.37 | 1.28 | 56.00 | 0.21 | 1.67 | 1.31 | -0.95 | 4.29 |
| | Equal variances not assumed | | | 1.37 | 46.36 | 0.18 | 1.67 | 1.23 | -0.79 | 4.14 |
| MPG After Month4 | Equal variances assumed | 2.07 | 0.16 | 1.11 | 59.00 | 0.27 | 1.54 | 1.38 | -1.23 | 4.31 |
| | Equal variances not assumed | | | 1.15 | 44.39 | 0.26 | 1.54 | 1.34 | -1.16 | 4.24 |
| MPG After Month5 | Equal variances assumed | 0.62 | 0.44 | 1.32 | 49.00 | 0.19 | 1.85 | 1.40 | -0.96 | 4.67 |
| | Equal variances not assumed | | | 1.45 | 40.76 | 0.15 | 1.85 | 1.27 | -0.72 | 4.43 |
| MPG After | Equal variances assumed | 1.20 | 0.28 | 0.82 | 47.00 | 0.41 | 1.27 | 1.54 | -1.83 | 4.38 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month6 | Equal variances not assumed | | | 0.93 | 41.86 | 0.36 | 1.27 | 1.37 | -1.48 | 4.03 |
| MPG After Month7 | Equal variances assumed | 1.45 | 0.24 | 0.85 | 44.00 | 0.40 | 1.31 | 1.53 | -1.78 | 4.40 |
| | Equal variances not assumed | | | 0.98 | 34.30 | 0.33 | 1.31 | 1.33 | -1.40 | 4.02 |
| MPG After Month8 | Equal variances assumed | 4.78 | 0.03 | 1.52 | 50.00 | 0.13 | 3.31 | 2.17 | -1.05 | 7.66 |
| | Equal variances not assumed | | | 1.85 | 40.19 | 0.07 | 3.31 | 1.79 | -0.31 | 6.92 |

## (C) Light Vehicle

| Period | Levene's Test for Equality of Variances | | | t-Test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Assumption | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | | Lower | Upper |
| MPG Befor Month1 | Equal variances assumed | 0.23 | 0.64 | -0.26 | 19.00 | 0.80 | -0.82 | 3.21 | -7.53 | 5.90 |
| | Equal variances not assumed | | | -0.26 | 18.65 | 0.80 | -0.82 | 3.17 | -7.46 | 5.83 |
| MPG Befor Month2 | Equal variances assumed | 0.36 | 0.56 | 0.12 | 20.00 | 0.91 | 0.39 | 3.23 | -6.35 | 7.13 |
| | Equal variances not assumed | | | 0.12 | 19.91 | 0.91 | 0.39 | 3.23 | -6.35 | 7.13 |
| MPG Befor Month3 | Equal variances assumed | 0.05 | 0.83 | -0.31 | 19.00 | 0.76 | -0.85 | 2.73 | -6.55 | 4.86 |
| | Equal variances not assumed | | | -0.31 | 18.81 | 0.76 | -0.85 | 2.73 | -6.56 | 4.86 |
| MPG Befor Month4 | Equal variances assumed | 0.01 | 0.95 | -0.09 | 19.00 | 0.93 | -0.17 | 1.82 | -3.98 | 3.64 |
| | Equal variances not assumed | | | -0.09 | 18.95 | 0.93 | -0.17 | 1.82 | -3.97 | 3.64 |
| MPG Befor Month5 | Equal variances assumed | 0.21 | 0.66 | -0.20 | 18.00 | 0.85 | -0.53 | 2.69 | -6.17 | 5.11 |
| | Equal variances not assumed | | | -0.20 | 17.69 | 0.85 | -0.53 | 2.69 | -6.18 | 5.12 |
| MPG Befor Month6 | Equal variances assumed | 0.55 | 0.47 | -0.05 | 22.00 | 0.96 | -0.12 | 2.42 | -5.14 | 4.91 |
| | Equal variances not assumed | | | -0.05 | 20.58 | 0.96 | -0.12 | 2.42 | -5.16 | 4.93 |
| MPG Befor | Equal variances assumed | 0.91 | 0.35 | 0.19 | 17.00 | 0.85 | 0.36 | 1.88 | -3.62 | 4.33 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month7 | Equal variances not assumed | | | 0.20 | 14.01 | 0.85 | 0.36 | 1.83 | -3.56 | 4.27 |
| MPG Befor Month8 | Equal variances assumed | 2.82 | 0.11 | 0.28 | 20.00 | 0.78 | 0.80 | 2.84 | -5.12 | 6.72 |
| | Equal variances not assumed | | | 0.30 | 17.84 | 0.77 | 0.80 | 2.70 | -4.88 | 6.48 |
| MPG After Month1 | Equal variances assumed | 0.10 | 0.76 | 0.23 | 21.00 | 0.82 | 0.64 | 2.75 | -5.07 | 6.36 |
| | Equal variances not assumed | | | 0.24 | 20.11 | 0.82 | 0.64 | 2.72 | -5.04 | 6.32 |
| MPG After Month2 | Equal variances assumed | 0.03 | 0.87 | 0.54 | 22.00 | 0.59 | 1.37 | 2.53 | -3.88 | 6.61 |
| | Equal variances not assumed | | | 0.54 | 21.53 | 0.59 | 1.37 | 2.52 | -3.87 | 6.61 |
| MPG After Month3 | Equal variances assumed | 4.03 | 0.06 | 0.21 | 20.00 | 0.84 | 0.60 | 2.91 | -5.47 | 6.67 |
| | Equal variances not assumed | | | 0.21 | 15.93 | 0.84 | 0.60 | 2.91 | -5.57 | 6.77 |
| MPG After Month4 | Equal variances assumed | 0.04 | 0.84 | 0.02 | 21.00 | 0.99 | 0.05 | 2.96 | -6.12 | 6.21 |
| | Equal variances not assumed | | | 0.02 | 19.49 | 0.99 | 0.05 | 2.96 | -6.15 | 6.24 |
| MPG After Month5 | Equal variances assumed | 0.01 | 0.93 | -0.26 | 18.00 | 0.80 | -0.78 | 2.97 | -7.02 | 5.46 |
| | Equal variances not assumed | | | -0.27 | 17.83 | 0.79 | -0.78 | 2.93 | -6.95 | 5.39 |
| MPG After Month6 | Equal variances assumed | 1.68 | 0.21 | 0.34 | 15.00 | 0.74 | 0.47 | 1.38 | -2.47 | 3.40 |
| | Equal variances not assumed | | | 0.33 | 12.68 | 0.74 | 0.47 | 1.40 | -2.57 | 3.51 |
| MPG After Month7 | Equal variances assumed | 1.19 | 0.29 | -0.33 | 15.00 | 0.74 | -0.64 | 1.91 | -4.71 | 3.43 |
| | Equal variances not assumed | | | -0.36 | 14.91 | 0.72 | -0.64 | 1.76 | -4.39 | 3.12 |
| MPG After Month8 | Equal variances assumed | 0.21 | 0.66 | 0.20 | 13.00 | 0.85 | 0.33 | 1.66 | -3.25 | 3.90 |
| | Equal variances not assumed | | | 0.19 | 11.22 | 0.85 | 0.33 | 1.69 | -3.38 | 4.03 |

# APPENDIX F