Environmentally Unfriendly Consumption Behaviour: Theoretical and Empirical Evidence from Private Motorists in Mexico City

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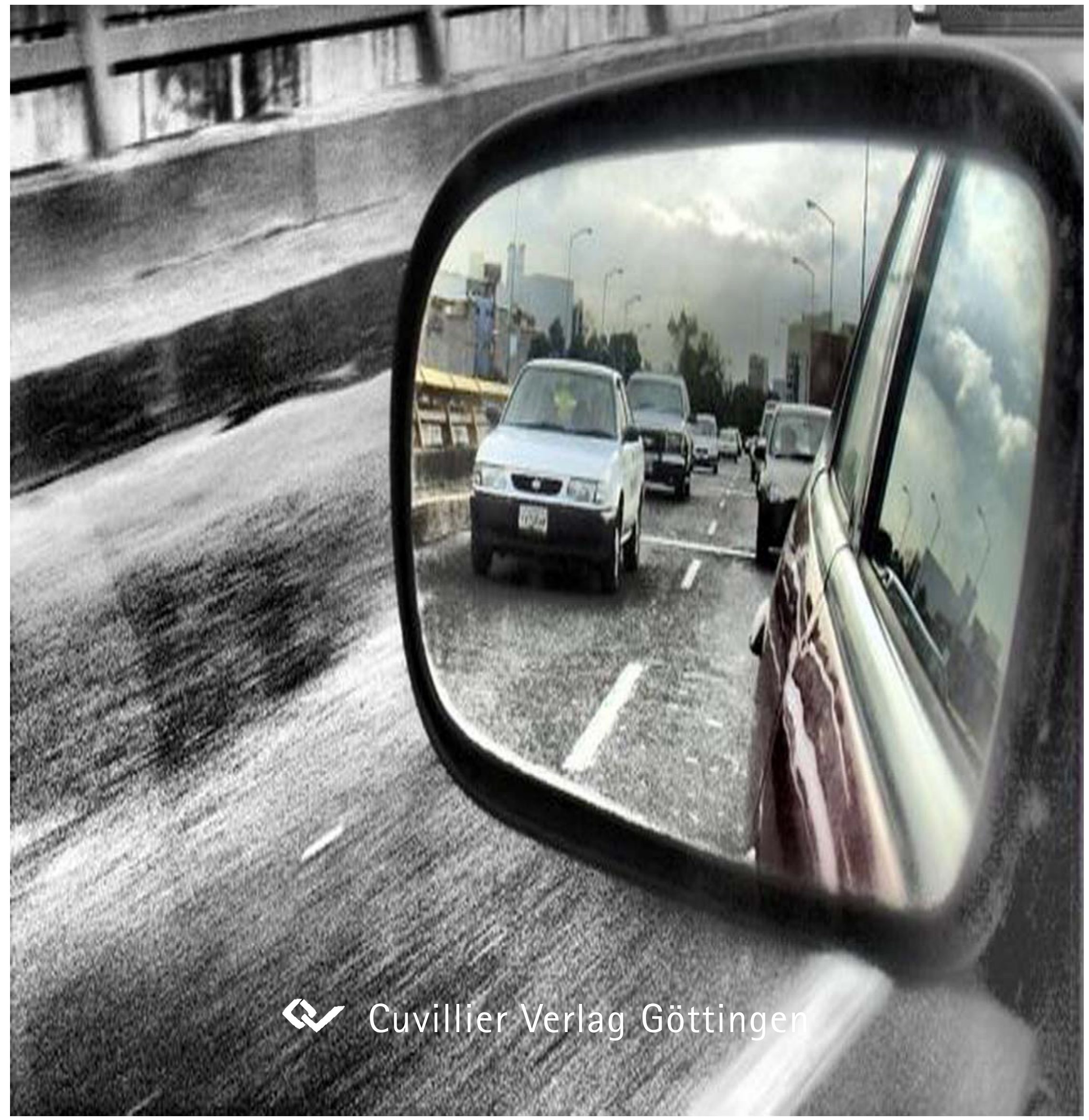

In memoriam my mother

ENVIRONMENTALLY UNFRIENDLY CONSUMPTION BEHAVIOUR:
THEORETICAL AND EMPIRICAL EVIDENCE FROM PRIVATE MOTORISTS IN MEXICO CITY

RHEINISCHE FRIEDRICH-WILHELMS-UNIVERSITÄT BONN

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THEORETICAL AND EMPIRICAL EVIDENCE FROM PRIVATE MOTORISTS IN MEXICO CITY

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I, Miguel Ángel Alva González, hereby declare that this dissertation is my own original work and that all source material used has been clearly identified and acknowledge. No part of this dissertation contains material previously submitted to the examiners of this or any University, or any material previously submitted for any other examination. I alone accept all responsibility for the ideas expressed in this work and for any errors or omissions.

To María Fernanda and Laia —empirical evidence of lovely behaviour.

“Mi ciudad [...], rehilete que engaña la vista al girar.”

GUADALUPE TRIGO, *Mi ciudad*

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ABSTRACT

This dissertation treats the topic of environmentally unfriendly consumption behaviour in relation to air pollution and the use of automobiles in Mexico City by analyzing three related aspects: i) relevant factors of driving patterns, ii) differences in the extent of pollution arising from environmentally friendlier vehicle use, and iii) the attitude of private motorists regarding the adoption of environmentally friendlier behaviour. The research includes not only economic but also social considerations. The specific objectives are to a) determine driving patterns specific to the Distrito Federal (core of the Mexico City Metropolitan Area), b) assess the behaviour of the driver regarding vehicle use and c) assess the conditions under which a switch to environmentally friendly alternatives related automobile use is possible. These objectives are analyzed using the approach of the Lancaster model of consumer behaviour with quantitative (the Distrito Federal's Vehicle Verification Program 2003-2004 information) and qualitative (a Mexico City's 2006 survey about consumers' car preferences) data in three regression models: linear, logit and multinomial logit. The findings of the research are compared with the results of other related studies and with programs that have been implemented to date.

The study demonstrates that several structural and behavioural factors determine the level of impact that private motorists have on urban air pollution. Also, it is demonstrated that the relation that motorists have with their vehicles revolves around function and use rather than simple ownership. In this sense, the more important results are that factors like income or purchase price do not explain automobile use; attitudes or personal attributes explain the behaviour much better than purely economic factors or the vehicle itself. One main conclusion is that the program implemented thus far to control vehicle use and alleviate air pollution in Mexico City has actually contributed to increased automobile use. In general, the approach applied demonstrates that sociological context is an intrinsic part of motorist choices regarding vehicle use, and that perceptions and attitudes influence motorists decisions.

DEUTSCHE KURZFASSUNG

Diese Dissertation beschäftigt sich mit dem umweltunfreundlichen Konsumverhalten in Bezug auf die Luftverschmutzung und die Nutzung von Autos in Mexiko-Stadt anhand der Analysierung drei wichtiger Aspekte: i) relevante Faktoren des Fahrverhaltens, ii) Unterschiede im Ausmaß von Umweltverschmutzung, die sich bei der Nutzung von umweltfreundlichen Autos ergeben, und iii) das Verhalten von privaten Autofahrern hinsichtlich der Annahme umweltfreundlichen Verhaltens. Die Untersuchung beinhaltet nicht allein ökonomische, sondern auch soziale Aspekte. Die Forschungsziele sind (a) die Bestimmung des derzeitigen Fahrverhaltens privater Autofahrer im Distrito Federal (Kern des Großraums von Mexiko Stadt), (b) Bewertung des Verhaltens von Autofahrern hinsichtlich des Gebrauchs ihres Autos, und (c) Bewertung der Bedingungen einer umweltfreundlichen Alternative zum Auto. Unter Anwendung des Lancaster-Modells wird das Konsumverhalten anhand quantitativer (Information des Distrito Federal Autoüberprüfungsprogramms 2003-2004) und qualitativer (eine Mexiko-Stadt 2006-Befragung über die Autovorlieben der Konsumenten) Daten analysiert und in drei Regressionsmodelle unterteilt: linear, logit and multinomial logit. Die Ergebnisse der Untersuchung stehen anderen verwandten Studienergebnissen als auch bereits praktischbezogenen Programmen gegenüber.

Die Untersuchung zeigt, dass verschiedene Struktur- und Verhaltensfaktoren den Grad der Beeinflussung privater Autofahrer auf die urbane Luftverschmutzung bestimmen. Es wird auch dargelegt, dass die Beziehung der Autofahrer zu ihren Autos sich mehr um die Funktion und den Gebrauch als einfach nur um den Besitz eines Autos drehen. In diesem Sinne sind die wichtigsten Ergebnisse dieser Untersuchung, dass das Verhalten viel mehr durch die innere Einstellung oder die personengebundenen Eigenschaften und nicht durch ökonomische Faktoren des Autos erklärt wird. Faktoren wie das Einkommen des Fahrers oder der Preis des Autos lassen keine Rückschlüsse auf den Gebrauch des Autos ziehen. Fazit ist, dass die bisherigen Programme zur Kontrolle des Gebrauchs von Autos und der Verringerung der Luftverschmutzung in Mexiko-Stadt letztlich zu einem Anstieg des Gebrauchs von Autos beigetragen haben. Die dargelegte Herangehensweise zeigt ebenfalls, dass der soziologische Kontext eine wesentliche Rolle bei der Wahl von Autofahrern hinsichtlich der Nutzung ihres Autos spielt und dass die Wahrnehmung und Einstellung des Autofahrers seine Entscheidungen beeinflussen.

RESUMEN EN ESPAÑOL

Esta tesis aborda el tema del comportamiento perjudicial al medio ambiente en el caso del uso del auto y la contaminación atmosférica en la Ciudad de México, a través del análisis de tres aspectos relacionados: i) los factores relevantes en los patrones de manejo, ii) las diferencias de emisiones contaminantes resultantes de un uso ambientalmente menos perjudicial del auto, y iii) la actitud de los automovilistas privados hacia la adopción de pautas menos contaminantes. La investigación incluye no sólo aspectos económicos sino también consideraciones sociales. Los objetivos específicos son: a) identificar los patrones de manejo de la flota vehicular del Distrito Federal (corazón del Área Metropolitana de la Ciudad de México), b) evaluar dichos patrones, y c) evaluar las condiciones que hagan posible un cambio hacia alternativas de uso con menor impacto ambiental. Estos objetivos son analizados bajo el enfoque del modelo Lancaster de comportamiento del consumidor, con información cuantitativa (los datos del Programa de Verificación Vehicular 2003-2004) y cualitativa (una encuesta del 2006 en la Ciudad de México sobre preferencias de compra de autos nuevos) empleada en modelos de regresión linear, logit y logit-multinomial. Los resultados de la investigación son contrastados con otros de estudios relacionados y con los programas que hasta la fecha se han implementando.

El estudio demuestra que distintos factores estructurales y de comportamiento determinan el nivel de impacto que los automovilistas privados tienen en la contaminación atmosférica. También, se demuestra que la relación de los conductores con sus autos gira alrededor del uso y utilidad más que de la propiedad. En este sentido, los resultados más importantes son que factores como el ingreso o el precio no explican el uso del auto y que actitudes o atributos personales tienen un poder explicativo mayor que factores meramente económicos o características del vehículo en sí. Una conclusión principal es que el programa hasta ahora implementado en la Ciudad de México para controlar el uso vehicular y reducir la contaminación ambiental, de hecho ha contribuido al incremento del uso del auto. En general, el enfoque aplicado demuestra que el contexto sociológico es parte esencial de las elecciones de los conductores para el uso del auto, y que las percepciones y actitudes influyen sobre las decisiones de los automovilistas.

LIST OF ABBREVIATIONS AND ACRONYMS

CAM	*Comisión Ambiental Metropolitana* (Metropolitan Environmental Comission)
CAC	Command and Control regulatory instruments
CO	Carbon monoxide
CO_2	Carbon dioxide
COE	Certificate of Entitlement
CONAPO	*Consejo Nacional de Población* (Nacional Population Council)
DF	*Distrito Federal* (Federal District)
ECU	Expected car use
EM	*Estado de México* (State of Mexico)
EPA	Environmental Protection Agency
FIMEVIC	*Fideicomiso para el Mejoramiento de las Vías de Comunicación del Distrito Federal* (Trust Fund for Communications Improvement)
FT	Frequency of transportation
FTH	Frequency of transportation per hour
GDF	*Gobierno del Distrito Federal* (Federal District Government –since 1997)
GDP	Gross domestic product
GHG	Greenhouse gases
HNC	*Hoy No Circula* (No Driving Day Program)
INE	*Instituto Nacional de Ecología* (Mexican National Institute of Ecology)
LGEEPA	*Ley General de Equilibrio Ecológico y Protección al Ambiente* (General Law of Ecological Balance and Environmental Protection)
µm	microgram
MCMA	Mexico City Metropolitan Area
MDG	Millenium Development Goals
MIT	Massachusetts Institute of Technology
MSE	mean square error
NAFTA	North American Free Trade Agreement

N.I.	not included
NO_2	Nitrogen dioxide
NO_x	Nitrogen Oxides
n.s.	not significant
O_3	Ozone
OECD	Organization for Economic Cooperation and Development
PICCA	*Programa Integral Contra la Contaminación Atmosférica* (Comprehensive Program Against Air Pollution –Mexico City's official air pollution control plan for 1990-1995)
PROAIRE	*Programa para Mejorar la Calidad del Aire en el Valle de México* (Program to Improve Air Quality in the Valley of Mexico)
PM	Particulate matter
$PM_{2.5}$	Mass of particulate matter with aerodynamic diameter smaller than 2.5µm
PM_{10}	Mass of particulate matter with aerodynamic diameter smaller than 10µm
ppb	parts per billion
ppm	parts per million
RECLAIM	Regional Clean Air Incentives Market
SETRAVI	*Secretaría de Transporte y Vialidad* (Ministry of Transport and Roadways – DF)
SO_2	Sulphur dioxide
TSP	Total suspended particles
UN	United Nations
UNEP	United Nations Environment Programme
US	United States (also USA)
VKT	Vehicle kilometres travelled
VOC	Volatile organic compound
VVP	*Programa de Verificación Vehicular Obligatoria* (Vehicle Verification Program—the mandatory emission inspection program in the MCMA)
WHO	World Health Organization

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CHAPTER 1

INTRODUCTION

"Natura deficit, fortuna mutatur, deus omnia cernit." (Marguerite Yourcenar, *Memoirs of Hadrian*)

"We shall require a substantially new manner of thinking if mankind is to survive." (Albert Einstein)

"National solutions ought to base themselves in local solutions, and only emerging from both is our contribution to international solutions conceived. If we do not attend to basic local problems, we will never gain true unmocking access to this most celebrated globality." (Carlos Fuentes)

1. INSIGHT

Environmental and resource problems can ultimately be traced back to consumption and lifestyles; consumption and production patterns in developing countries have been following the same patterns that were and are typical of most of their industrialized counterparts[1]—the difference is one of magnitude, but is likewise unsustainable (UNEP 1999a). The seventh goal of the Millennium Development Goals (MDG)[2] from the United Nations (UN) includes as Target 9: "Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources" (UN 2003). Principle 8 of the 1992 Rio Declaration on Environment and Development states that "to achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies"[3] (UN 1992). Thus, for developing countries (like Mexico) one of the

[1] For example, 88% of all trips in the United States are by car; unsurprisingly, transport accounts for more than 30% of US carbon dioxide emissions (Walsh 2007).
[2] It was in the city of Monterrey, Mexico where the eighth MDG was reaffirmed. This meeting elaborated how the seven goals can become a real fact: "Develop a global partnership for development". At the same time, each goal calls for particular attention to seven different but related areas: poverty, lack of education, gender inequality, child and maternal mortality, mortal diseases and environmental degradation. This research finds its broad justification within this last goal.
[3] In the same text, Principle 11 complements and states: "States shall enact effective environmental legislation. Environmental standards, management objectives and priorities should reflect the environmental and development context to which they apply. Standards applied by some countries may be inappropriate and of unwarranted economic and social cost to other countries, in particular developing countries." It fits then the question concerning the conditions that we have to take into account to get into this sustainable path (policies,

greatest challenges (besides demographic control) is to know how to move from consumption patterns based on quantitative values to enlightened consumption based on qualitative values. Primarily, as Piorkowsky (1998) states, *sustainable consumption* refers to the steady reduction of wasteful consumption levels of energy and other natural resources, i.e., improvements in efficiency and changes in lifestyle.

At the same time, urban areas are expanding rapidly and increasing stress on the natural environment[4]. In 2000 nearly half (48%) of the world's population lived in such areas, and this proportion is expected to grow by 2% per year; the urban population in developing regions will double from 2 billion (in 2003) to 3.9 billion in the year 2030 (UN 2004). However, urban centres are not only concentrations of people with harmful consequences at urban, regional, continental and global scales, but also centres of economic growth, education, technological advancements and culture. Cities present a special opportunity to manage a growing population in a sustainable way (Molina and Molina 2004)[5].

Of the many and various problems associated with urban areas, air pollution is one of the most important[6]. Chronic and infectious respiratory diseases are highly associated with air pollution; also, dispersion of locally generated pollutants has been well established in the case of acid deposition, climate change and stratospheric ozone depletion (Krupnick 2004). During the past century, air pollution of human origin has become a major and persistent problem in many urban areas around the world. Growing population and changing lifestyles continue concentrating air pollution in cities today. In 1992 the United Nations Environment Programme (UNEP) and the World Health Organization (WHO) evaluated air quality in 20

measures and results) in a scenario like the Mexican one. So far the objectives and instruments, in cities like Mexico City for example, have not reflected the environmental and development context to which they apply.

[4] More than 60 million people are added to cities each year. Most of this expansion occurs in urban areas of developing countries, aggravating already backlogs in housing and infrastructure development (UN 2004). Also, by 2015, 23 of the 27 cities expected to reach 10 million will be in developing countries.

[5] On the other hand, one can find other statements such as "urbanization blinds the modern eye to ecological reality by separating people both spatially and psychologically from the ecosystems that support them" (Rees in Shumacher 1999). All in all, cities require resources—including energy—to sustain the increasingly consumer lifestyles of their inhabitants, and the task is to find the best possible way to do it.

[6] Definitions of air pollution and other related technical terms are provided in the Appendix B: Glossary; also, the List of Abbreviations and Acronyms includes some technical terms.

megacities[7] and found that air pollution was widespread; each had at least one major pollutant in excess of WHO health guidelines; 15 had at least two, and seven had three or more (UNEP/WHO 1992). These seven cities were Mexico City[8] (Mexico), Beijing (China), Cairo (Egypt), Jakarta (Indonesia), Los Angeles (USA), Sao Paolo (Brazil) and Moscow (Russia). Society has only recently become sufficiently aware and informed to take actions against this problem: In the case of Mexico City, which in 2000 had 18 million inhabitants and a density of 12,200 people/km^2, major air pollution control efforts started only a decade ago. On the one hand scientists have developed, for example, an understanding of smog formation and how to reduce smog levels, but on the other hand significant social and political barriers still must be overcome in order to implement solutions.

Transportation plays an integral role in cities: it provides benefits but also costs that can act to inhibit further benefits. The challenge at hand is to find the way to reap these benefits without incurring negative impacts. In terms of Ayres (1994), transportation gives a peculiar industrial metabolism to cities: it is not only a way to consume our transportation facilities and to produce displacements and movement of goods and services, but also a production of externalities and consumption of time. The above mentioned UNEP/WHO report called for the urgent need (mainly for the particular set of reviewed megacities) of more effective planning of energy requirements and transport in order to reduce human exposure to pollutants and to decrease risks to health and environment. Also, it revealed that motor vehicle traffic is a major source of air pollution in all these megacities and actually the most important source in half of them. In Mexico City, the transportation sector accounts for nearly all of the CO, 80% of the NO_x, 40% of the VOC, 20% of the SO_2 and 35% of the PM_{10} (CAM 2002). Given then that transportation is the greatest source of pollution, intervention is needed to reduce the sector's adverse impacts.

[7] Megacity is defined as an urban agglomeration with population of 10 million or more (UNEP/WHO 1992). The definition is arbitrary, as major urban centres often include people who are not located within a city's political boundaries (e.g., Mexico City).

[8] Mexico's megacity, referred to as Mexico City or the Mexico City Metropolitan Area (MCMA), includes 16 districts (*delegaciones*) within the Distrito Federal (DF), which is actually the capital city known internationally as Mexico City, and clusters of municipalities (*municipios*), including 37 in the State of Mexico (*Estado de México* or EM) and one in the State of Hidalgo. This definition is explained in detail in section 4.1 of Chapter Two.

Returning to consumption and lifestyles, one of the starkest differences in consumption patterns between developed and developing countries concerns motor vehicle ownership and, more importantly, the use of automobiles and their related gas emissions[9]. Technological and institutional advances have led to a reduction in vehicle emissions, but the number of vehicles in circulation and total vehicle kilometres travelled (VKT) has increased. To put it differently, the problem of air quality has not been solved by better motor vehicles[10]. As some studies have demonstrated (see the study of "The Automotive Industry" in UNEP 1999b), better fuel and motor technology may lower emissions per litre of fuel but may also increase VKT due to the reduced cost of travel, in turn increasing total emissions and cancelling the positive effect. Overall, motor vehicle emissions depend not only on technical issues (e.g., fuel and motor quality) but also on behavioural factors (e.g., better usage and buying conditions facilitate a more intensive use of automobiles). There are significant constraints on what fuel and technology improvements can deliver; in many cities reductions in per-vehicle emission levels have been offset by increases in the number and use of vehicles (Molina and Molina *op. cit.*).

Finally, from a modal share perspective and drawing upon the case of this empirical research, the most worrying trend in cities in developing countries is the massive shift toward lower capacity modes of transportation (i.e., private cars, taxis and minibuses) at the expense of collective modes of transportation such as subway and bus[11]. In Mexico City the number of private cars has in recent years accelerated at a rate of six percent annually; the existing transportation system has not adequately adapted to the changing socio-economic and increasingly urban distribution of the population with its resulting new displacement

[9] Air emissions from road transport not only reflect differences in the number of vehicles but also show a higher proportion of older, i.e., more polluting cars and trucks in developing countries. CO_2 emissions per capita might not be the best indicator to show the magnitude of the problem but rather emissions per kilometre travelled, e.g., for each million kilometres travelled, vehicles emitted 363 tonnes of $C0_2$ in the US, 450 tonnes in Spain, 802 tonnes in Turkey, 1159 tonnes in the Republic of Korea and 1752 tonnes in Mexico (UNEP 1999a).

[10] Piorkowsky (1998) highlights this issue through the classification of lifestyles, i.e., four lifestyle options for more sustainable household production and consumption. Regarding the "new technology style" (that focuses on avoiding reductions in the standard of living through technologies that are cleaner, more efficient and spare natural resources, e.g., by using low or zero-emission cars), there is little evidence to validate its assumption of a more far-reaching environmentally conscious consumer behaviour amongst adherents to this lifestyle option.

[11] For example, in 1986 electric transport was 22% of the transportation demand in Mexico City, as compared with less than 14% at the present. On the other hand, bus and taxi demand increased from 11% to 58% in the same period (CAM 2002).

patterns. The key question is how to balance the mobility needs of the population of cities like Mexico City with the environmental impacts of transportation activity. Ultimately, Mexico City expects continued economic growth that will drive transport demand still higher and require the integrated implementation of technological and social policy options. In this context, this research aims at understanding and modifying private automobile use as a contribution to better policies for reducing pollution caused by motorists in Mexico City, demonstrating with this unique case study, as every city is, a way to work toward a comprehensive understanding of the complex environmental problems found within every city.

2. OBJECTIVES AND RESEARCH QUESTIONS

In general, government interventions against the air pollution problem in cities began in the 1970s. In Mexico, significant efforts started in 1982 with the second Federal Environmental Legislation (i.e., LGEEPA), which established norms for industrial emissions. In Mexico City in 1989, the "No Driving Day" program (HNC) became mandatory[12]. Since then this program has been a permanent measure and a major component of air quality management programs. In 1990 the first integral programme against atmospheric pollution (i.e., PICCA) was implemented with a five-year time horizon. However, in recent years applied policies have not tackled fundamental issues like behaviour related to the consumption of transport at all. Among various and focused programs on transportation management (which include a workable vehicle verification program), as Connolly (1999) states, questions of, for example, gasoline prices, taxes, and subsidies are debated in purely economic terms, never as a potential tool for modifying transport behaviour and ultimately reducing pollution[13].

[12] It was in 1987 when an environmental group named *Mejora tu Ciudad* (Improve your city) persuaded the drivers in Mexico City to participate in a voluntary initiative to avoid use of cars once a week. The initial response was favourable, however, support declined rapidly due to lack of resources and promotion. The program was adopted again when local government deployed a short-term 'emergency program' during the winter months when the ozone concentrations were very high due to several thermal inversions.

[13] Efforts like the "Integrated Program on Urban, Regional and Global Air Pollution: Mexico City Case Study" initiated in 2000 at MIT by Nobel laureate Mario Molina are outstanding. The results of the first phase, summarized in Molina and Molina 2002, are a touchstone for this research.

To summarize, Mexico City, following the above mentioned unsustainable consumption patterns, has developed an "automobile dependence", which has not received adequate attention by either government or scientists. This dissertation builds on previous studies related to automobile dependence, urban sustainable development and the problem of air pollution and transportation in Mexico City by investigating the use of private automobiles and their impact on transport-related emissions.

Specifically, the objective of this study is to obtain an in-depth understanding of the preferences and constraints of private motorists in Mexico City, which includes the following:

(a) data on relevant factors and driving patterns;

(b) differences in the extent of pollution arising from environmentally friendlier driving;

(c) attitudes of motorists regarding the adoption of environmentally friendlier behaviour.

The basic research questions for each case are:

(a) What driving patterns are relevant for the current private motorists' situation in Mexico City[14], in particular for private automobiles in the Distrito Federal? What factors determine these patterns?

(b) What factors influence the driving decisions of the environmentally friendlier motorists? How is the motorist's behaviour regarding automobile use (i.e., to what extent does the motorist see and take into account the outputs of driving)?

[14] Distrito-Federal (DF) is the capital city of Mexico and the central part of the Mexico City Metropolitan Area (MCMA), and it is known internationally as Mexico City (See above footnote 7, and Section 4.1 of Chapter 2, for an extended explanation).

(c) How and under what conditions is a real switch to environmentally friendly alternatives related to automobile use possible (i.e., to what extent it is possible to modify the current motorists' behaviour)? How can the use of automobiles be optimized within the already existing transport management-programs? How different behaviour in motorists can be stimulated and what are the related implications?

Most economic studies about the problem of air pollution in Mexico City concentrate on the evaluation of the benefits and costs of improving air quality (e.g., Pedrero 1993; Cesar *et al.* 2002; Chapter 4 in Molina and Molina 2002). Other studies address the issues of traffic control and demand side management (e.g., Goddard 1997), but little attention has been paid to the behavioural aspects of transportation consumption as such. The studies have been silent on motorists' decisions about use of their automobiles. This study is an attempt to fill this knowledge gap. I expect that economic analysis will allow us to foresee to what extent policy instruments can promote or guide desirable behaviour patterns among private motorists.

3. THEORETICAL FRAMEWORK AND DATA FOR EMPIRICAL ANALYSIS

The analytical framework to be used takes into account that the essential nature of transportation is not only the distance travelled but also vehicle performance (and its environmental impacts). Motor vehicle use is reflected not only through pollutant emissions levels, but also through kilometres travelled; what matters is neither emissions nor kilometres alone but both. Particularly I expect that with the data collected every six months by the Vehicle Verification Program (VVP)[15] in the Distrito-Federal, it is possible to take pollutant emissions and kilometres travelled into account in the model. This will introduce a better tool to evaluate and control current automobile use and improve the already applied HNC program. In particular I follow the framework provided by Seel and Hufnagel (1994) where

[15] The mandatory emission inspection program in the MCMA, coupled to the HNC program.

activities and final outputs are more important and relevant than goods per se, mainly because of the activities' environmental impacts.

An important basis for this framework is Lancaster's model of consumer behaviour (1966), which offers the possibility of comparing goods with similar characteristics and different qualities, e.g., to compare two similar automobiles with different environmental impacts. We then move from the traditional approach, where commodities are the direct object of utility, to one where utility is derived from the properties or characteristics of commodities[16]. In general, the decision to use an automobile depends on the demand for the final outputs (i.e., kilometres travelled and, to some extent, associated and accepted pollutant emissions), the preference for driving a particular kind of motor vehicle, and the restrictions upon its operation.

The empirical analysis is based on two data sets. The first contains data collected in Distrito-Federal's *Verifi-Centros* (Centres for Verification) by the VVP, for respective periods of 2003 and 2004. The second is a survey about consumers' automobile preferences collected during first semester 2006 by the Mexican National Institute of Ecology (INE)-Environmental Economics Area. More details on the models and data are provided in the corresponding sections of the dissertation.

4. OVERVIEW

In order to answer the research questions, rather than a single (econometric) model, I use the Lancaster-Seel-Hufnagel theoretical model as a tool jointly with statistical data description and, importantly, a revision of previous studies related to the topic (going beyond a mere economic point of view). The aim is to adapt new elements to the already existing models, and in this way to attain a better framework for analysis that permits going beyond limited theoretical matters and to treat empirical evidence for the use of automobiles in Mexico.

[16] In other words, a car does not give utility per se but because its use, and that's why we need a different approach to analyse how people choose to use their cars, how they use different cars based (directly or indirectly and in some extent) on its performance.

There is a need to identify specifics that can help to overcome restricted worldviews where well-being depends entirely on economic activity; environmentally unfriendly behaviour is a phenomenon where the usual methods of analysis tend to be insufficient. For this reason, each chapter of this dissertation provides results that depict different sides of the same problem. The research aims to include not only economic but also social considerations, and so to present an integrated vision of the different components of the problem.

The dissertation proceeds as follows: Chapter two describes and analyses the air pollution problem in selected large cities and regions and its particular relation with the use of automobiles, and revises the case of Mexico City. Chapter three presents the theoretical framework used for the analysis of empirical data. In chapter four the suggested implications of the framework are applied and the results are presented. Chapter five compares the findings with those of other related studies and programs implemented to date, and also discusses some political implications. Finally, chapter six concludes with key findings and recommendations.

CHAPTER 2

AIR POLLUTION AND THE USE OF PRIVATE AUTOMOBILES IN URBAN CENTRES, EXEMPLI GRATIA, MEXICO CITY

"Take cars. Take most people, they're crazy about cars. [...] I'd rather have a goddamn horse. A horse is at least 'human' for God's sake." (J.D. Salinger, *The Catcher in the Rye*)

"Mexico [City] must be without doubt one of the most beautiful cities that Europeans have ever founded in both hemispheres." (Alexander von Humboldt)

"[...] the city that we all dream and that unceasingly changes as we dream it/ [...] I speak of the immense city, daily reality made of two words: the others/ [...] of the coming and going of cars, mirror of our ambitions, errands and passions (why? what for? where to?)/ [...] I speak of the city, shepherd of the centuries, mother that engenders us and devours us, that invents us and forgets us." (Octavio Paz, *I speak of the City*)

1. INTRODUCTION

As noted in the previous chapter, the continued rapid expansion of urban areas presents us with an array of associated environmental impacts, one of which is air pollution. This chapter reviews the problem of air pollution for the set of urban areas known as megacities, drawing in particular upon the example of Mexico City. Transport, mainly with respect for the use of private automobiles and their associated acute impacts, is one of the key sectors in need of attention if our objective is to reduce or control air pollution. The chapter begins by treating the problem of air pollution in megacities at the macro and sector levels. Discussion then turns to include the private use (i.e. consumption) of automobiles. This discussion provides the contextualization for the final section, which analyzes the case of Mexico City.

The following chapter is divided into four main parts. The first (Section 2) discusses the issue of air pollution in urban centres and the tools of environmental economics as a way to deal with the problem. The second (Section 3) is about the use of private automobiles in cities. The third (Section 4) presents the case of Mexico City. Finally, the chapter concludes with a summary of the key issues related air pollution, cars and Mexico City (Section 5).

This chapter introduces the main parts for an economic model and an empirical discussion in order to lead into treatment of relevant variables in the subsequent chapters. The purpose is to start the analysis by providing the basis for both theoretical and empirical discussion. Reviewing a case of air pollution consists in more than a focused analysis on private automobile use (or the transportation sector, for example), but this particular point remains to be worked out in greater detail. To facilitate such a task, this chapter broadly profiles the case of private automobiles in Mexico City, providing: i) background on air pollution in megacities over the last decades; ii) a general description of the main control programs implemented to date that have been based on environmental economics analysis; iii) an overview of automobile-related emissions; iv) a review of the role played by the use and ownership of automobiles in cities; v) a description of the character of Mexico City's air pollution problem; and vi) a description of its transport problem with an emphasis on the use of private automobiles.

Drawing from this profile, the chapter concludes with elements that later on, in Chapter five, will be taken and compared with the empirical results obtained (and presented in Chapter four) from a broader perspective. Guidelines to shape more effective policies than those currently applied in Mexico City are also presented.

2. AIR POLLUTION IN CITIES

Rather than undertaking a well rounded assessment of Mexico City's problems or a comparative evaluation of several cities, this section focuses on the air pollution problem and how this issue has been tackled by some of the instruments offered by environmental economics. The aim is to give initial ideas about how to formulate the problem for the specific case of Mexico City; that is to say, the problem of air pollution is not exclusive for Mexico City, but the particulars of the case are indeed unique. Every city has particularities that have to be taken into account, although this does not rescind examining other cases: on the contrary, it is imperative to learn from others, but always taking into account those unique points that are the difference when policy measures are carried out. How have other large cities addressed air pollution problems? This section provides a briefing on this question.

2.1 Relevant International Findings

Cities have historically been associated *inter alia* with the evolution of public health and practice. As industrialization intensified, the absence of air quality controls allowed pollution levels to increase in industrialized cities. This increasing level of pollution consequently ushered in new legislation which has since generally led to a decrease in air pollution in developed countries. However, emissions of carbon dioxide and fine particulates are still rising, both in developed and developing countries. Cities foster the generation of ideas, energy, creativity and technology, but also continue being sources of environmental health hazards[1]. There is already sufficient evidence that air pollution in the urban environment can lead to a variety of harmful short- and long-term effects on health; these effects are reasonably well understood for the pollution conditions in developed countries, but for developing countries the evidence is still in need of further research (Krupnick 2004).

The discussion of air pollution has plenty of case studies to draw upon, each with differing specifics (i.e., depending on the city). The direction of analysis and factors to be taken into consideration necessarily vary. Factors such as topography, demography, climate and weather, and level of industrialization and socio-economic development influence and shape the problem of air pollution. Molina and Molina (2004) conduct such a varied analysis on nine cities (Mexico City included) and identify key points for each one. The only common feature among these cities, besides being megacities, is the air pollution problem they are facing. The selected cities are from industrialized as well as developing countries, drawing attention to the commonness of the problem. The following paragraphs summarize the results of Molina and Molina's review, and illustrate the different faces of air pollution.

Los Angeles metropolitan area (the second-most populated urban area in the United States with 12 million inhabitants in 2003) and Ontario (Canada's most populated province:

[1] For example, evidence from epidemiological studies has pointed out the importance of exposure to fine particulates and sulphates as determinants of respiratory morbidity and mortality, both from cancer and from lung diseases (McMichael 2000).

12.1 million inhabitants in 2003) are conditioned by their geographical characteristics, and even applied controls and measures against air pollution, there climate plays a very important role for the current situation. For example, in Los Angeles regulation standards for PM_{10}, $PM_{2.5}$, O_3, NO_2, and CO were exceeded during 2002 particularly in the spring and summer; in Toronto (capital and largest city of Ontario) elevated O_3 concentrations are generally recorded on hot, sunny days from May to September, between noon and early evening, with much of the O_3 originating from cross-boundary transport[2]. In both cities motor vehicles account for significant amounts of pollutant emissions[3].

Across the Pacific, Delhi (India) and Beijing (China) present other characteristics that are more common to cities in developing countries, dealing with more issues than geographical elements. Delhi has faced significant population growth[4], an increasing number of vehicles[5] and small-scale industrial producers (from 8,200 in 1951 to 120,000 in 1996), and climate factors like the hot summer. Along with the other Indian cities of Mumbai and Calcutta, Delhi ranks among the top-ten cities in the world for worst air-quality (along with Los Angeles but not Toronto). Beijing is also part of this list[6]; more motor vehicles are on the streets of Beijing than any other city in China, which is explained mainly by the fast economic development the city has undergone since the 1980s. Major sources of SO_2 are home heating and industry, while traffic and industrial activities are the most important sources of NO_x. Still, annual mean concentrations or air pollutants have generally decreased from 1998-2002, except for NO_x, as expected because of a fuel switch from coal to oil[7].

Back in the Americas, Santiago (Chile), Sao Paulo (Brazil) and Bogotá (Colombia) reveal some other sides of the problem. Santiago, unlike Sao Paulo and Bogotá, does not have a tropical climate, but weather is an important factor during the winter (April to

[2] In general, the Central Ontario Region's proximity to the border makes it vulnerable to the long-range transport of pollutants from the United States.
[3] In Los Angeles motor vehicles are the largest source of VOCs, and the Ontario transportation sector emitted ~63% of the NO_x and 85% of the CO, based on estimates in 2001.
[4] The population growth rate was 90% in the decade 1941-1951. Delhi's population increased from 4 million in 1971 to ~14 million in 2001.
[5] During the same above mentioned period the number increased more than 19-fold: from 0.18m to 3.46m
[6] Actually, in general, twenty of the world's 30 most polluted cities are in China.
[7] China is the world's biggest producer of coal, which makes up the greatest source of air pollution there. Its abundant use means that China will overtake the United States as the world's biggest producer of carbon emissions by 2009. The current share is 17% of the world's total, against America's 22%.

September). Air pollution there has been associated with a growing economy, rapid urban expansion, industry and an increasing rate of automobile usage. As in the case of Mexico City, government has taken some steps to mitigate air pollution levels including a rotating schedule that restricts the number of cars allowed on the streets on given days. Molina and Molina emphasize that during the 1990s the number of studies related to air quality in Santiago increased considerably: they cite, among others, one study discussing changes in land use, seasonal and daily weather cycles, and geographical and cultural factors that contribute to pollution. Studies are an important tool because their results (air pollution forecasting, for example) can be used to predict pollution levels and accordingly regulate city activities. Empirical results show that the relative importance of mobile sources for $PM_{2.5}$ levels has doubled in the last decade, whereas stationary source contributions have been reduced to half the value of the early 1990s.

Mobile sources of pollution, such as vehicles, have doubled in Sao Paulo in the last decade, reaching 3.5 million today; as well, a significant proportion of buses and automobiles is more than 10 years old (i.e., with high emission factors). Since 2003, this has been a reason for introducing cars with low emission factors that can run with any mixture of gasoline/alcohol[8]. Air pollution from PM_{10}, O_3 and aldehydes, presents a severe problem; vehicular emissions are responsible for nearly 35% of PM_{10}, while industrial emissions account for about 25%. The same problem counts for Bogotá, which experienced a 12% increase in PM_{10} and a 15% increase in SO_2 between 1998 and 2002, although the air quality monitoring system showed reductions in average annual concentrations of CO, NO_2 and O_3 during the same period. There was enough reason then to operate in this city the TransMilenio Program which has had success by, amongst other actions, replacing an obsolete public transit fleet, running more efficient bus transit operations and shifting to more energy efficient transportation system.

[8] The fuel used in Brazil is mostly gasohol (gasoline with 23% ethanol), and a small fraction of automobiles runs on pure ethanol. As a consequence, the atmosphere is heavily loaded with aldehydes, in particular acetaldehyde and formaldehyde.

In Africa[9], Cairo is not only the largest city but also the most polluted[10]. It is one of the world's most densely populated cities with one of the lowest provisions of road space per capita and a significant growth in the number of private vehicles in circulation (also it is the only African city with a metro system). According to a 1996 report by the Egyptian Environmental Affairs Agency, motor vehicle emissions contributed in a significant way to the problem of acute PM lead concentration, though Cairo began to phase out leaded gasoline in 1996[11].

In Europe, levels of most air pollutants are currently very low compared to those that occurred at the beginning of past century; successful measures for reducing air pollution levels in Europe over the past 20 to 30 years have resulted in major improvements in air quality. These measures have included the regulation of fuel for domestic heating, development of communal heating facilities, building of high smokestacks for industrial emissions, introduction of filtering techniques and reducing the lead content in petrol. While NO_x emissions from stationary sources have decreased in many areas, emissions from motor vehicles have increased due an increase in the number of trips and distance travelled per vehicle (which has been much larger than the reduction in emission factors). In particular, road transport contributes up to half of the nitrogen oxide emissions in Europe and is the main reason why NO_2 and CO levels show stability or upward trends in all European cities. The makeup of air pollution has changed in recent years: from SO_2 and suspended particulates to traffic-related pollutants such as NO_2, VOC, benzene, CO and fine particulates. Mobile sources of air pollution are thus becoming increasingly important throughout Europe.

[9] Currently Africa is experiencing the fastest urbanisation process, because it has been the latest to get started and because parts of the continent have been affected by severe climate change, making marginal land agriculturally unproductive.

[10] The population of the Cairo urban agglomeration is 10.8 million, and is projected to reach 13.1million by the year 2015. Greater Cairo consists of Cairo, Giza and Kalubia, and has a population of more than 20 million.

[11] In spite of the introduction of unleaded fuel, ambient lead remained a major problem. For 2000, the annual average PM_{10} and $PM_{2.5}$ lead levels in most contaminated sites exceed 20µg/m^3. Observed levels were reduced by 40% in 2001 through the Cairo Air Improvement Project.

2.2 Environmental Economics in Action

Pollution control measures involve many types of action, including economic action (that is, originated through environmental or ecological economics analysis[12]). In general, most kinds of action can be placed into the following three categories: 1) technology-based regulatory mandates on processes, fuels and emissions treatment; 2) economic instruments such as incentives, emission taxes and emissions trading; and 3) policy adaptation such as land-use planning, infrastructure development and transport management. The most effective strategies use a combination of these approaches[13].

Regulatory instruments can be divided in two main types: command and control (CAC) and economic incentives. The basic concept of CAC is for the regulator to specify the steps individual polluters must take to solve a pollution problem; the essence is that the regulator collects the information necessary to decide the actions to control pollution: the regulator then *commands* the polluter to take specific tangible steps to *control* the pollution. The regulator is generally quite specific as to what steps must be taken. Economic incentives, on the other hand, provide rewards for polluters to do what is perceived to be in the public interest; economic instruments have the advantage of placing decision making for pollution control in the hands of those most familiar with pollution control options, i.e., the polluter (Kolstad 2000).

Whichever the final chosen strategy, it is first necessary to identify which source of pollution has to be controlled. Economics does not have the main task, but depends greatly on the results obtained by other sciences; ultimately there is not only a relation of dependency but a mutual dependence between factors throughout process of pollution control decisions. For example, exposure to SO_2 and SO_4 from burning coal was identified during London's "killer smog" events in the 1940s and 1950s, which were correlated with

[12] What follows in the analysis pertains to the environmental economics approach. Ecological economics does not consider that the standard economics solution of internalisation (which uses prices and markets to deal with environmental effects and resources) is a sufficient means of achieving sustainable development. Instead the solutions are seen to lie in steady-state dynamics, biophysical equilibrium, the laws of nature and moral growth. However, ecological economics does have many policy prescriptions that are consistent or that overlap with environmental economics.

[13] Categories 1 and 3 also can be classified as non-economic policy instruments which include, in general, common law solutions, government pollution abatement or treatment facilities, regulations and standards, prohibition, zoning, moral persuasion/dissemination of information, and voluntary agreements.

increased sickness and death; switching to low-sulphur fuels improved this situation. Determining the causes of high PM and O_3 concentrations is not as straightforward: reductions of NO_x or VOC emissions, many of which are emitted by the transportation sector, may have little or no effect, or may even increase O_3 concentrations. In general, measurements and modelling studies of atmospheric pollutants provide the scientific base for devising emissions control strategies, which ought to be framed by economic analysis[14].

Economic analysis is a fundamental part of the second stage of air quality management[15]. Once the type and severity of the problem are determined (i.e., problem identification stage), policy is formulated to solve it (i.e., policy formulation stage). This policy consists of those strategies to reduce/eliminate pollutant emissions: in economic terms this is simply internalizing externalities. What follows in this section is the review of these formulated strategies under the guidelines of environmental economics: economic policy instruments[16]. Table 2.1 classifies these instruments.

[14] Regarding emissions measurements, although emission inventories are an essential tool for managing and regulating pollution, large uncertainties in emission rates, temporal cycles, spatial distribution and source identification often confound the development of cost-effective control strategies. Emission factors and activity levels are highly uncertain for vehicle exhaust, one of the largest source categories in megacity inventories (Molina and Molina 2004).

[15] Third and fourth stages are implementation and monitoring, respectively. The implementation stage enacts and enforces the strategy; the monitoring stage ensures control (of the situation) and gives the inputs for identifying new air quality issues that may arise.

[16] Defined as those instruments that incorporate economic incentives and the operation of markets to internalise the external costs and benefits that are associated with environmental effects.

Table 2.1 Classification of Economic Policy Instruments for Pollution Control

1. Instruments involving price adjustments and financial transfers	*2. Rights-based measures, i.e., policy based on extending private markets to cover environmental resources*
A. Charges • effluent or emissions charges • product charges/taxes differentiation • administrative charges • user charges B. Subsidies • direct subsidies for waste reduction • grants • soft loans • tax allowances C. Combined charges (taxes) and standard approaches D. Deposit-refund schemes	A. Emissions trading (marketable emissions rights) B. Market intervention C. Liability insurance[a]

[a]Liability is referred sometimes as a separate type of economic incentives (i.e., three basic types: fees, marketable permits and liability). The basic idea is that if you harm someone, you must compensate that person for damage. Source: Kolstad 2000.

In the space of three decades, the popularity of economic incentives approaches to controlling air pollution has gone from virtually nil (i.e., policy dominated by CAC approaches) to a point where, at least in developed countries, tradable permit policies, for example, are often the first approach considered by policymakers. In the early 1970s the only example of economic incentive approaches in the US was the attempt by the Nixon administration to tax sulphur in fuels. Today there are dozens of examples of serious attempts to implement tradable permit and emissions tax programs. While most successful implementations of these approaches have occurred in industrialized countries, developing countries are increasingly turning to them.

In 1990 with the beginning of public policies against acid rain, the Environmental Protection Agency (EPA) in the United States discovered how cost-effectively economic incentives can counter pollution: the EPA's SO_2 Allowance Trading Program under Title IV of the Clean Air Act[17] is probably the best-known tradable permit air pollution example, and it is the first policy to be fully worked out and well functioning (Krupnick 2004). The EPA set up an auction for permits to emit sulphur dioxide; polluters were given a set number of emissions permits and could either buy more in the auction or reduce their emissions by shutting down, installing sulphur scrubbers or buying cleaner coal. When the EPA simply tried mandating the installation of sulphur scrubbers, electricity firms argued that it would be very expensive, but when the EPA conducted the auction, very few polluters made high bids for additional permits: by 1996 many polluters were buying cleaner coal or installing scrubbers rather than buying permits to continue polluting.

Emission trading has been most often implemented to reduce SO_2 emissions, and is gaining favour for global CO_2 trading. In 1993, the South Coast Air Quality Management District (Los Angeles Air Basin, California) adopted the Regional Clean Air Incentives Market (RECLAIM) program, which imposes an overall emission limit on each of the region's larger facilities by establishing SO_2 and NO_x credits. The limit was set to decline each year, such that by 2003, for example, these facilities had reduced their emissions by 35 US tons of nitrogen oxides and 8 tons of sulphur oxides per day (Molina and Molina 2004). The strategy of tradable emissions permits has received attention primarily as an incentive mechanism for reducing emissions from stationary sources[18].

Economic policy instruments for controlling mobile sources of pollution are almost completely focused on the use of fees, such as congestion pricing (or road pricing)[19]. The most well known case is London, where since 2003 a program to charge tolls to drivers for each entrance into the central city has been in effect[20]. During the first six months, passenger vehicle traffic decreased by about 20% while bus usage increased by 14% during

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[17] Title IV of the 1990 Clean Air Act Amendments initiated as a strategy to reduce regional SO_2 emissions from power plants by 50%.

[18] Goddard (1997) proposes the use of tradable vehicle use permits. In Chapter 5 this point is discussed more in detail.

[19] Although not its primary purpose, there is evidence that road pricing (or any close variant thereof) is likely to have a very beneficial effect on urban air quality. This occurs partly because under a system of road pricing there are fewer vehicles on the road and partly because of the increase in vehicle speeds and the elimination of stop-start driving conditions.

[20] Actually Singapore pioneered this approach with a license system that began in 1975.

peak traffic hours; many people also adjusted by car-pooling, bicycling or walking into central London instead of driving.

Fuel prices and taxes on vehicle ownership are other types of pricing strategies. These instruments have been used, however, as an important source of public revenue rather than a tactic to rationalise the use of transport and impact pollution levels. According to Cracknell (2000), such pricing strategies do not manage transport demand where and when it is most needed. In the case of Mexico City, differential fuel pricing has been used to encourage the use of unleaded gasoline for environmental reasons; there the policy appeared to be successful in commencing to alleviate harmful emissions, but because it was not aimed at demand traffic management, pollution levels were less affected.

Singapore has been a major exponent of taxes on vehicle ownership[21]. Initially control was exercised through high import duties and high annual charges, with a charge-structure designed to encourage the scrapping of older cars and to discriminate against the ownership of company car. However, continued rapid growth of vehicle ownership led to a 1990 decision to introduce absolute limits on vehicle registrations through the Vehicle Quota System[22]. Even with this system in operation and a sound public transport system, congestion pricing still forms part of the applied instruments in Singapore.

Further discussion about economic instruments and air pollution control (focused on automobiles) is presented in Chapter 5, where the research results are discussed in light of other economic and social analyses. The next section moves into the particular case of automobiles and their impact on air pollution in urban centres.

[21] In this sense, as with fuel prices, generalised taxes on vehicle ownership are applied nationally and do not address the specific problem of congestion and air pollution, additionally posing political and equity problems.

[22] The target was to reduce the annual increase in vehicles owned to 3%. Prospective buyers of new vehicles must bid for a 'certificate of entitlement' (COE) in a monthly tendering process within a predetermined supply of COE's.

3. USE OF PRIVATE AUTOMOBILES IN URBAN CENTRES

Demographers estimate that by 2030 approximately two-thirds of the world population will live in large cities; that is, the human population is urbanizing. Consequently, the modern urban environment combines industrialization, crowding, waste generation and dense transport systems. In particular, there is a strong link between air quality and the transportation sector in urban centres; indeed, transport defines to a certain extent both city form and quality. Road traffic is currently the main contributor to air pollution in most urban settings, and is likely to remain so. In other words, transportation emissions are the major cause of air quality problems, and the trend in the megacities of the developing world is for these emissions to become the dominant source of air pollutants.

Moreover, economic growth is closely linked to efficient personal and freight transport, such that restrictions on transport activities, while perhaps improving air quality, could hinder economic growth. Nevertheless, without traffic control, demand management or infrastructure improvement, increasing numbers of vehicles cause congestion resulting in both poor air quality and hindered economic growth. This section revises in particular the role of automobiles in cities: what kind of relation is there between air pollution and automobile use? Through the next three subsections the question is revised.

3.1 Automobiles and Pollutant Emissions

There are formally seven criteria pollutants: carbon monoxide (CO), sulphur dioxide (SO_2), ozone (O_3), nitrogen dioxide (NO_2), lead (Pb), and suspended particulate matter, measured through PM_{10} and $PM_{2.5}$ levels. Standards vary between countries, with varying definitions of acceptable pollution levels; debate on what level of pollutant concentration is safe, especially in the case of fine particles, is continuous. To provide an overview of some differences among these standards, Table 2.2 lists recommended air quality values (i.e., concentration limits for each pollutant over a specified period of time[23]) set by various countries and the WHO.

[23] The most commonly used unit in specifying concentrations is parts per million (ppm), which is the number of molecules of a specific pollutant found in a million molecules of air, this is equivalent to the number of volumes of the pollutant in a million volumes of air; another unit of measurement is mass of pollutant per volume of air, usually expressed as micrograms per cubic meter (µg/m3).

Table 2.2 Ambient air quality standards for WHO and different countries

	CO ppm	SO_2 ppm	O_3 ppm	NO_2 ppm	PM_{10} µg/m^3	$PM_{2.5}$ µg/m^3	Lead µg/m^3
WHO	26 (1h) 9 (8h)	0.13 (24h)	0.08 (1h) 0.06 (8h)	0.21 (1h) 0.08 (24h)			0.5-1 (1y)
United States	35 (1h) 9 (8h)	0.14 (24h)	0.12 (1h)	0.21 (1h)	150 (24h)	65 (24h)	1.5 (qtr)
Mexico	11 (8h)	0.13 (24h)	0.11 (1h)	0.21 (1h)	150 (24h)	a	1.5 (qtr)
Colombia	10.5 (8h)	0.13 (24h)	0.08 (1h)	0.17 (1h)	160 (24h)		
Brazil	9 (8h)	0.14 (24h)	0.08 (1h)	0.17 (1h)	150 (24h)		
Chile		0.14 (24h)	0.08 (1h)	0.05 (24h)	150 (24h)		
Canada	30 (1h)	0.06 (24h)	0.05 (1h)	0.03 (24h)	30 (24h)	50 (24h)	
China	3.5 (24h)	0.019 (24h)	0.06 (1h)	0.04 (24h)	50 (24h)		1.5 (qtr)

[a]In Mexico there is still no official standard for this pollutant, the monitoring of which began recently in 2003. However, it would be set, according to PROAIRE 2002-2010 program, 65µg/m^3. Source: Molina and Molina 2002, 2004

As seen in the table, countries like Canada generally have more stringent standards than countries like Mexico or Brazil; policies and instruments have accordingly reflected these lax standards. The lack of monitoring some pollutants like $PM_{2.5}$, illustrates the difference between countries' environmental policies.

As mentioned in the previous section, virtually all large cities make important contributions to the production of greenhouse gases due to their large number of vehicles in operation. That is, there is indeed a high incidence of automobile pollutant emissions among the air pollution levels of major urban centres. Specifically, motor vehicles emit several pollutants that contribute to air pollution in a significant way, mainly: volatile organic compounds (VOC), carbon monoxide (CO), nitrogen oxides (NOx) and sulphur dioxide (SO2). Table 2.3 lists the primary air pollutants[24] emitted into the atmosphere from motor vehicle operation, and the potential local, regional and global consequences of the release of these

[24] These are distinct from secondary air pollutants formed in situ in the atmosphere as a result of oxidation or photochemical reactions.

chemicals into the environment. For example, the NO_x pollution of air correlates strongly with the incidence of respiratory symptoms (above all among children[25]); also, an increase in exposure to breathable particulate matter (i.e., PM_{10}) correlates with elevated mortality rates and a higher incidence of cardiovascular and respiratory disease[26]; in addition, some VOCs that are important ozone precursors, such as 1,3-butadyne and benzene, are also classified as air toxins because they are carcinogens[27]. In brief, motor vehicles contribute to the seven criteria pollutants emissions plus many other different substances (the next section, focused on the case of Mexico City, gives further details).

[25] Although it does not appear to be involved in the development of asthma, it is related to the exacerbation of symptoms of existing asthmatic diseases.
[26] On the other hand, a reduction in the exposure increases life expectancy.
[27] This also means that, for these particular substances, no limit value can be specified below which there is no risk of developing a disease. For example, the intake of benzene by humans increases the risk of developing leukaemia.

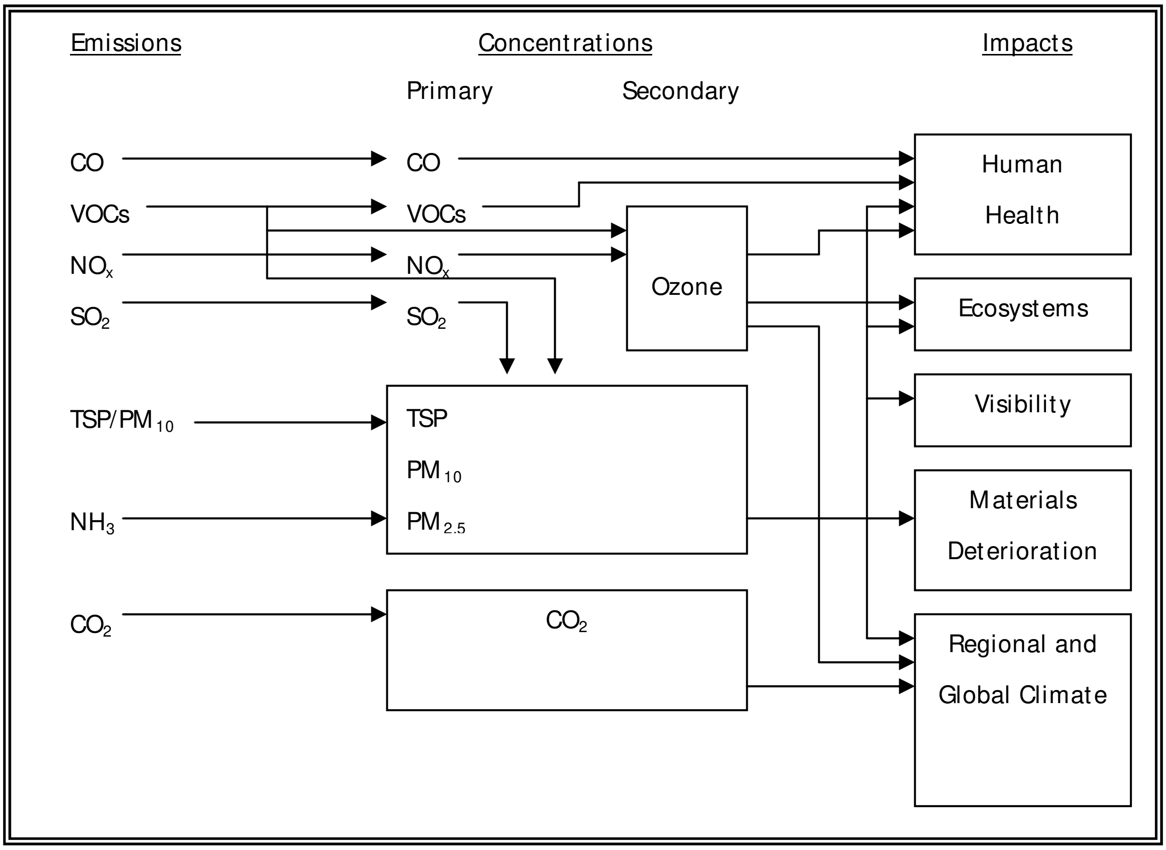
Table 2.3 Major primary pollutants from automobiles use and their impacts

Pollutant	*Source*	*Effects and Consequences*
1,3-butadyne	Vehicle exhaust	Probable carcinogen; ozone precursor
Formaldehyde	Vehicle exhaust	Respiratory irritant; probable carcinogen; ozone precursor
Benzene	Vehicle exhaust	Carcinogen
Alkenes, aromatic hydrocarbons	Vehicle exhaust	Ozone precursors
Nitrogen oxides (NO_x)	Vehicle exhaust, combustion	Increased respiratory disease; ozone and acid rain precursors
Polycyclic aromatic hydrocarbons (PAHs)	Incomplete combustion	Some are probable carcinogens
Sulphur dioxide (SO_2)	Coal and other sulphur-containing fossil fuel burning	Increased respiratory disease; acid rain precursor
Ammonia (NH_3)	Vehicle exhaust	Respiratory irritant; neutralizes acids
Respirable particulate matter (PM_{10})	Incomplete combustion	Increased respiratory disease; reduced visibility
Fine particulate matter ($PM_{2.5}$)	Fuel combustion, diesel exhaust	Increased respiratory and cardiopulmonary disease; reduced visibility
Lead (Pb)	Leaded gasoline	Kidney and brain damage; learning disabilities
Carbon monoxide (CO)	Incomplete combustion	Cardiovascular and neurobehavioral disease
Carbon dioxide (CO_2)	Fossil fuel and biomass burning	Global warming

Source: Molina and Molina 2002

The above information is illustrated in the following Figure 2.1, which shows the connections between pollutant emissions, ambient concentrations and impacts. The diagram shows the multiplicity of impacts and pollutants, which interact chemically in complex ways. For example, VOCs react with NO_x in the atmosphere to form ozone (O_3) and also generate particulate matter. Also, motor vehicles powered by petroleum products emit carbon dioxide (CO_2), one of the greenhouse gases accumulating in the atmosphere. It is noted in the literature that automobiles are not the sole source but indeed the most important one for many of these pollutants (INE 2000).

Figure 2.1 Connection of emissions pollutants, ambient concentrations and impacts



Source: Molina and Molina 2002

However, the impact on air pollution and the particular emission depends in large part on the type of automobile in question; much of the progress in controlling urban air pollutants can be traced to motor vehicle emission reductions, and significant changes in fuel quality[28]. For example, automotive lead emissions were once the dominant source of

[28] In this sense, when fuel composition is changed, all vehicles using the fuel may experience changes in emissions, although the amount of emission reduction will depend on vehicle technology and maintenance. One

atmospheric lead, but were virtually eliminated in many cities as unleaded gasoline supplanted leaded fuel[29]. For other pollutants, governmental tailpipe-standards have helped to reduce new vehicle emission rates, but declines in emissions from vehicles already in circulation have not kept pace with those new vehicle emissions.

Pickrell (1999) shows how large the resulting emissions gap between automobiles already on the road versus brand-new automobiles: automobile CO and VOC emissions in everyday use average eight to ten times those of brand-new automobiles under test conditions; amongst all automobiles NO_x emissions rates during everyday driving average about four times those of brand-new automobile test levels. The difference is because, as expected, most cars on the road were introduced under less stringent emissions standards (plus associated decreasing motor performance). Additionally, vehicle emission control systems do not perform as well under real-world driving conditions as they do under the carefully controlled temperatures, fuel consumption and performance demands used to test new models' compliance with emissions standards.

Among automobiles there are strong relations between aging, real-world driving, malfunctioning emission control systems and pollutant emissions. Ageing is self-explained: older cars have less sophisticated emission control equipment, and the condition of the emission control equipment deteriorates with time and use. In the case of Mexico City, vehicles equipped with catalytic converters (i.e., 1993 and newer) represent about 40% of all vehicles, but contribute only 15% of total emissions, whereas older vehicles (i.e., produced 1985 and before) represent 30% of those in circulation but contribute 55% of total emissions (INE 2000). Real-world driving factors include higher speeds and more rapid acceleration, steeper road grades, widely varying temperatures, use of accessories such as air conditioning and fuel consumption. As a result of malfunctioning emission controls, the emission characteristics of cars can change markedly over time, particularly if the vehicle is not well maintained.

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important feature of changes in fuel formulation is that resulting emissions reductions occur much sooner than those from measures such as tighter emissions standards that depend on vehicle turnover to take effect.

[29] In the US most of the decline in lead emissions from gasoline-powered vehicles occurred between 1975 and 1985.

Additionally, fuel evaporation is considered another significant type of automobile emission[30]. Evaporative fuel loss occurs during vehicle refuelling, at different rates during various phases of operation and during both short and long-term parking (which can include traffic jams). Pickrell (*idem*) reports that emissions caused by evaporation of gasoline account for nearly 40% of the difference in VOC emissions from vehicles in day-to-day driving over tailpipe emissions measured during new-model testing[31].

Lastly, this section ends with some lines about the costs (and their internalisation) of the above mentioned automobile pollutant emissions. Costs of vehicle emissions, unlike with congestion costs, are borne by everyone, and unlike accident costs there is no doubt that emission costs are external. Thus, there are three important characteristics of air pollution from vehicles of which policies must take heed. First, emissions differ substantially between automobiles according to the characteristics of the vehicle. Second, the marginal damage caused by emissions varies enormously over time and space for all but a handful of pollutants: most emissions do not dilute perfectly but rather have local effects[32]. Thirdly, emissions from individual vehicles cannot be monitored[33].

3.2 Automobile Dependence in Cities

Automobile dependence in cities consists of high levels of per capita vehicle kilometres travelled, automobile oriented land use patterns and limited transport alternatives (Newman 1996). The term refers to the attitude (by consumers and government) toward the use of automobiles and also describes the broader situation involving the extensive use of automobiles. To illustrate the latter, Litman and Laube (2002) offer the following example: if by restraining from automobile usage during a given period of time a person faces significant problems moving from one point to another in the city, including troubles with commuting, running errands and even crossing streets, then the city can be characterized as automobile dependent. Another example apart would be a case where, even with the availability of

[30] In general, evaporative emissions are regulated separately from tailpipe emissions.
[31] Nonetheless, in the case of Mexico City, an important source of uncertainty in the emissions inventory for mobile sources is actually the proportion of evaporative emissions compared to tailpipe emissions.
[32] What this means is that the same emission has the potential to harm many more individuals if it is released in an area of high population density at low level.
[33] Although there are attempts afoot to test the technology to do just that.

transport services and infrastructure, the individual is still automobile dependant. In the latter case, there is a kind of opposition to the use of public transport, a particular attitude (i.e., unawareness of system improvements), which the traditional approach tends to obviate (in the, say, traditional analysis).

Automobile-oriented land use patterns have been analysed more in the urban planning literature as a factor for automobile-dependence. It is significant that neighbourhood type (the degrees of orientation toward auto travel and being conducive to walking, bicycling and public transit) is a strong predictor of displacement mode. In particular, neighbourhood characteristics exert their strongest effect on local non-occupational displacements (Cervero and Radisch 1996). There is also a relation between vehicle ownership, non-work travel and neighbourhood type. Cervero and Radisch (1996) report that pedestrian-oriented mixed-use neighbourhoods may reduce the need to own a second or third family car, which in turn could induce more non-auto displacements for neighbourhood convenience shopping and other more discretionary trips. Household automobile ownership rates are indeed relatively low in compact, mixed-use neighbourhoods[34]. Above all, residents of compact, mixed-use and pedestrian friendly neighbourhoods substitute walking for automobile travel.

Explanations for this auto dependence offer us additional views of the link between urbanization and motorization. The problem is not autos per se or urban growth, but rather personal values and economic growth (or the conditions of this process). Likewise, auto dependence varies greatly between cities, even for cities where residents have comparable income levels; there are wealthier regions with balanced transportation systems (e.g., most European cities) but also some others with high or very high auto dependence (e.g., most American cities). Some poorer regions can be also quite auto dependant, or currently are in the process of becoming so. Differences generally result from public policies that affect transport choices and land use patterns (Litman and Laube *op. cit.*); these kinds of policies include public expenditure on roads and traffic services, abundant parking requirements, favourable pricing policies and land use scaled for automobile travel. Litman and Laube

[34] Mixed-use is a land-use term which refers to commercial, residential, industrial and recreation zones, as opposed to traditional single use zoning.

(*idem*) summarize the transport market distortions that favour automobile use. Under the assumption that the market is best able to allocate resources (with respect to private goods), current transport markets violate principles of choice, competition, optimal pricing and economic neutrality. In particular, when few transport alternatives are present, policies favouring automobile use under-price and so lead to auto dependency.

One might think that all necessary information about transport alternatives (i.e., besides automobiles) is readily available, but auto-dependency can only be overcome in relation to the extent that this information reaches its target group. Brög *et al.* (2002) take this issue into account and show how "soft policies"[35] can make people think about their travel behaviour. They argue that lack of information and motivation are the starting point for auto-dependence. Brög (2003) adds that the importance of motorised private transport is overestimated and that the possibility of reducing it is underestimated; according to his conclusions, perceptions about automobile alternatives are considerably worse than the true state of affairs[36].

In general, many cities in the Global South (referred commonly as the less developed part of the world) face comparable problems to Northern cities with regard to traffic congestion and air pollution arising from road vehicles. However, some European, Australian and Canadian cities are showing trends towards reduced growth in VKT due to the provision of more appealing alternatives than automobile-driven policy-making[37]; these cities are also increasing the number of transport alternatives and reducing automobile subsidies such as free parking. On the other hand, cities like Los Angeles continue to be cases where addressing the problem of auto-dependence faces a culture that grants little clout to planning other than the facilitation of individual mobility (Newman 1996). The common view is that the proliferation of motor vehicles in the developing world, above all in urban settings, presents a substantial threat to environmental sustainability (Dahl 2005).

[35] This refers to informing people to enable improved perception, to motivate them and to empower them to make better decisions, rather than telling them what they should do (Brög *et al.* 2002).
[36] The fact that perception controls behaviour patterns, presents the key to effective and sustainable influence.
[37] On the contrary, most cities rely too much on technological advances to resolve problems.

3.3 Ownership versus Use: A Reappraisal

This last subsection reviews two different dimensions of automobile consumption: 'ownership' versus 'use'. This review will conclude that ownership is not the salient factor in studying the environmental impacts of automobile consumption, but rather use. For this research, the consumption of an automobile is synonymous with the use of it, and not ownership[38].

Research inputs and outputs are subject to a particular notion of consumption. Automobile ownership, i.e., purchasing an auto, is a kind of consumption, but for the aims of this research, buying an auto does not have the same environmental impact as auto usage. Indeed Ferrer-i-Carbonell and van den Bergh (2004) show how automobile ownership can be taken into account in order to analyse unsustainable consumption. However, their research did not focus on the estimation of the environmental impacts of consumption (i.e., the externalities of using the automobile). This research does not estimate such impacts either, but it does figure into the analysis of unsustainable consumption.

As opposed to the early stages in automotive history, automobile usage is today more important and relevant than ownership when considering the societal nature of automobiles. Automobile usage is what delivers on buyer expectations at the time of purchase, and the outputs of this kind of consumption are shared by both the individual and society. Policies consequently reflect the difference between owning and using automobiles[39].

For example, pricing methods (as economic instruments for demand management tools) can be focused on both ownership and use of autos, however, only those policies

[38] Regarding the concept of car sharing, certainly it is a type of auto consumption, but it can be considered another way of 'use'. Above all, what matters for this research is the impact of using an auto, in particular, the private (i.e., personal) use of it.

[39] Moreover, further implications (and theoretical discussion) surface when considering usage as one feature of the auto as a 'positional good' (i.e., scarce in some absolute or socially imposed sense and subject to congestion or crowding through more extensive use). That is, for example, if the problem is that certain forms of private consumption currently seem more attractive to individuals than to society as a whole (e.g., use of private cars versus use of public transport), the simplest solution is to make those forms less attractive by taxing them (Frank 1997). By considering the idea of positional goods it can be argued that the economic growth, to the extent that it increases socially unattainable aspirations, may actually reduce social welfare. However, as Ng (1978) points out, what is needed is not to stop growth but to realise that growth can make an average person better off if aspirations remain realistic (i.e., more non positional goods rather than more positional goods).

focused on the 'use' will ultimately achieve the desired result of reducing negative environmental impacts. Specifically, taxes on car ownership have been used as sources of public revenue and the basic purpose has not been to rationalise activity per se (of having and driving autos). What can be achieved with taxes or restrictions on automobile ownership amounts to limitations on the total stock of automobiles, this is not equal to controlling the impacts of automobiles already on the road. Moreover, reducing auto-dependence is possible even in societies with high levels of car ownership; in Germany, Freiburg's car ownership rose from 113 cars per 1000 people in 1960 to 422 per 1000 in 1990: despite this growth, car use has remained virtually constant since 1976; the increase in mobility was supplied principally by increased public transport and bicycling (Newman 1996)[40].

Policies to improve transport demand management must be focused on automobile usage. Demand management tools aim to increase the perceived and paid costs of vehicle road use in order to reach the full real costs. As noted, the cause of the problem is not ownership of one or many autos, but trips driven and the price paid per trip, particularly the price paid for one additional trip. Automobiles do not cause much pollution or congestion: displacements are the problem, i.e., use and not ownership of automobiles.

4. THE CASE OF MEXICO CITY

The country of Mexico contributes nearly 2% of the global greenhouse gases (GHG) emissions, placing it among the 15 largest GHG-emitting countries in the world (Molina and Molina 2004). Following current trends in energy consumption, it is expected that in the year 2010 Mexico will produce nearly twice its current emissions. Since 1994, Mexico, as member of both the OECD and NAFTA, has been under pressure to limit its growth in GHG emissions; at the same time, Mexico is clearly a developing country in terms of its average income per capita, the lack of basic services for a large fraction of its population and its emissions per

[40] Newman (1996) also mentions another example: Copenhagen, Denmark. He quotes Gehl: "By the 1960s, American values had begun to catch on separated isolated homes and everyone driving [...] We decided to make the public real so attractive it would drag people back into the streets, whilst making it simultaneously difficult to go there by car." The result was a reduction in the traffic, despite the conventional wisdom, says Newman, that "Danes will never get out of their cars".

capita. Furthermore, the country does not have the economic resources needed to carry out incremental investments in GHG reduction measures[41]. A decrease in emissions of GHGs, particularly CO_2, depends directly on the efficient use of energy and on the carbon content of fuel[42].

A recent survey by Grupo Reforma (2007), about the quality of life in Mexico City reveals some resident attitudes and perceptions. For example, in general, there is satisfaction regarding the quality of life in Mexico City (i.e., “How much do you like living in the city?”): 40% of residents like living there very much, 30% somewhat, 38% are satisfied living in the city and 7% are very unsatisfied. In particular, people from the southern sections of the city feel much more satisfied with the quality of life, an expected result since people with higher incomes tend to live there (South and West). Conversely, scientific literature tends to focus on the problems and challenges of Mexico City. This chapter has reviewed some of those problems and issues common to cities like Mexico City. This section focuses its analysis of air pollution and autos on the case of Mexico City; what are the characteristics of Mexico City’s air pollution problem and its transportation system, particularly with respect to private motorists in the Distrito-Federal? This question is analysed step by step in the following paragraphs. Contrary to what the above mentioned public-opinion surveys show, this chapter will conclude that private motorists and their associated environmental impacts are indeed a real problem for Mexico City and its development.

The next four subsections will follow the same basic approach as above. First, a profile of Mexico City’s characteristics and peculiarities is presented. Then, a review of what is possibly its most important problem: air pollution. Discussion then narrows to the transport sector, with the dual quality of being both a major source of air pollution and a critical enabler of economic activity and beneficial social interactions. The problems of autos

[41] For example, regarding the more significant GHG, the total emissions of CO_2 associated with fuel consumption in Mexico City are nearly equal to 13% of the national emissions. Similarly to energy consumption, transport represents 55% of the emissions of CO_2, followed by industry (20%), the residential sector (16%), electricity generation (8%) and the commercial and agricultural sectors (1%). In the transport sector, private vehicles are specially important, contributing 38% of the emissions from this sector.

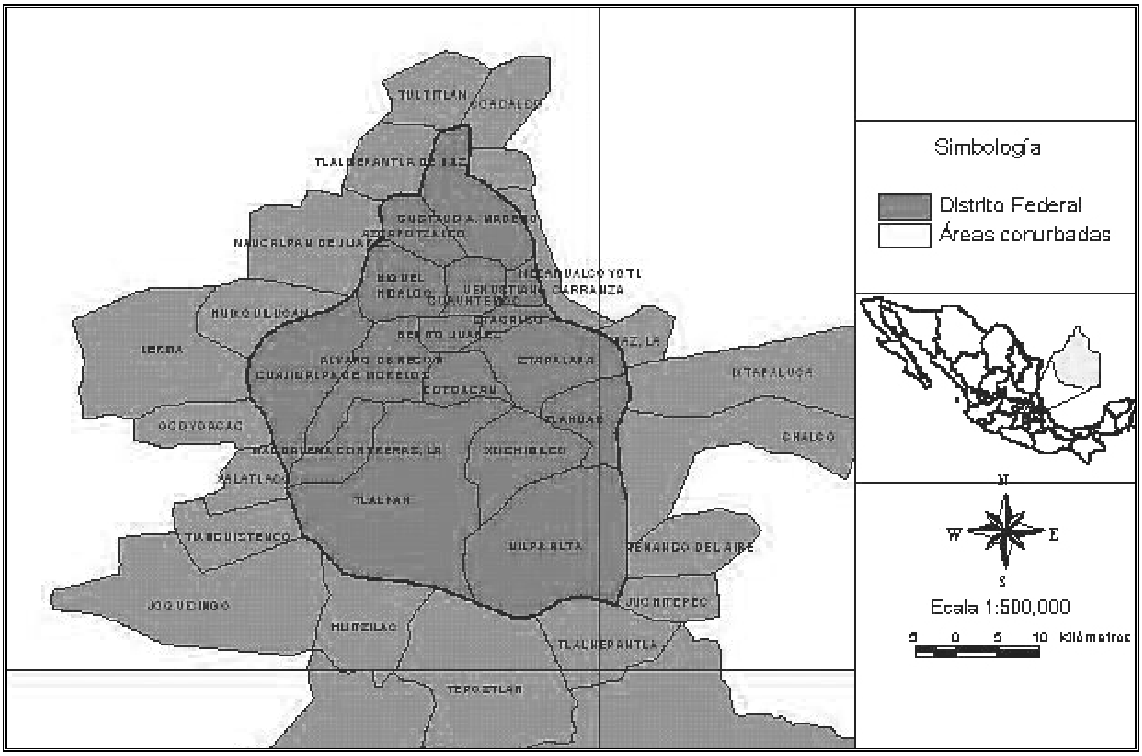
[42] The policy that has contributed most to the decrease in emissions of CO_2 in the region is the change from fuel oil to natural gas in industry. However, technologies for controlling transport emissions have not contributed to the decrease in emissions of CO_2.

and private motorists are then discussed in light of this. The section concludes with a description of the *Hoy no circula* (HNC) program, the only demand management program applied in Mexico City thus far.

4.1 Mexico City Profile

In this research I use the definition of Mexico City provided by the Mexican National Council of Population (*Consejo Nacional de Población*, CONAPO). The metropolitan region includes four geographic scales. First, the historical inner city or downtown area (known as the *Ciudad de México* or the “City of Mexico”) includes four *delegaciones* (Miguel-Hidalgo, Cuauhtémoc, Benito-Juárez and Venustiano-Carranza). Second, the Federal District (Distrito-Federal or DF; see Figure 2.2), which includes the four *delegaciones* listed above and twelve others: Azcapotzalco, Coyoacán, Cuajimalpa, Gustavo-Madero, Iztacalco, Iztapalapa, Magdalena-Contreras, Milpa-Alta, Álvaro-Obregón, Tlahuac, Tlalpan and Xochimilco. The DF is the federal capital of Mexico; it is the site of the national government and is the financial, commercial and service centre of the region (and to a certain extent of the whole country). The next scale up is the Metropolitan Area of Mexico City or Mexico City Metropolitan Area (MCMA) or, in short, Mexico City. This third level is comprised of the DF (i.e., its 16 *delegaciones*, its political divisions) and 37 major urbanized municipalities (*municipios*) from the State of Mexico (EM) and one from the State of Hidalgo (EM and Hidalgo are both federal states of Mexico and their political divisions are called municipalities). Finally, at the fourth and highest level, there is the so-called “Megalopolis” which extends beyond the MCMA 75-150 km from the city centre to include the surrounding “crown” of cities including Puebla, Tlaxcala, Cuernavaca, Cuautla, Pachuca and Toluca,. The present research refers only to the MCMA (or Mexico City) and, in particular (regarding the data), to the Distrito-Federal area.

Figure 2.2 Map of the Distrito-Federal and outskirts



Mexico City (19°25' N Latitude and 99°10' W Longitude) lies in a basin at an altitude of 2240 m above mean sea level. Thus its air contains 23% less oxygen than at sea level; as a consequence, internal combustion engines must be carefully tuned to the proper oxygen/fuel ratio; improper adjustment leads to inefficient combustion and increased emissions. Another consequence of this high altitude is quite logical: humans must inhale more air in order to gain an equivalent amount of oxygen; a correspondingly higher dose of air pollutants is also inhaled than would be the case at a lower elevation. For any given concentration of pollutants in the atmosphere, people in Mexico City are likely to inhale more than people in most other large cities and be more seriously affected by respiratory ailments.

Moreover, the basin where the city lies, covering approximately 5000 km^2 of the central Mexican Plateau, is confined on three sides (East, South and West) by mountain ridges, with a broad opening to the North and a narrower gap to the South-Southwest. The surrounding ridges vary in elevation with several peaks attaining an elevation of nearly 4000 m; two major volcanoes, Popocatepetl (5452 m) and Ixtazihuatl (5284 m), are located on the mountain ridge southeast of the basin. Mexico City is located on the southwest side of the basin and covers about 1500km^2 of land. The Southern and Western ridges present a natural barrier which makes more difficult the natural dispersal of pollutants, at the same time blocking North winds from sweeping through and cleaning the zone[43].

Next, in contrast to mid-latitude megacities, high ozone episodes can occur throughout the year because Mexico City's subtropical latitude and high altitude are conducive to ozone production during the winter as well as the summer (although, during the wet summer months high ozone episodes are less frequent because clouds inhibit photochemistry and rainfall removes many trace gases and particulates). The combination of altitude and latitude is thus optimal for ozone creation and thermal inversions—in winter, when rain is less common, these thermal inversions are more frequent and air pollution is generally worse.

Added to these natural factors is a large and increasing human population. Table 2.4 shows the population growth since 1940 and the projection for 2010 (by CONAPO) for the MCMA and the DF, and the percentage of the national population in each of these two regions. Table 2.5 shows the rate of population growth.

Table 2.4 Population growth in the MCMA and DF, in millions of inhabitants, and as a percentage of national population (%)

Year	*National*	*MCMA*	*DF*
1940	19.65	1.76 (9.16%)	1.75 (8.94%)
1950	25.80	2.98 (11.55)	2.92 (11.31)
1960	34.92	5.16 (14.78)	4.85 (13.89)
1970	48.23	8.65 (17.93)	6.87 (14.24)
1980	66.85	13.73 (20.54)	8.83 (13.21)
1990	81.25	15.05 (18.52)	8.24 (10.14)
2000	97.35	17.87 (18.36)	8.59 (8.82)
2010	111.68	20.74 (18.57)	8.67 (7.76)

Source: CONAPO 2000

[43] Actually, what usually happens is that these winds blow pollution from the region of heaviest industrial development towards downtown and the residential areas southwest of the city.

Table 2.5 Average annual population growth rates for the MCMA and DF

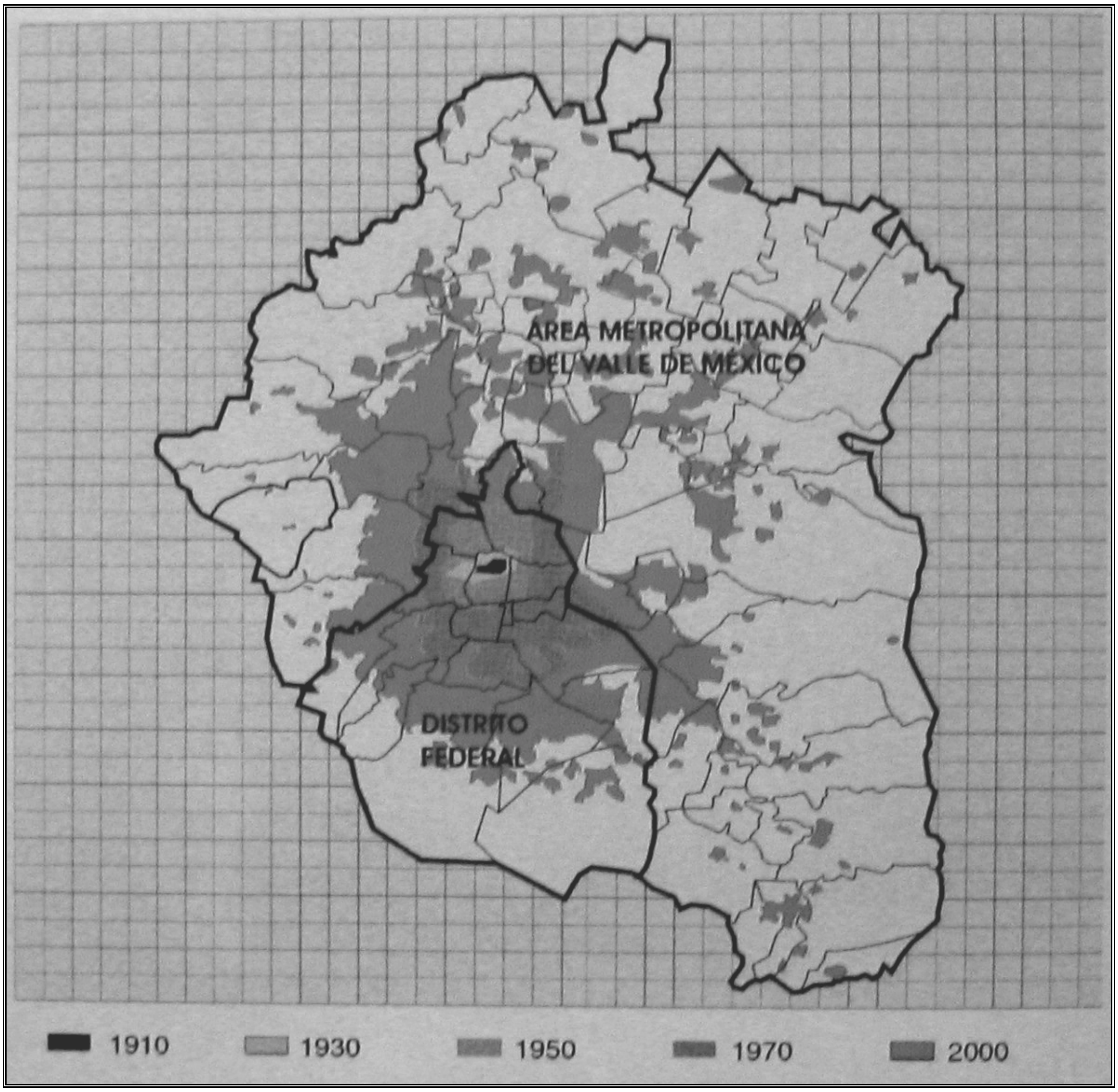
	National	*MCMA*	*DF*
1940-1950	2.76	5.17	5.25
1950-1960	3.07	5.64	5.2
1960-1970	3.28	5.3	3.5
1970-1980	3.32	4.73	2.5
1980-1990	1.974	0.92	.69
1990-2000	1.82	1.73	.42
2000-2010	1.38	1.5	.09

Source: CONAPO 2000

In recent decades the average annual growth rate for the MCMA has declined. For example, while the annual average rate for the MCMA in 1960 was over 5%, it had dropped to 1.7% by 2000. The rate of growth in the DF has also continued to decline; recent data show that eight *delegaciones* had negative annual average growth rates during the period 1990-2000, while the other eight showed positive growth. In general, the rate of population growth in the DF is expected to decline[44]. Figure 2.3 shows the expansion of the MCMA from 1910 to 2000.

[44] This fact does not mean at all a less demographic pressure. As Connolly (1999) correctly summarizes: "Adults require more space than children, to live in, to travel in, to work in. They also eat and drink more, consume more energy and create more rubbish. In short, for the predictive and provide mentality, the demographic transition has its ecological downside".

Figure 2.3 Expansion of the MCMA from 1910 to 2000



Source: Molina and Molina 2002

The average population density of the MCMA is 12000 inhabitants per km^2, which is high relative to other megacities in the world (e.g., 840 in Los Angeles, USA). Only the Asian cities of Bombay, Calcutta and Hong Kong have higher densities. In the DF, average densities rose steadily from 12,700 to 17,200 inhabitants per km^2 between 1960 and 1980, and then dropped gradually to 12,100 by the year 2000. These dynamics of population and city growth are basically based on rural-to-urban immigration combined with high to moderate fertility. The rate of growth has not been homogeneous throughout the MCMA: while the DF had an annual growth rate of 0.5% during the last decade, the population of the surrounding municipalities grew faster, at about 3.2% annually from 1990 to 1999, even higher than the national mean.

Overall, the MCMA has followed an expansion model of urban development, which has been fuelled primarily by suburbanization and weak enforcement of laws protecting natural areas that were established in the first place out of an attempt to control growth and urban sprawl. Trends predict that the most rapid growth in the MCMA will occur in the EM, which by 2010 is expected to have over 60% of the MCMA's population. With respect to the physical extent of the MCMA, its urbanized area increased from 118 km^2 in 1940 to 683 km^2 in 1970 and approximately 1500 km^2 in year 2000. If this trend continues (i.e., intense urbanization over large tracts of vacant land) the population density will remain constant.

Finally, the MCMA represents the largest concentration of economic activity in the country, with around 33% of GDP. Its economic behaviour shows a strong positive correlation with the national economy. However, the DF has experienced an average economic growth that is less dynamic than the national economy (which is not the case for the EM, which has enjoyed a very similar growth rate to that of the national economy). It is arguably expected that the contribution of the DF to the national product will over time decrease around 1% every five years (GDF 2001), but the GDP per capita in the DF will grow faster than in the State of Mexico (due to large demographic pressure in EM and the population stagnation in the DF)[45]. Another issue to take into consideration is that further growth will not occur simultaneously in all economic sectors throughout the MCMA; that is, agricultural activities will not develop further in either the EM or the DF, while the industrial sector will show significant growth in the EM, and the services sector will be developed mostly in the DF.

[45] These differences in per capita income are generating important geographic disparities in consumption structures: for example, private cars are used intensively in some areas while the demand for public transport and the use of old cars is concentrated in other parts of the city.

4.2 Pollution Problems: Air quality[46]

The same geographical conditions that make Mexico City such good place to live (i.e., temperate sunny daytime weather and cool nights) also serve to aggravate atmospheric pollution. Its large population, industries (i.e., economic activity), 3.5 million vehicles (reviewed in the next section), history of urban development, complex topography and meteorology cause high pollution levels. Major air pollution control efforts started in Mexico City only a decade ago[47], where, despite significant progress, serious problems still persist with high concentrations of ozone and particulates that are detrimental to public health.

By the mid-1980s public concern about air quality heightened with worsening pollution. Ozone levels in the city increased dramatically, reaching peaks above 350 ppb, and had become the worst in the world. The legal framework was strengthened in 1988 with the new General Law of Ecological Balance and Environmental Protection (LGEEPA), which defined responsibilities at federal, state and local governmental levels[48]. At the end of the 1980s, air quality management had achieved higher political priority, but still suffered from persistently weak institutions and limited technical capacity. In 1986, still before the LGEEPA, new petrol with added detergent to reduce lead emissions was introduced. Jointly, these were the (real) first of a series of measures to control vehicle and industrial emissions, culminating in a comprehensive metropolitan anti-pollution policy put into action from the early 1990s onward. The following Table 2.6 summarizes the chronology of Mexico City's anti-pollution measures.

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[46] By way of definition, air is a mixture of nitrogen, oxygen and minute amounts of other gases that surrounds the earth and form its atmosphere (i.e., argon, neon, helium, krypton, hydrogen, nitrous oxide and xenon, which are the permanent gases, and, as variable gases, water vapour, carbon dioxide, methane, carbon monoxide, ozone, ammonia, nitrogen dioxide, sulphur dioxide and hydrogen sulphide), if there are other particles or gases in the air that are not part of its normal composition, we have then "air pollution" and such particles or gases are called "air pollutants". Humans can see some air pollutants such as the reddish-brown haze in smog but other air pollutants, including some of the most dangerous to human health, are invisible (See Appendix B).

[47] Air pollution has been monitored routinely since the mid-1970s but policy initiatives started to be enacted in the 1990s. Regarding monitoring, before 1988, measurements had been built up over a number of years from early manual systems initiated in 1967. Data from these are inconsistent but provide a picture of rapid deterioration throughout the 1980s, particularly concerning pollution from carbon monoxide, sulphur dioxide and hydrocarbons. Emissions inventories have been developed since 1986; however, there are substantial differences in the emission inventory reported in different years, explained partly by changes in emissions over time and more likely by differences in emission inventory methodology (Molina and Molina 2004).

[48] In addition, the LGEEPA encouraged the development of policy instruments based on alternative regulatory schemes such as the polluter-pays principle, other market mechanisms and the inclusion of cost-benefit analysis into policy making.

Table 2.6 Mexico City's Clean Air Policy

1971	Federal Law for the Prevention and Control of Environmental Pollution.
1976	Creation of the Sub-secretary of Environmental Improvement, in the Secretary of Health.
1978	Establishment of the Inter-ministerial Commission for the Environment was established to oversee the implementation of the 1971 regulations.
1982	Second environmental legislation: Federal Law of Environmental Protection, administered by the newly created Ministry of Urban Development and Ecology (SEDUE). The law was amended in 1984 to include an air quality monitoring system.
1985	Establishment of the National Commission on Ecology to define priorities in environmental matters and to coordinate the different institutions dealing with environmental actions.
1988	Reform of the above legislation into the new General Law of Ecological Balance and Environmental Protection.
1989	Introduction of unleaded gasoline, implementation of the "No Driving Day" (HNC) program, mandating of the Vehicle Verification Program (VVP).
1990	Implementation of the Comprehensive Program Against Air Pollution in the MCMA (PICCA)
1992	Separation of the federal environmental administration into two autonomous offices: the National Institute of Ecology (INE) and the Attorney General for Environmental Protection (PROFEPA); Reorganization of SEDUE into the Ministry of Social Development (SEDESOL); creation of the Metropolitan Commission for Pollution Prevention and Control (CMPCCA); establishment of the Ministry of Natural Resources, Environment and Fisheries (SEMARNAP).
1996	Program to Improve the Air Quality in the Valley of Mexico (PROAIRE), 1995-2000, replacing PICCA.
2000	Ministry of Environment and Natural Resources (SEMARNAT), replacing SEMARNAP; the CMPCCA was succeeded by the Metropolitan Environmental Commission (CAM).
2001	Program to Improve Air Quality in the Valley of Mexico (PROAIRE), 2002-2010.

Source: Molina and Molina 2002 and Connolly 1999

The most significant improvements during the 1980s until the mid-1990s came mainly from the removal of lead from gasoline (in 1989) and measures arising out of the 1990 first Integral Programme against Atmospheric Pollution in Mexico City Metropolitan Area (PICCA)[49], such as the reduction in the sulphur content of diesel and heavy oil, closing of an oil refinery located in central Mexico City (i.e., "*18 de Marzo*"), obligatory catalytic converters in all new cars (to decrease carbon monoxide concentrations), and stricter inspection of cars (starting as a yearly emissions-test and increasing to six-monthly tests in 1994). In short, industrial atmospheric pollution was cut by 65% between 1992 and 1997;

[49] PICCA was implemented in October 1990 and lasted until 1995. Its main objectives included reducing lead, SO_2, particulates, hydrocarbons and NO_x emissions. Without the benefit of accurate emissions inventories (see above note 36) or modelling capabilities, most strategies were based technology modernization and fuel improvement, focusing on robust measures successfully implemented in other parts of the world.

while the 1990s saw ambient measures of SO_2 decline sharply, carbon monoxide concentrations decrease to acceptable levels, and the extreme high peaks in ozone and particulate pollution virtually disappear.

During the decade of the 1990s, several administrative bodies were established to address environmental issues (e.g., the Secretary of Environment, Natural Resources and Fisheries, and the Metropolitan Environmental Commission). In 1996, the Program to Improve the Air Quality in the Valley of Mexico (PROAIRE 1995-2000) was initiated to replace PICCA. Its objectives included, as with PICCA, reducing hydrocarbons, nitrogen oxides and particle emissions, as well as modifying the overall distribution of ozone concentrations to reduce ozone peaks and averages and increase the number of days in compliance with national standards[50]. The major resulting measures from PROAIRE were stricter emissions-testing levels, and (the above mentioned) reformed LGEEPA, widening federal jurisdiction in industrial regulation and imposing stricter fuel emissions standards for industry and services, especially for nitrogen oxides and volatile carbon compounds. During the 1990s, the most significant progress came from the use of improved vehicle and fuel technologies to mitigate vehicle exhaust; concentrations of lead are not a public health concern any longer, sulphur dioxides are now at relatively low levels and dust storms, frequent in the past, have been eliminated (Molina and Molina 2002).

Despite implemented actions, concentrations of ozone, nitrogen dioxide and particulate matter showed only marginal improvement over the 1990s. Ozone and particulate matter are the air quality standards most commonly violated in Mexico City[51]. Also, some data indicate that NO_x control programs have resulted in little NO_x reduction. Table 2.7 shows the difference between air quality standards and peak concentrations in Mexico City from 1997 to 1999. As it can be seen, substantial challenges remain to effectively reduce concentrations of these mentioned pollutants. Consequently, the ongoing PROAIRE program (i.e., PROAIRE 2002-2010) focuses in particular on ozone and PM.

[50] PROAIRE was the first program to stress the importance of health, providing data from epidemiological surveillance and relating particulate matters with mortality.

[51] Violations of other standards are much less common now. In the case of ozone, the standard has been violated on about 80% of days every year since 1980s. The daily standard of PM_{10} has been exceeded on more than 40% of the days in some years (INE 2000).

Table 2.7 Air quality standards and peak concentrations in Mexico City in 1997-1999

Pollutant (averaging time)	*Units*	*Air quality standard: Mexico/WHO*	*Peak concentrations*		
			1997	*1998*	*1999*
Ozone (1h)	ppm	0.11/0.08	0.318	0.309	0.321
CO (8h)	ppm	11/9	16.4	14.9	12.8
NO_2 (1h)	ppm	0.21/0.21	0.448	0.421	0.279
SO_2 (24h)	µg/m^3	0.13/0.13	0.133	0.116	0.094
PM_{10} (24h)	µg/m^3	150	324	371	202

Source: INE 2000

Current air quality levels have impacts on health, visibility, regional ecosystems[52], climate change and global pollutant transport. Health studies, for example, indicate a 1% change in daily mortality per 10µg/m3 increase in PM_{10} levels; a ten per cent reduction in levels of air pollution could yield health benefits on the order of $2 billion per year, however, such economic benefits are highly uncertain[53] (Molina and Molina 2002). Despite these uncertainties (regarding the quantitative issue), there is no doubt about the exposure of Mexico City residents to unhealthy concentrations of air-borne pollutants, especially ozone and particulate matter, the two most important pollutants from the standpoint of public health[54].

4.3 The Transport Problem

Regarding the previously mentioned survey of Grupo Reforma, traffic is perceived by 9% of inhabitants as the major “obstacle to enjoy the city”[55]. Other problems like lack-of-money and delinquency are seen as major problems by 25% and 50%, respectively. By contrast, studies show facts about the transportation sector rather than perceptions: The sector

[52] Some studies document the significant damage to forests surrounding the Mexico City air basin caused by exposure to high levels of photochemical oxidants, mainly O_3.
[53] Not only are there substantial uncertainties about the existence and exact magnitude of the health effects themselves, but there are also difficulties in assigning monetary values to the reduction of health risks.
[54] Studies conclude that premature mortality associated with air pollution is caused predominantly by PM rather than by ozone which is linked to morbidity.
[55] The answer was open ended. Survey results showed the most recurrent answers.

accounts for nearly all CO, 80% of NO_x, 40% of VOC, 20% of SO_2 and 35% of PM_{10}; of ozone precursors, transport accounts for 81% of NO_x and 40% of VOCs (CAM 2002)[56]. The sector's high share of NO_x emissions (See Table 2.8) suggests that control measures to address this pollutant must be an important part of any ozone abatement strategy.

Table 2.8 Contribution to total emissions by the transport sector in 1988-1998 (in percent)

Pollutant	*Year of emissions*				
	1988	*1989*	*1994*	*1996*	*1998*
PM_{10}	2	3	4	25	36
SO_2	22	14	27	21	21
CO	97	94	100	99	98
NO_x	76	71	71	77	81
VOCs	52	51	52	33	40

Source: CAM 2002

In terms of transportation related emissions, new technologies (including improved fuels) have been responsible for significant improvements in automobile emission performance; however, despite these technological improvements, the condition of the transportation system has severely deteriorated in the last years (Cesar *et al.* 2002). In other words, benefits from technological measures have only been temporary because the organizational policies for transportation are inefficient and the enforcement of regulations and related standards deficient as well.

The continuation of current trends[57] in transport activity is likely to create much more unacceptable congestion, air pollution and its associated economic and social costs. In addition to the growing motorization rate, from a modal share perspective, the most worrying trend is the massive shift towards lower capacity modes: automobiles, taxis and

[56] As a comparison, in the US state of California, where transport is the big problem as well, cars and trucks account for more than 40% of the state's greenhouse-gas emissions. The national figure is 32%.

[57] For example, according to official projections (i.e., FIMEVIC 2005), overall daily trip segments in the MCMA will increase from 29 million (in 1994) to nearly 37 million by 2020. Virtually all growth is projected to occur in the State of Mexico, where the figure will increase from 9.6 million to 16.4 million. For the DF the increase will be very moderate: from 19.5m to 20.5m. However, one interesting and suspect aspect of these projections is that there is no change in the modal share between public and private transport.

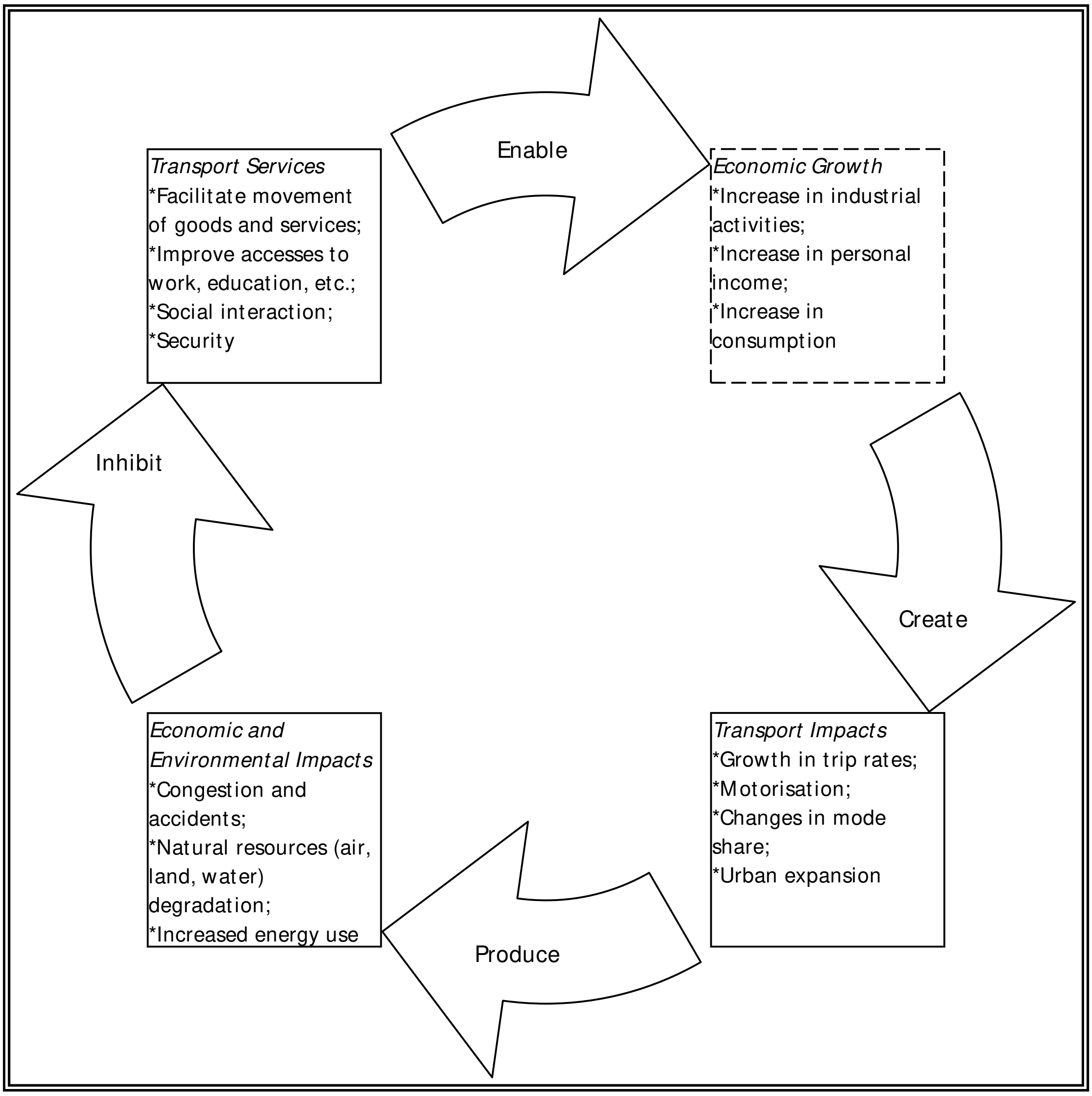
colectivos (microbuses and/or minibuses[58]) at the expense of the Metro trips and bus use[59]. These changes have occurred because the existing transportation system has not adequately adapted to the changing population distribution, economic changes and the resulting new travel patterns. On the whole, Mexico City faces an important and complex set of problems related to chaotic transit conditions and severe air pollution; as mentioned previously, the city has experienced rapid population, territorial and economic growth in recent decades, while the transportation system has not been optimized to meet these trends; it has followed the vicious circle brought about by such rapid and unsustainable growth.

Figure 2.4 illustrates the critical route that transport and economic growth could follow. Mexico City faces the acute consequences produced by the environmental impacts of its economic and transportation growth. Indeed, like many other developing world cities, the growth of Mexico City has occurred rapidly and chaotically, and effects such as pollution have been more severe than in the cities of the developed world (*inter alia,* because of the significant differences in their transportation systems).

[58] In general, *colectivo* is a form of collective taxi, which is either a 25-seat chassis on a 2.5 tonne pick-up truck or a 12-10 seat passenger van, most commonly a Volkswagen "combi".

[59] The Metro is losing passengers despite costly expansions of its infrastructure, from a peak of 25% in mode share in 1983 to below 15% in 1995 (SETRAVI 2005). A major reason for the decline in ridership is that the population has expanded further away from the urban core and the Metro does not effectively serve these new land-use patterns. On the other hand, the bus fleet has shown a decline over the past 20 years (from some 15000 in 1976 to a little over 2500 in 1996), and the average number of daily passengers declined accordingly (SETRAVI *ibid.*). Policy regarding minibuses, as with other types of franchised transport (i.e., taxis and buses), has owed more to political expediency than to any technical objectives of a transport policy.

Figure 2.4 The vicious circle of growth and transport



Source: Molina and Molina 2002

The challenge is to realise the benefits that transportation can provide without incurring the negative impacts that can result from such a vicious circle (of inefficient) urban transport.

Regarding the spatial distribution of trips, about 55% of the trips within Mexico City remain within the DF, 25% occur between the DF and the EM, and 20% within the EM

(SETRAVI 2005). The DF thus accounts for a significant share of trip attraction and generation: even in the most distant areas of the MCMA, the majority of trips are destined for the central area of the DF. DF residents make twice as many trips as their EM counterparts; projections suggest that by 2020 residents of the DF will make three times more motorized trips than their EM counterparts[60]. Over 60% of automobile trips occur within a radius of 10 km from the city centre[61] (SETRAVI 2005). According to SETRAVI (2005), of the approximately 29 million vehicle trip segments per day made in the DF in 1994, 75% were via public transport and 25% were by private motorized transport, with numbers today remaining approximately the same; Molina and Molina (2002) point out data inconsistencies in this kind of information[62].

Mexico City has no overarching public transport policy; each mode is determined separately by its own economic logic and political actors. Policies to promote public transport thus far have only envisaged investment in improving bus services or extending the Metro. The fundamental issue of travel behaviour has not been addressed; planning and building legislation, including the provision of parking, for example, do not relate to transport, much less so to the environmental problem. Public transport prices, taxes and subsidies are debated purely in terms of their financial implications, never as potential tools for modifying transport behaviour and reducing pollution. As a result, besides the shift from high-occupancy modes of transport to medium-and low occupancy mass transit vehicles, individual transport in automobiles and taxis have been allowed to dominate Mexico City, unchecked and actively supported by government policy.

4.3.1 Problems Related to Automobiles

The question of the amount of vehicles in the City and their use is especially important for calculating accurate emission inventories, and to create a better idea of the problem's magnitude. According to official estimates (i.e., SETRAVI), in 1999, 72% of gasoline fuelled vehicles were automobiles (private 79.5%, taxis 4.6% and commercial 15.9%), the rest were

[60] For this reason this research focuses on DF's data (regarding automobiles and motorists): it is a sensible starting point for the analysis of one part of this many-sided issue.
[61] And when examined according to motive, less than half of auto trips are work trips, 27% are shopping trips and 25% social trips.
[62] Basically, the problem concerns the undercounting of trips and/or misinterpretation of the data by the authors and the Mexican authorities.

van wagons (8%), pickup trucks (12%) and vehicles with gross vehicle weight of 4,500 kg or greater (6%). The gasoline powered vehicle population has increased from about 2 million in 1985 to about 3 million by the end of 1999: of these, 2.2 million were automobiles. The average age of the auto population in the city increased over this period from 7.3 years to 10 years. Such stock ageing certainly entails an increase in pollution emissions, but also the higher the vehicle lifetime VKT, the lower the expected general engine performance (Molina and Molina 2002).

The annual increase in the number of autos is estimated to be from 4 to 10%. Next, the motorisation rate (i.e., automobiles per capita) has increased more than 5% per year: from 78 cars per 1000 people in 1976 to 91 per 1000 people in 1986 and 166 in 1996[63], and this rate is expected to continue increasing. In particular, in the DF, according to SETRAVI (2005), there are 2,653,870 vehicles: 92% are private autos, 4% are taxis and 18% of trips are by automobile. In another study of 28 intersections across the DF, private autos accounted for an average of 65% of all vehicles, taxis for 17%, *colectivos* 10%, trucks 7% and buses just 2% (SETRAVI *ibid.*). In short, private autos dominate the landscape.

Similarly taxis have grown in importance as a means of transport, mainly since the beginning of the 1990s. SETRAVI (2005) estimates that of the 69,000 taxis registered in the metropolitan region, 64,000 are in the DF. The age of this fleet is of particular concern, i.e., there is a need for taxi fleet renewal. Most of the taxi fleet continues to age, and the emissions of this fleet are expected increase with age. Less than 10% of all taxis operate from a dispatch[64]: the rest roam the streets, often without passengers. For the most part, they are highly contaminating vehicles although more recent taxis have catalytic converters. Taxis are the most polluting of all forms of transport in the MCMA in relation to the proportion of passenger trips they cater.

63 According to a 1994 origin-destination survey (by the Nacional Statistics Institute), 37% of all households in Mexico City had at least one car, comparable to the situation in the UK in the mid-1960s.

64 Fixed-site taxis are somewhat more structured in their organization, since by nature they must coordinate amongst each other regarding scheduling and fares at different taxi sites. In contrast, among the rest of taxis circulating the streets, taxis operating illegally with forged papers present a large problem.

4.3.2 The Problem of Private Motorists

In 2001 there were 1.7 million private automobiles in the streets of Mexico City satisfying 20% of the total transport demand and generating more than 80% of transport sector air pollution (SETRAVI 2005, Molina and Molina 2002). Despite the recognized overwhelming contribution to pollution, there have been virtually no attempts to curb automobile ownership and use, except as emergency measures when pollution levels become intolerable. In Mexico City, as in most cities in developing countries, the policy towards private autos has been to encourage them to be less polluting while providing the necessary infrastructure for their increased use; the only exception to this is the ban program on the use of (some) autos for one day a week, first implemented in 1989 (see next section).

Average car occupancy ranges from 1.21 to 1.76 persons per vehicle, depending on type, with an overall average of 1.5. The percentage of automobiles with only a single occupant ranged from 48% to 83% (SETRAVI 2005). Automobiles in Mexico City cover a mean distance of 23,300 km per year, however, more than one quarter of all private autos cover an average distance per year of less than 5,000 km. Older vehicles are driven less; cars up to 5 years old travel around 19,000 km/yr, while those between 15 and 20 years older travel about 15,000 km/yr (FIMEVIC 2005). Based on inspection data, there is a emission reduction devices (e.g., catalytic converters) deteriorate with age and model year (INE 2000).

Whereas early anti-pollution legislation placed most responsibility on auto owners to keep their vehicles tuned and serviced (e.g., increasing frequency of obligatory emission-testing), subsequent legislation, which raised the emissions standards on new models while exempting those which met standards from the one day a week ban, has had a radically different effect: Those who can afford new cars are simply not affected by the policy, which becomes merely a matter of negotiation between the government and the auto industry. For the lower income auto user, both the need to pass the emissions standards twice a year and the once a week ban reduce the advantages of auto ownership to some degree.

Ultimately, a wide array of public and private investment patterns enforces automobile dependency. New and wider roads pave the way for more cars. Traffic congestion continues to be dealt with by road-widening schemes and the construction of overpasses. This is even justified on environmental grounds by the argument that cars pollute more when moving slowly; thus congestion is the major problem (e.g., FIMEVIC 2005). Parking is widely and cheaply available (at a maximum cost of about one US dollar per hour). Parking near supermarkets and other commercial centres is often free. New buildings, including most housing, require parking spaces throughout the city, and recent policies have actively promoted the construction of new down-town subterranean car parks, for which the government has provided land and other indirect subsidies. Empty lots are routinely authorised to be used as parking lots. Like roads, the provision of parking lots is justified on environmental grounds in that on-street parking causes traffic congestion, which is depicted as the ultimate pollution generator. Unsurprisingly, auto-owning Mexicans are not usually willing to walk more than half a block to their final destination, and they usually do not have to.

4.4 Current Situation: The HNC Program

In November 1989, in an effort to alleviate congestion and pollution problems, a new program was launched: "No driving day" (*Hoy no circula* or HNC)[65]. This program consisted of a regulation mandating that each car in Mexico City could not be driven on one specific day (determined by the last digit of the license plates) between Monday and Friday. The aim of the program was to reduce congestion, pollution and fuel consumption by reducing VKT (specifically, a 20% reduction for private vehicles), all as a part of the short-term emergency program deployed by the government during the winter months when the ozone concentrations were very high due to severe thermal inversions. Because of its initial success, the program became a permanent measure (since March 1st 1990), and since then every major program such as PICCA and PROAIRE has included it as a major component.

The program at first received wide support, however, motorists were not willing to abstain from their automobiles one day a week on a permanent basis. Many considered

[65] The origin of the program is actually 1987, when an environmental group named *Mejora tu ciudad* ('Improve Your City') persuaded motorists in the Mexico City Metropolitan Area to participate in a voluntary initiative to avoid the use of the car once a week. The initial response was favourable, however, support declined rapidly due to lack of resources and promotion.

public transport to be inefficient, inconvenient and unsafe. A 1995 Mexican government study reported that 22% of drivers obtained a second automobile in response to the extension of the driving ban (Molina and Molina 2002); the circulation ban only affected drivers not wealthy enough to afford a second car. One major unintended consequence of the policy was induced additional travel: Traffic patterns were indeed modified, particularly on weekends, when all autos could freely circulate, each adult-family member could drive each one of the, say, two autos, and Saturday became one of the most intense traffic days of the week[66].

The longer-term quantitative effects of the HNC program are difficult to calculate, with conclusions depending on the authors (e.g, Eskeland and Feyzioglu 1997, Mendoza *et al.* 1997, in Molina and Molina 2002). For example, the conclusions regarding these effects include, on the one hand, that the program led to a significant increase in gasoline consumption and, on the other hand, by contrast, that the HNC program led to a decrease in consumption of about six per cent in the early 1990s. Overall, the restrictions under the program have produced mixed results, which have lead to modifications on the circulation ban and related policies since 1989.

Such modifications included the extension of the program to taxis and minibuses (in 1991), the implementation of a restrictions system based on verification stickers according to emissions level and vehicle technology equipped, and the broad shift in principal objective from restrictions on circulation to incentives for vehicle turnover[67]. The current restriction of circulation covers only 8% of automobiles, and by 2010 it is expected that the figure will be less than 3% (GDF 2004). Thus, the program has evolved from a program where on a random basis a certain amount of automobiles did not circulate, regardless of their emission level, to a differentiated system where clean autos (i.e., those which have acceptable levels of

[66] Actually, on Saturday 14th April 2007, after five years without critical atmospheric conditions (i.e., 'pre-contingency' or 'contingency' status) in Mexico City, according to the Environmental Contingency Program, it was declared a 'pre-contingency' status. Afterwards, on Saturday 23rd the same status was declared for the second time of the year.

[67] Specifically, older vehicles (i.e., models 1993 and earlier) are now subject to the ban for one to two weekdays as well as some weekends through the creation in 1995 of the measure Doble hoy no circula ("No driving for two days"), which prohibit the circulation of all cars with sticker number "2" when emergency air pollution levels are reached. However, cars with catalytic converters and tighter emission standards could be exempt if they meet certain emission requirements in the inspection/maintenance test.

emissions at the time of testing) are allowed to operate all the time without taking into account that this increased freedom, implies further and significant impacts on emissions and behaviour in the medium and long term.

The system based on verification stickers (i.e., adhesive labels) is taken in this research as a tool to analyse the impact of the program on the use of automobiles. Later in chapters four and five this analysis is presented and discussed. Upon revision and inspection, there are four possible sticker types: “hologram double zero”, “hologram zero”, “hologram one” and “hologram two”. Respectively, every sticker implies: entitling an auto to be driven all seven days of the week and its excusal from semi-annual inspection for the first two years; for the following three possibilities the vehicle must be inspected every six months, entitling vehicle circulation all seven days of the week, banning operation for one day per week and banning for two days.

5. CONCLUSION

Environmental problems that developing countries ought to occupy themselves with are not necessarily the potential problems in the next century, but rather the indisputable harm being caused today by, above all, polluted air. Contrary to conventional wisdom, solving such problems need not hurt economic growth; indeed dealing with them now will cost less than allowing them to cause further unchecked harm. In most urban centres of developing countries, air pollution is getting worse, not better; most large cities in Latin America suffer rising levels of air pollution. From Brazil to China, governments are passing increasingly tough environmental regulations, many of them modelled on green standards in Europe and North America. Often this is an empty gesture as many countries are unwilling or unable to enforce green regulations. Although there are environmental lessons to be learnt from wealthier countries, these do not involve blindly copying everything they do. Government and regulators have often forced particular technologies on polluters rather than allowing them to find their own optimal way to reduce emissions.

Increasing urbanisation is environmentally worrying. The UN expects that between 1990 and 2025 the number of people living in urban areas will double to more than 5 billion, and that 90% of that growth will be in developing countries (UN 2004). Industrialisation at the national level is another cause of environmental problems. That is, developed countries moved historically first from agriculture to manufacturing industries and later to services and less polluting types of manufacturing; by comparison, many developing countries are now undergoing that first transition and at the same time adopting a dependence not available in the 19th century: automobiles.

In rich countries there are typically around 40 automobiles per 100 people; in Latin America the figure is about seven, in China two. But the numbers are growing and, for example, in China the number of vehicles registered has been growing by 12-14% a year for the past 20 years. In this sense, governments have found it relatively easy to influence big polluters such as factories and power stations, but much more difficult to persuade small polluters to change their behaviour. In Mexico City, for example, airborne lead levels have fallen by 98% since 1988 because Pemex (the national oil company of Mexico) introduced cleaner fuels; but levels of ozone and small particulates in the air remain dangerously high.

The total external costs of air pollution currently being imposed on Mexico City society by automobiles are clearly very significant. Theory suggests that a tax equal to the marginal external damage caused to society should be imposed on the source of these emissions. However, air pollution damages vary substantially according to the type of vehicle, as well as where, when and how (often) a vehicle is driven and maintained. Given the impossibility of monitoring emissions from individual vehicles, most countries have adopted a command and control approach to regulating automobile emissions. These require that vehicles reach certain emission standards when they are produced (i.e., before they can be sold at the market). But reliance on such standards does not encourage motor manufacturers to invest in the development of new technologies. That is, once these standards are reached there is no incentive to exceed them; simply penalising the purchase of vehicles with poor environmental characteristics may give motor manufacturers an incentive to invest in the research and development of new environmental technologies. Many countries have differential purchase taxes that, apart from encouraging research, also improve the characteristics of the vehicle stock.

In Mexico City, periodic checks of road-worthiness have been mandated, but these checks have provided continuing incentive neither for drivers of heavily polluting vehicles to better maintain their vehicles nor to drive them less. At the present, only exhaust emissions are monitored, while particulate emissions cannot yet be monitored at all. Until this technology is developed, further indirect means of confronting motorists with the damage done by their vehicle emissions must be found.

Total emissions are not linked very closely to total consumption of fuel. However, higher fuel taxes are often seen as a viable means of securing improvements in air quality; the damage caused by emissions, however, depends strongly upon geography in a way that fuel taxes are unable to reflect. Fuel taxes demonstrate only a weak correlation with pollutant emissions, and they cannot be varied temporally or spatially. This means that fuel taxes have a very limited role except in carbon dioxide control (as they are the best instruments for dealing with such emissions); in contrast with other pollutants, there is no means of removing carbon dioxide from vehicle emissions, and there is a tight relation between the quantity of fuel used and the carbon emissions.

Greater fuel efficiency, however, encourages more trips and the consumption of more fuel. Vehicle excise duty and other taxes on ownership serve this purpose even less. They are disconnected with the damaging aspects of vehicle use. There are arguments for moving the taxation of vehicles away from ownership and towards using variable taxes. Sales taxes and recurrent taxes both have the advantage of being cheap to administer but the major drawback that, once the owner has paid the fee, there are no further (i.e., marginal) incentives to reduce vehicle usage.

In Mexico, as in most countries, the policy towards private automobiles has been to encourage them to be less polluting while providing the necessary infrastructure for their apparently inexorable increased usage. Recent trends in real estate development further enhance the advantages of automobile mobility. Auto dependence is inculcated early on, as those who own autos tend to drive their children to school, for example. Most people who presently own an auto cannot envisage a future without one. Not only the auto owning population is hooked on their cars: the country's economy as a whole is highly dependant. In all, there are very many stakeholders in automobiles. Moreover, the HNC program should be continued with some further modifications; as any vehicle stock is constantly in a state of flux, the program must also incorporate an evolutionary approach so that it is constantly and effectively reducing both emissions from major emitters and VKT from major motorists.

Altogether, improving air quality involves a variety of technical solutions and changes in consumer behaviour. Theoretically, if drivers pay according to the amount of emissions they discharge per litre, then a perfect incentive pattern emerges. Motorists will find the best balance of reducing mileage, buying more fuel-efficient cars, driving in a more emissions-sensitive manner, and investing in existing technology to reduce emissions.

CHAPTER 3

THE LANCASTER MODEL: A THEORETICAL FRAMEWORK

"[...] Economics is a science of thinking in terms of models joined to the art of choosing models which are relevant to the contemporary world." (J.M. Keynes)

"The total suppression of qualitative distinctions, while it makes theorising easy, at the same time makes it totally sterile." (E.F. Schumacher)

1. INTRODUCTION

This chapter presents the theoretical framework that forms the basis of the empirical analysis of private motorists' decisions to adopt environmentally friendlier behaviour. Specifically, such framework will help to obtain answers regarding the factors that determine driving patterns for the current situation of motorists in Mexico City, in particular to the Distrito-Federal's corresponding stock of private automobiles in circulation. The model will help to draw scenarios displaying to what extent it is possible to stimulate different behaviour in motorists and the related implications of this change.

Most economic studies about the problem of air pollution concentrate on the evaluation of the costs and benefits of improving air quality or on issues of traffic control and demand side management. Less attention has been paid to the issue of travel behaviour as such. For this reason, the theoretical framework of this research attempts to fill the silence on motorist decisions about the use of their vehicles. It is ultimately a way of following that which Scitovsky (in *The Joyless Economy*, 1976) reminds economists: "The better we understand the complexity of human satisfaction and human behaviour, and grasp the fact that economic goods and services are only two among several sources of satisfaction, the more clearly we realize, or should realize, the inappropriateness of the economist's valuation."

Among others, influencing consumer patterns in order to manipulate desires is a suggestion resulting from an extended approach of utility functions and consumer economic problems. This theoretical chapter opens room for surveying this possibility, setting out how and which elements are to be included in the analysis of the case of private motorists and their environmental impact.

The rest of the chapter is organized as follows. Section 2 revises alternative approaches for the analysis of private motorist decisions. The suitability of the Lancaster model for automobile usage is introduced in Section 3, and Section 4 presents theoretical framework of the model developed in the context of motorists and air pollution, and discusses its empirical implications. Section 5 summarizes the chapter.

2. ALTERNATIVE APPROACHES

Individual consumer decisions are based on utility maximizing behaviour but are at the same time influenced by the society[1]. The task is to analyse to what extent social and behavioural issues have particular consequences. For example, theoretical and empirical market implications (e.g., price and product characteristics), although proven to be important in several markets, are still unclear (and still not worked out in developing country contexts). Grilo, *et al.* (2001), Bernheim (1994) and Arkelof (1997) take the challenge and develop models that include human complexities, analysing its effects on markets, activities and social decisions.

Regarding environmental issues and consumption, Conrad (2003) proposes to determine how environmental concern affects prices, product characteristics and market shares of competing firms. Basically the method is to try to formalize those elements expressed in the literature (sociological, psychological and anthropological) about consumption behaviour and include them in a concise model that extends its reach beyond the domain of consumer preferences so as to take into account various social variables related to the consumption and production processes. The method is exhaustive and implies quantitative and qualitative analysis in order to model consumer behaviour; it is also assumed that the pleasure of consuming is affected directly by the consumption choice (or

[1] Which can be seen as an externality themselves.

expectations) of other consumers[2]. The result of Conrad's analysis is that characteristics differ, as expected, between private and social decisions, and, more importantly, that it is possible to choose environmental policy instruments in order to stimulate private firms to produce optimal social qualities.

At the same time, DiClemente and Hantula (2003) review the applied behavioural literature on consumer choice and confirm the importance of behaviour as the most basic 'currency' that is traded with the environment; as such, the cues, costs and consequences involved may be understood in economic terms. Nonetheless, the influence of social interaction on preferences, pointed out by economists for centuries, is generally dismissed in the standard economic assumption of individual interest maximizing behaviour. O'Hara and Stagl (2002) investigate consumer behaviour (for the case of community supported agriculture groups) and its relevance for sustainable development; they emphasize that the conceptualization of consumer motives is crucial for understanding the influence that consumer behaviour has as an integral factor in the demand side analysis of sustainable development.

As mentioned in the previous chapter, Ferrer-i-Carbonell and van den Bergh (2004) analyse unsustainable consumption by modelling household decisions regarding total expenditures among different consumption categories (i.e., food, leisure, clothing, personal care, energy use and appliances). This serves to get information about the sensitivity of consumption to variables (determinants) that can be influenced or controlled by policies. Thus, a wide range of socio-economic household characteristics are relevant in explaining consumption patterns; this suggests that policies aimed at changing consumption to reduce pressure on the environment and energy resources could be effective if brought to bear upon these household characteristics[3].

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[2] In this sense, a basic research assumption is that the environmental performance of automobiles is part of the "menu" of characteristics that are taken into account by the consumer; this does not mean automatically, as in Conrad's model, that environmental concern plays into individual preferences.
[3] However, in the case of automobiles, they take into account ownership and not the use. That is, ownership of a car and a second car serves, they say, as a proxy for gasoline demand. That brings us on to the issue of what matters for environmental purposes is the marginal use of the car, and not the average ownership of it.

An alternative approach to the study of environmentally friendly behaviour is presented by Solér (1993). It is suggested that an understanding of such behaviour can only be gained by first describing the meaning that ecologically friendly buying has for consumers. That is, personal experience of ecology-related problems shapes consumer understanding of this concept as well as the motives for engaging in such behaviour. It is thus proposed that the main question addressed in environmental attitude research, "Why is the behaviour of most people not environmentally conscious?", be reformulated[4]. Questions should start from consumer experiences, e.g,, "How do consumers experience or conceive of ecologically friendly buying?" or "In what way is information about ecologically friendly products conceived by consumers?". In short, the principle implies a particular focus on the link between the *how* and the *what* of experience. In addition, I take from Solér the definition of 'environmentally friendly consumption behaviour', defined as human consumption motivated by concern for the environment; that is, 'environmentally friendly' denotes people who are concerned, to some degree, about environmental issues, an attitude toward incidents and behaviour having present and future implications for the environment[5].

With a broader approach, Piorkowsky (1996) shows statistical evidence for the ecological impact of the household sector as a whole, i.e., all private households of a national economy. The focus is not on large polluters on the supply side of the economy, but rather on the key role of private households in performing economic functions, as consumers and producers of household commodities. Accordingly, the data in the Piorkowsky study traces, for example, a decrease in air pollution caused by internal combustion processes of the official statistical sector 'households', but revealed an increase caused by external processes, i.e., by using private vehicles (which is defined as the sub sector 'road traffic'). Regarding the determinant factors of environmental damage caused by private households, Piorkowsky mentions household size and composition, income, possession and use of household appliances, amount and division of household labour, size of the house and the level of

[4] Ferrer-i-Carbonell and van den Bergh would answer probably, according their results and regarding the ownership of a second car (i.e., environmentally unconscious attitude): because of the level of income, family size, being self-employed and having a second earner in the household.

[5] Solér changes 'environmentally' to 'ecologically' as a way to distinguish the ecological effects from effects on other aspects of our environment (i.e., cultural, social, etc.). All in all, both terms describes the buying and using of products which have considerable effects on ecosystems.

environmental consciousness. With reference to this last factor, four reasons explain low or absent environmental consciousness: private costs of natural resource exploitation (i.e., very low), irrelevant quantities of waste output (in light of the single household orientation), differences between concrete consumption and abstract environmental quality, and the public good problem for many natural resources (i.e., to gain private benefits but to escape from private costs).

Golob *et al.* (1996) focus on predicting VKT by vehicle type. Basically, they forecast the usage of automobiles as a function of household and auto characteristics, and the characteristics of the principal driver or drivers of the vehicle. As expected, there are links between how automobiles are used and which household member is the principal driver of each automobile. However, environmental impact is not discussed. Likewise, Golob and McNally (1997) extend the model to explain household activity interactions, and they also use the formal relations between household members to explain household demand for travel. Altogether, the implications are indeed useful in the matter of forecasting, but limited as a way of understanding the behaviour per se and its consequences (i.e., the effects of travel duration, corresponding to each individual activity type; these represent not only travelling as derived from demand but also produced externalities)[6].

Lastly, I mention three references which review and analyze the effectiveness of measures that are instrumental in controlling vehicle emissions. First, Chin (1996) takes the case of Singapore and its road pricing and vehicle quota schemes. In brief, Singapore's success in containing congestion does not lie solely with the above mentioned measures; legislative and fiscal measures, careful land use planning, reorganization of and investment in efficient public transport, investment in road infrastructure, traffic management measures and efficient enforcement make up the rest of the management model. In fact, the wider impact of the area license scheme (i.e., road pricing) on commuter behaviour and on the whole network is not known, nor does the vehicle quota scheme directly address usage. Using Mexico City as a case study, Goddard (1997) proposes the use of tradable vehicle use

[6] One even can say that derived policies under this kind of framework would be *ad hominem*, e.g., tax on younger drivers (taking into account that having younger principal drivers means that vehicles are used more). Nonetheless, as the authors acknowledge, the research itself was part of a project aimed at developing a model system to forecast demand for clean fuel vehicles.

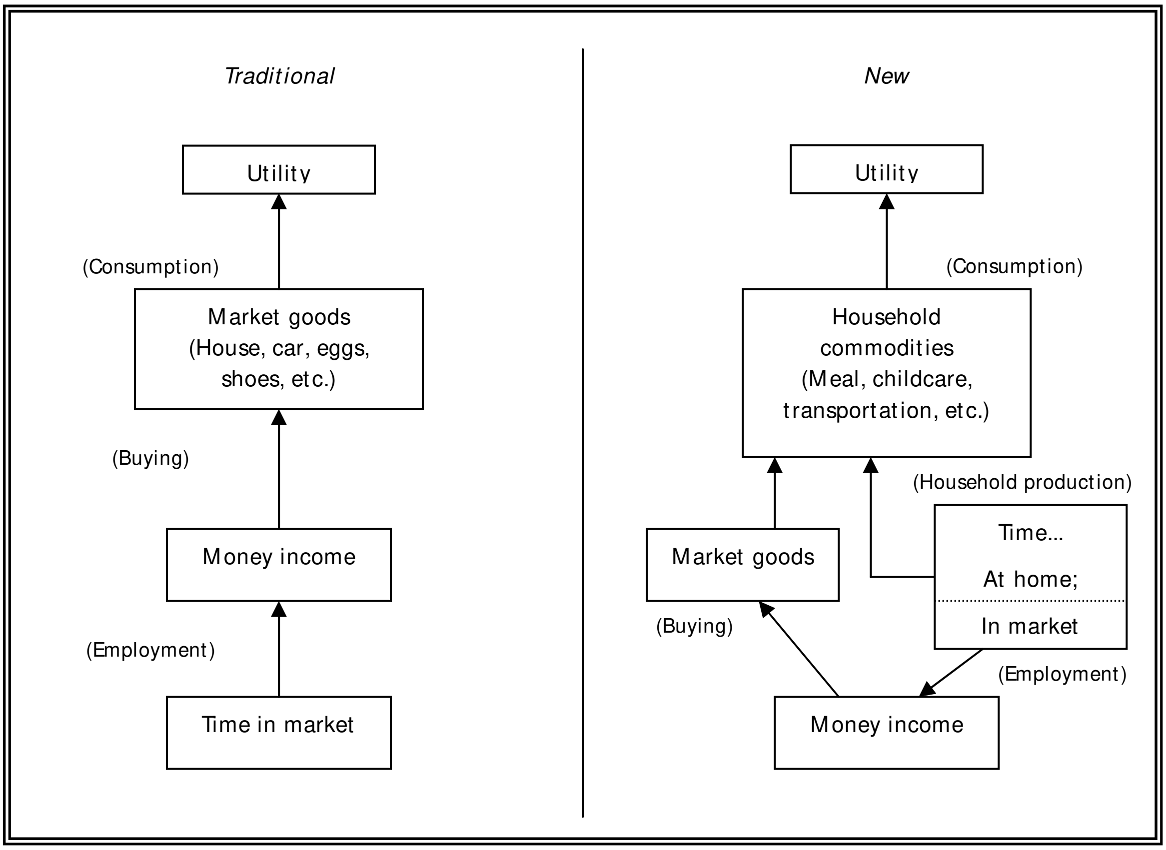
permits as a cost-effective complement to technological abatement for mobile emissions control. With it the measure aims to alter the incentive structure surrounding the decision to use autos. Such decisions are thought of as a problem of minimizing the total cost of emissions reduction subject to a constraint on allowable emissions. Nevertheless, there is no consideration of automobile type (i.e., no differences among vehicles) and a positive relation between automobile use and consumer welfare is assumed[7]. Finally, Niemeyer and Tisdell (1998) explore the benefits and limitations of adopting a mixed incentive scheme applied to fuel consumers to reduce pollution emissions from transport. The scheme incorporates elements of tradable permits, carbon taxes and emission reduction subsidies. Broadly speaking, the approach introduces a package of taxes, subsidies and standards such that those who emit less are rewarded and those who pollute more are taxed, but only after a tolerated level of emissions is exceeded. The theoretical and practical features of this scheme are remarkable, i.e., flexibility (and so closer approximation to an optimal solution), low transaction costs and incentives for technological innovation and equitability.

3. LANCASTER APPROACH AND AUTOMOBILE USAGE

The core of the proposed model is to capture those elements that have not been incorporated, or that have been outright ignored, into Mexico City's policies and practices related to pollution control and private motorists. Thus, I start this modelling issue with the help of a model framework of household production[8]. In particular, as do Seel and Hufnagel (1994), I take the approach of production theory within modern microeconomic household theory, as a reference point for the research model; the theory of time allocation by Becker (1965) and the new approach to consumer theory by Lancaster (1966) make up the main basis for this kind of analysis. Figure 3.1 summarizes the scheme of this kind of approach and compares it with the traditional theory.

[7] Later in chapter five the implications of such assumptions are compared with the results of this research.
[8] Through a revision of the theoretical basis of household production models we have the agricultural area as the one that gives better idea and support for the intended work in the research.

Figure 3.1 Traditional and new theories of household behaviour



Source: Berk 1980

The proposed framework admits that the essential nature of transportation is not only the distance travelled but also vehicle performance (and its environmental impacts). Furthermore, mobility is not treated as an end in itself. The ultimate objective of most travel is access: the ability to obtain desired goods and to do different activities. Applied to transportation, a certain amount of automobile use can be expected to provide significant consumer benefits. However, as individuals use their autos more, the benefits of additional vehicle trips decline since the most valuable trips have already been realised[9]. In other words, as marginal benefits decline, many costs increase with more vehicle use; thus, the unit price

[9] This is not to say that more car trips provide no consumer benefits, just that the incremental benefits of additional trips tend to decline with increased use.

of auto travel increases with auto use[10]. This being the case, consumers are predicted to significantly reduce their auto usage in a more economically efficient transportation system.

To turn to the nature of transportation activity, as with most agricultural households, consumers and producers also face a duality in their activities (e.g., to produce rice for others and for themselves), using their own inputs and/or purchasing them. Private motorists face the same pattern when travelling: to move because of others (e.g., job) and because of their own consumption (for example, pleasure from using the car) using their own inputs (e.g., time) and purchasing others (e.g., fuel). Private households not only consume goods but also produce 'bads', i.e., private transportation produces not only trips or kilometres travelled but also air pollution[11]. In short, automobile use is reflected not only through pollutant emission levels but also through kilometres travelled; what matters is not emissions or kilometres alone but both[12].

The Lancaster approach to consumer theory (Lancaster 1966) offers the possibility of comparing goods with similar characteristics and with different qualities, e.g., to compare two similar cars with different environmental impacts. Hence, I move from the traditional approach where goods are the direct object of utility to the approach where it is the

[10] However, consumers are accustomed to prices that decline with increased use/consumption. Indeed, auto purchase and usage may have provided economies of scale during the early periods of auto production and road development; but once an automobile industry develops and a basic road network exists these external benefits no longer exist.

[11] Consequently, as with the agricultural household model, the model should enable the examination of decisions in three dimensions: i) the well-being of a representative urban household, ii) the 'spillover' effects of changes in the behaviour's scheme, and iii) the performance of the private sector from an extended perspective not restricted to technology and economical issues but including environmental aspects. Well-being refers to the minor impact of the pollution and it is expressed as emissions per kilometre travelled associated with passengers kilometres travelled (where less is better). Next, since travelling implies such different responses to a change in, for example, technology, spillover effects may well be important. The performance of the private transport sector refers *inter alia* to incorporate environmental impact into the evaluation of scenarios related with automobile usage.

[12] With programs such as HNC it has been taken into account only one element in order to control the use of the cars. The program tries to reduce the use of cars by checking the car pollutant emissions but not by monitoring how the car has been used during the period. It has not been clear then that the private motorists (from Mexico City) take into account this HNC program so as modify driving (to drive less) or the vehicle itself (to have a better car). What drivers finally observe are not the emissions but the kilometres travelled: how drivers be made to see both activity outputs?

properties or characteristics of the goods from which utility is derived[13]. With this particular application of the Lancaster model, I can describe in which way Mexico City's motorists choose how to move when two different automobiles are available and how this decision can be affected. In general, decisions to use the auto will depend on the demand for final outputs (i.e., kilometres travelled and pollutant emissions), the preference for driving a particular kind of auto and the restrictions upon driving it.

4. THE MODEL

Transportation has two general outputs (i.e., household end-products): kilometres travelled and air pollution. At the same time, several technical activities can exist to produce our desired product, e.g., use of an environmentally friendlier automobile or a 'normal' one. These activities also require time and goods as inputs, as well as a budget restriction, i.e., the full price of consumption, which is the sum of direct and indirect costs (the "full income" in Becker's approach).

At the end, the solution will describe which actions are possible for the household, and which desired and undesired products and effects result from these actions. Overall, a large variety of actions are possible; which decision a household will make will depend on individual preferences. It is rather complicated to find an adequate expression of the utility function: it requires assumptions about the question how the household estimates its influence on its produced externalities, and about the question if the utility function includes other arguments besides its own *consumption* of the environment, e.g., the satisfaction caused by the compliance with environmental standards. Thus, the utility function shall not only depend on the available goods, but also on the quality of its environmental impact (Seel and Hufnagel 1994).

[13] A car does not give utility as such but because its use (and here it is included the 'social distinction': it only appears when the car is showed, i.e., used) and that's why I need such approach to analyse how people choose to use their cars. In particular, how they use different cars based on its environmental performance.

The model consists basically of two equations: a utility function to maximize and a single constraint that captures the duality of behaviour of an urban household that travels in Mexico City; consumption behaviour is not independent of production behaviour: households are producers as well as consumers[14]. The following paragraphs formalize the model.

4.1 Theoretical Setting

Following Lancaster (1966), I have three main assumptions. First, consumption is an activity (*k*) in which goods (*x*) are inputs and in which the output is a collection of characteristics (*z*). In particular, for the case of private motorists there are two options: driving automobile A or automobile B (i.e., inputs)[15], and two outputs, kilometres travelled and air pollution[16]. Second, utility (*U*) ranks collections of characteristics (*z*) and it only ranks collection of goods (*x*) indirectly through the characteristics that they possess[17]. In general, even a single good (e.g., a car) will possess more than one characteristic (e.g., colour, brand, performance), such that the simplest consumption activity (i.e., driving a car) will be characterized by joint outputs (i.e., kilometres travelled and air pollution-emissions). Lastly, the characteristics (*z*) possessed by a good (*x*), or a combination of goods, are the same for all consumers and, given units of measurement, are in the same quantities, so that the personal element in consumer choice arises in the choice between collection of characteristics only, not in the allocation of characteristics to the goods. That is, kilometres travelled and pollutant emissions by one car are certainly the same even with different drivers, so they cannot choose the pollutant

[14] The duality of households is better explained by Becker (1965), "a household is truly a small factory: it combines capital goods, raw materials and labour to clean, feed, procreate and otherwise produce useful commodities." At the same time, households derive utility from the consumption of both market-produced goods and time. The theoretical framework intends to add the environmental element, i.e., the presence of negative externalities in the consumption because of automobile usage.

[15] In particular, two kinds of cars: with acceptable environmental performance and without. To put it otherwise, it is like to see how the choice is when we have a grey and a black car: they are neither the same commodity (otherwise we ignore that maybe the colour is a relevant aspect of the choice) nor different between each other (with no a priori assumption that they are close substitutes), but goods associated with satisfaction vectors which differ in only one component. Accordingly, as not all autos are automatically and directly bad for the environment, i.e., their use and their outputs indicate differences, this approach treats with the issue in a better way.

[16] Traffic jams are indeed another output, however, one can assume that individuals, through their final choice about the number of kilometres travelled and the associated air-pollution emissions, take into account this variable, and in a way this is reflected in the two considered final outputs.

[17] In other words, the purpose is not to see how many automobiles are driven or sold, e.g., to model demand for autos, but *how* they are driven (and *how* to control their use), i.e., to model automobile usage.

emissions associated with a given number of kilometres driven, but can choose between two different cars in order to arrive at the desired trip.

Essentially, the above mentioned can be summarized in the following terms: 1) the good, per se, does not give utility to the consumer; it possesses characteristics and these give rise to utility[18]; 2) in general, a good will possess more than one characteristic, and many characteristics will be shared by more than one good; and 3) goods in combination may possess characteristics different from those pertaining to the goods separately.

Next, we have a consumption activity (k) and an associated scalar for it, i.e., level of activity (y_k). In particular, we have two activities: transporting with automobile W and transporting with automobile G, where automobile W is environmentally worse than automobile G (which is "good"). I assume that Mexico City's inhabitants use two types of vehicles (i.e., W and G); in total we have the number of kilometres travelled and also the number of trips, i.e., the number of automobiles used by city residents in order to get those (total number of) kilometres. In other words, an individual has an output (kilometres travelled with associated pollutant emissions), two ways to arrive at it (driving automobile W or automobile G) and a certain number of trips which can be measured by simply counting those automobiles that together produce the output[19].

The above situation is similar to Seel and Hufnagel's example of burning coal. The outputs are electricity and sulphur emissions, the input is burning two kinds of coal (with higher sulphur and with lower sulphur), and the level of activity is the use (i.e., quantity burned) of each kind of coal (Seel and Hufnagel 1994). In the case of motorists, the outputs are kilometres travelled and emissions, the input is driving two kinds of cars (with good and bad performances), and the level of activity is the use intensity of each car.

[18] Like a cake, as Lancaster illustrates, where the whole cake does not give utility but rather its taste which derives from the ingredients used. In the case of cars I see vehicles as the cake motorists consume, just needing gas to be a car and with it altogether utility is attained.

[19] It can be assumed that this theoretical individual is moving the entire time and that at the end of the period he has travelled some total number of kilometres by using two kinds of cars at different levels of use, e.g., using 30 units of car W and 80 units of car G to travel, in total, 200 km. It is considered then the number of characteristic-related cars as the level of activity. With this there is an assumption as well that there are no restrictions upon the time; the time is the level of activity itself, and it is measured not with number of trips but rather with number of cars in Mexico City.

The model assumes that the relation between the level of activity *k*, y_k, and the goods consumed in that activity to be both linear and objective, so that, if x_j is the *j*th commodity we have:

$$x_j = \sum_k a_{jk} y_k \qquad (1)$$

The equation is assumed to hold for all individuals, the coefficients a_{jk} being determined by the intrinsic properties of the goods themselves and possibly the context of technological knowledge in the society.

Second, each consumption activity produces a fixed vector of characteristics, and that relation is linear.

$$z_i = \sum_k b_{ik} y_k \qquad (2)$$

Here I consider two characteristics: kilometres travelled (z_1) and pollutant emissions (z_2).

Third, the utility function is assumed as an ordinal utility function on characteristics *U(z)*. And as do Seel and Hufnagel (*ibid.*), I take the Stone-Geary function:

$$\ln U = \sum_i \alpha_i \ln(z_i - \pi_i) \qquad (3)$$

where π_i is the subsistence level of z_i. That is, if we think about a collection of desired characteristics, it could be the minimum distance to travel and with it also a minimum of allowed externalities (e.g., minimum air-quality standards). Next, following Seel and Hufnagel, the subsistence level for an externality (such as pollutant emissions) can be defined in these terms

$$z_2 + \Gamma_2 \bullet \ddot{A}_h / H$$

where z_2 is the pollutant emission, and the maximum level of allowed emissions is defined as the total environmental strain Γ_2 (≈accumulative effect of the pollutant emission) multiplied by the relation between the proportional impact ($\ddot{A}_h$) and the number of households (H). Therefore,

$$-\pi_2 = \Gamma_2 \bullet \ddot{A}_h / H$$

that is, the pollutant emissions existing prior to the activity, or the maximum level of allowed emissions. If there is no minimum distance to travel then we take the current distance travelled (z_1) and associate the standard pollutant emissions when motorists travel this number of kilometres.

In the Lancaster model, the relation between the collection of characteristics available to the consumer (i.e., the vector *z*), being the direct ingredients preferences and welfare, and the collections of goods available (i.e., the vector *x*) representing the consumer's relation with the rest of the economy, is not direct and one to one (as it is in the traditional model) but indirect, through the activity vector *y*.

4.2 Optimal Conditions

We have thus, *r* number of characteristics, *m* activities and *n* goods. According to Lancaster, only if *r = m = n* will there be a one-to-one relation between *z* and *x*, otherwise the relations are between vectors in spaces of different dimensions. This is our case: *m > n*, that is, equation (1) places only *n* restrictions on the *m*-vector *y*, such that *y* can still be chosen with *m – n* degrees of freedom.

Formally,

$$\max U(z)$$
$$s.t. px \leq I$$

$$\text{with} \quad \begin{aligned} z &= By \\ x &= a_1 y_1 + a_2 y_2 \\ x, y, z &\geq 0 \end{aligned}$$

U is defined in characteristics-space (C-space); the budget constraint is defined in goods-space (G-space). The model needs a transformation between G-space and C-space. In traditional analysis, both the budget constraint and the utility function are defined on G-space. Here we can only relate the utility function to the budget constraint after both have been defined in the same space. We have two choices: 1) transforming the utility function into G-space and relating it directly to the budget constraint, or 2) transforming the budget constraint into C-space and relating it directly to the utility function *U(z)*.

The central role in the model is played by the transformation equation $z=By$ and the structure and qualitative properties of the matrix *B*. *B* is the consumption technology of the economy and the behaviour of the consumers. Also, the leading structural property of the consumption technology is the relation between the number of characteristics (*r*) and the number of activities (*m*). With no one-to-one relation between goods and activities the Lancaster-model can still be employed. That is, it would be a special case. We have then, as part of technology, $x=Ay$ (i.e., the vector of total goods required for a given activity vector), such that the budget constraint $px<I$ can be written directly as $pAy<I$. The price of goods transforms directly into the implicit price of activity $q=pA$. Lancaster states that the number of goods in relation to the number of activities is irrelevant at this stage [i.e., to analyse the consumption technology and the role it plays in the consumer behaviour implied by the model], since each activity has a unique and completely determined price *q*, at a given price of goods.

Therefore, at the end, Lancaster argues: "The manifestation of the efficiency substitution effect in goods-space depends on the structure of the A (goods-activities) matrix (...) If all goods [e.g., our special case] are used in all activities, the efficiency substitution effect will simply result in less consumption of a good whose price rises, not a complete disappearance of that good from consumption."[20]

[20] Lancaster talks about a cake and eggs, that is, baking cakes requires eggs but in different proportions (like driving different kinds of cars, all using the same kind of fuel but at different levels). A rise in the price of eggs will cause a switch from egg-intensive cakes to others, with a decline in the consumption of eggs, but not to zero. How can this situation, in our particular case, be reflected or taken into account by the analysis? The application of this kind of model helps to do it.

4.3 Empirical Implications

The solution of the model describes which actions are possible for the motorists, and which desired and undesired products and effects result from these actions. Which decisions a motorist will make, depend on individual preferences.

As a rule, when the motorist has only two alternatives from which to choose, where one vehicle is environmentally friendlier than the other, environmental conservation (i.e., less pollutant emissions) is a superior good (i.e., less pollutant emissions as income rises) if driving a environmentally friendlier vehicle produces less kilometres travelled per fuel consumed compared to driving the other (less friendly) vehicle. In other words: If, measured in terms of reduction of kilometres travelled, environmentally friendlier behaviour “costs” more, the motorist will be better able to afford it in direct relation with increases in income.

On the other hand, when conservation of the environment is inferior (i.e., more pollutant emissions as incomes rise), if income increases, the kilometres travelled and pollutant emissions increase. The driving of less-friendly vehicles increases with income, but their use reaches a saturation level at some point. Driving friendlier cars is not necessarily a good indicator of the environmental strain that is really caused by motorists. An impression of the important characteristics of consumption technology (i.e., which kind of vehicle motorists decide to drive) could therefore very well be important, if a possible counterproductive effect of environment politics is to be avoided.

5. SUMMARY

The Lancaster model is set out as a general replacement of the traditional analysis, rather than as a special solution to a special problem. It is a reasonable and sensible framework for this research. Two cars (each one with a different environmental performance but the same kilometres travelled) are two commodities associated with satisfaction vectors that differ in only one component (i.e., the pollutant emissions).

Moreover, it is uncertain whether private motorists from Mexico City are concerned about environmental impacts; the model can provide information as to whether there is such concern (by seeing how motorists use the vehicle). There is indeed an environmental feature related to automobile use, and this theoretical framework can reveal to what extent this characteristic is taken into account by private motorists.

By modelling according to the production theory of decisions relevant for the environmental economic aspects in private motorists, our model could have implications that remain unexplained by the typical household model. Hence, it is obvious to look for an approach for the elaboration of the effect mechanism that contributes to the explanation of the variance in the personal behaviour regarding the environment.

CHAPTER 4

EMPIRICAL EVIDENCE

"A great city is not to be confounded with a populous one." (Aristotle)

"We only harm others when we are incapable of imagining them." (Carlos Fuentes)

"When you look at a city, it's like reading the hopes,
aspirations and pride of everyone who built it." (Hugh Newell Jacobsen)

1. INTRODUCTION

This chapter presents an empirical investigation of the factors that explain the behaviour of private motorists in Mexico City, based on the suggested implications of the theoretical framework presented in the previous chapter. One set of the analyzed factors includes the vehicle characteristics themselves and vehicle use (by private motorists in the Distrito Federal). Another set of factors investigated consists in private motorist preferences regarding the purchase of a brand-new automobile and, above all, its expected use and its intensity. The analysis uses quantitative and qualitative data; information includes, on the one hand, vehicle kilometres travelled (VKT, registered by the odometer), characteristics of the automobile and its related pollutant emissions, and, on the other hand, consumption levels, consumption preferences and consumption desires (regarding the use of automobiles), and the characteristics of the motorists themselves. The applied techniques on the model's regressions are ordinary least squares (OLS) for one linear model, and maximum-likelihood estimation for one logistic (logit) regression and one multinomial logit model. The discussion and implications of the results are presented at length in the next chapter.

The following chapter is organized as follows: the next section describes the data sources (and their relevance) and defines the variables; section three presents the estimation results, and finally section four provides a summary.

2. DATA SOURCES AND DEFINITION OF VARIABLES

The empirical research is based on two data sets and accordingly carried out in two stages. The first can be seen as a quantitative stage where the use of automobiles in Mexico City is analyzed via data from the Vehicle Verification Program (VVP) for the Distrito Federal (DF). These data allow the examination of patterns and levels of automobile usage for private motorists with different demographic characteristics and income levels; the kind of automobile (in particular, model and year) is assumed to be reflected by such personal features. The postal code of the motorist's place of residence is also used as an indicator. By doing this, I develop some policy options (presented in next chapter) that take into account the already generated and available information (from the VVP and to policy makers, respectively) for a better pollution reduction policy aimed at private motorists; that is, depending on automobile use (i.e., how intensive and extensive it is) and not exclusively on the vehicle characteristics or personal characteristics of the motorist.

The importance of focusing attention on the VVP rests with the fact that vehicle inspection lays at the core of emissions control policy for Mexico City[1]. Moreover, according to Molina and Molina (2002), improvements in the inspection and maintenance program have helped to decrease trends in emissions of CO and hydrocarbons (sharply for automobile model years more recent than 1988), and NO_x emissions (sharply for automobiles introduced since 1992)[2]. The first set of data for this research is thus from the *Programa de Verificación Vehicular* (VVP), in particular, from its verification centres (*VerifiCentros*) in the Distrito Federal (DF). The next subsection (2.1) gives some features of this kind of program by describing the VVP, and subsection 2.2 presents the particular data (variables) that this research uses.

The second stage includes the qualitative analysis. Individual questionnaires supplement the quantitative data and provide insights into the dynamics of consumer

[1] Besides, the centralization of a limited number of centres designated exclusively for inspection has allowed authorities to gain better control of the problem. The previous system, in which thousands of shops were responsible for inspection and repair simultaneously, had many problems. The continuous technological modernization of measurement systems has also been important.

[2] At the same time such improvements clearly result from the introduction of automobile emissions controls, particularly fuel injection and catalytic converters.

automobile usage among those motorists buying a brand-new automobile. The survey examines current consumption levels, consumption preferences, and consumption aspirations regarding automobile usage. This survey was conducted by the Environmental Economics Area of the Mexican National Institute of Ecology (INE) in order to get data regarding the consumption of brand-new automobiles, but they offered thorough cooperation by allowing for a questionnaire including aspects for both parts of the research interests (i.e., the purchase and use of automobiles). The final subsections, 2.3 and 2.4, of this section give more details about this second source of data, the INE survey, and describe its variables that are relevant for this research.

2.1 The Vehicle Verification Program

In general, the goal of vehicle inspection and maintenance programs is to identify high pollution-emitting vehicles and effectuate their repair[3]. A number of reasons could contribute to the lack of success that vehicle inspection programs have generally had. First, behavioural effects: motorists wishing only to pass the test may have their vehicle adjusted or collude with the inspection station. Second, enforcement may be weak: many owners of vehicles that fail a test do not repair their vehicles and then fail to return for re-testing[4]. Third, repair may be inadequate, or malfunctions may be intermittent: this could be due to faulty repairs, faulty or fraudulent test procedures or erratic vehicle malfunctions (CAM/IMP 2000). The MCMA emissions inspection program, i.e., the VVP, was the first obligatory and massive measure applied in Mexico City[5]. Each vehicle that circulates (and is registered) in the MCMA must be inspected every six months, according to the last number on its license plate or the colour of its registration sticker.

[3] Additional emissions reductions could occur from motor owners who repair their vehicles before the inspection, or from owners who scrap or sell their vehicles out of the area of verification since they judge repair not to be a cost-effective option.

[4] In Japan and in Germany, perhaps due to differences in level of enforcement or cultural factors, vehicle inspection programs have led to a marked increase in vehicle fleet turnover. Older cars in these countries are more expensive to operate due to inspection requirements and, in some cases, taxes. Vehicles older than six years constitute a small percentage of the private car fleet in these countries.

[5] It was initiated in 1988 for the specific purpose of reducing emissions generated by the vehicles in circulation by ensuring that they are properly maintained, and by fostering vehicle turnover.

2.1.1 Organization of the program and testing procedures

The management of the VVP is the responsibility of the governments of the DF and the State of Mexico (EM). The program does not include federally registered vehicles (which are under the responsibility of the Federal Secretary of Communication and Transport). Until 2001, private vehicles registered in the DF and the EM could have been verified in any *VerifiCentro* in the MCMA. As of September 2000, 161 *VerifiCentros* were operating in the MCMA, 84 of which were in the EM and 77 in the DF. Since 2001, all vehicles registered in the DF must be inspected in the DF.

Test procedures, data acquisition and the permissible maximum limits of emission were established by the Secretary of Environment, Natural Resources and Fisheries (SEMARNAP) of the federal government. Program requirements have become stricter since it was initiated in 1988; starting with two manual gas analysers (CO and HC) in 1989, progressively different technologies have been introduced. Currently the *VerifiCentros* are measuring five gases emitted from the tailpipe: CO, HC, NO_x, CO_2 and O_2. HC is also produced through evaporative emissions, emissions from fuel tanks, evaporation of fuel while the vehicle is operating, and evaporation of fuel when the motor is turned off and fuel leaks; no evaporative emissions tests are conducted in the MCMA, either in DF or EM (CAM/IMP 2000).

2.1.2 Relevant program figures

Around two million emissions tests are carried out every six months. Fluctuations in the number of vehicles inspected have occurred between 6-month inspection periods due to a) deficiencies in inspection information handling and/or b) motorists avoiding the program (Molina and Molina 2002). Among other anomalies, it has been observed that the percentage of vehicles verified in *VerifiCentros* of the EM that do not have catalytic converters is much larger than in the DF. This could indicate that a larger share of high emitting vehicles is located in the EM, or it could also be a sign that many motorists intentionally verify their vehicles in the EM (because apparently in such centres there is a lower quality of standards). Overall, as the number of *VerifiCentros* in the EM increases, the number of inspections in the DF has decreased[6].

[6] At the same time, data for the number of inspections (and their results) in the EM is not available.

In total, the program generates 140 variables (for every inspected vehicle), including physical characteristics of the tested vehicle, personal data from the motorist/owner (i.e., name and address) in addition to emissions data. Characteristics pertaining to the motorist were not available for this research, and so only vehicle characteristics and emission data are included. Regarding the emissions of the above mentioned five gases, 20 main variables are generated: technically the gases are measured applying two brake-force levels (50 and 25[7]) at two different speeds (i.e., 24 and 40 km/hr).

In particular, the datasets include the following figures: for the first 6 months of 2003 (2003_S1), there are 2,363,382 observations (i.e., number of inspected vehicles); for the second 6 months (2003_S2) there are 2,081,465 observations; for the first period of 2004 (2004_S1) there are 2,450,600 observations; and for the second period of 2004 (2004_S2) there are 2,148,369 observations. However, for this last period, there are incomplete data for more than 70% of the checked vehicles (specifically, no kilometres registered in the database). Furthermore, there are duplicate cases, i.e., vehicles tested more than one time (because of *inter alia* reasons like a failed first test, not obtaining the desired sticker and errors in information handling), which represent around 10% for each dataset.

2.1.3 The VVP and the 'Hoy No Circula' (HNC) program

In order to enhance fleet turnover and keep older catalyst-equipped vehicles operating with low tailpipe emissions, the DF coupled the VVP with the HNC program (see also section 4.4 of Chapter 2). For example, in 1999 it was announced by environmental authorities that automobiles equipped with Tier 1 technology[8], equivalent to 1994 US emission controls, would be awarded a sticker "double zero" starting in the year 2000. These automobiles could be driven all seven days of the week and were excused from semi-annual inspection for the first two years (i.e., unlimited driving without revision/inspection during said period of time). The sticker "double zero" was, literally, a driving force to get manufacturers to put Tier 1 technology into vehicles designed for the Mexican market a few years earlier than they wanted to do. There are then, after the inspection, four kinds of stickers (i.e., adhesive labels):

[7] 50 and 25 are supposed to refer to the magnitude of torque; we can assume 50 and 25 Newton metres (N m), but these unit are not stated in the database, which only indicates "brake-force level of 50 and 25"

[8] Tier's are tailpipe technical standards: Tier 0, Tier 1 and Tier 2.

sticker "*hologram* double zero" (HZZ), sticker "*hologram* zero" (HZ), sticker "*hologram* one" (HONE) and sticker "*hologram* two" (HTWO).

In addition to this, sticker "HZ", entitling a vehicle to drive all seven days of the week, could only be obtained for catalyst-equipped vehicles. Catalyst-equipped cars older than five years had to have their catalytic converter replaced in order to qualify. Above all, concern has been expressed that relying on catalyst replacement to effectively reduce emissions may not be realistic (CAM/IMP 2000 and Molina and Molina 2002). Also, according to results released in 2000 (by CAM/IMP), audit laboratory tests found that 45% of vehicles (included in the sample) are considered to be high emitters; this is in fact about the same share of the total stock of vehicles in circulation that have an approved certificate and sticker. This could be caused by misreading gas samples by the analysers or by fraudulent testing in some *VerifiCentros*.

2.2 Variables of the Vehicle Verification Program

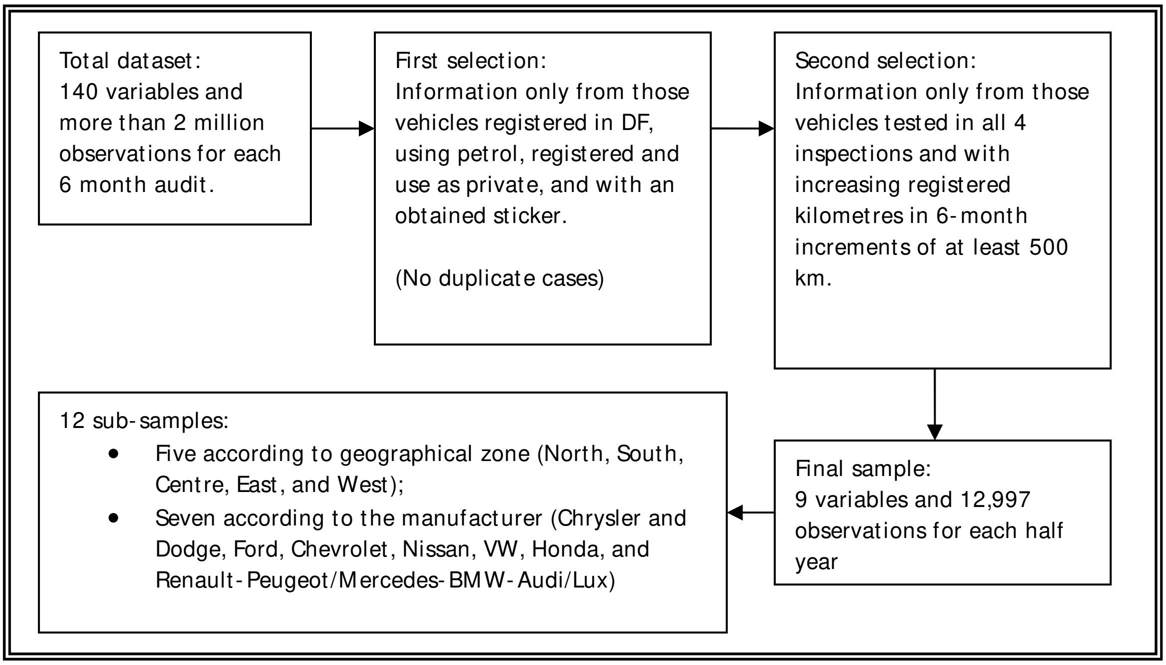
From the above-mentioned total number of vehicles, the analysis takes information (i.e., purposeful sampling) from only those automobiles: i) registered in DF, ii) using petrol (as fuel), iii) registered and used privately (i.e., personal use and not commercial or other kind), and iv) with a sticker obtained on the first-try (i.e., not rejected after the first test). This represents a selection using five variables from the original database. After this first selection, duplicate cases are identified and deleted from the datasets[9]; thus, the datasets finally included 1,103,869 automobiles for the first half of 2003 (2003_S1), 1,026,969 for the second half of 2003 (2003_S2), 1,152,257 for first half of 2004 (2004_S1) and 1,062,835 for the second half of 2004 (2004_S2).

The data was filtered a second time in order to obtain only those automobiles that were tested in all four inspections, for which the vehicle odometer for each 6 months was registered as having increased (i.e., taking into account that for some vehicles there was sometimes the surprising and unfeasible data where, e.g., the second 6 month audit had less

[9] Including the correspondent primary cases; in this way I get more certainty about the rest of the cases because for those with duplicates it is not clear enough why they had to be tested again, so better I choose this way.

kilometres than the first one, due to purposeful technical alterations and/or misreading of the odometer), and for which the odometer difference between each inspection was registered as greater than 500 km (i.e., assuming that 1000 km per year is the minimum distance driven by a regular motorist). The final sample (i.e., VVP dataset) includes: 12,997 vehicles. From this sample 12 sub-samples are generated (five according to geographical region and seven according to manufacturer). Figure 4.1 summarizes the steps of information selection mentioned.

Figure 4.1 Steps of information selection for VVP-dataset



As noted in Figure 4.1 this research takes into account nine variables from the data of DF's *VerifiCentros* (i.e., all vehicles inspected in those centres located in the DF), collected for the respective halves of 2003 and 2004 (i.e., four data sets: 2003_S1, 2003_S2, 2004_S1 and 2004_S2)[10]. For the analysis itself, seven variables are manipulated (i.e., included in the regression model), and the rest serve as control variables (i.e., to group, describe or classify the information of the whole dataset).

[10] Important to take into account is that, as it was mentioned, there was no available information about the driver, even this kind of data is indeed registered. Furthermore, only by the cooperation with the researchers at the INE, it was possible to get access for the information. I am totally indebted.

With respect to the above-mentioned information about pollutant emission measurements, the attention (i.e., what is considered for the econometric regression) is not on such technical measures of the gases but on the obtained sticker, which reflects to what extent the vehicle pollutes (i.e., sticker “zero” represents the less polluting vehicle, followed by stickers “one” and “two”)[11]. In other words, depending on the level of associated pollution for a particular vehicle there is a correspondent sticker; the sticker type is the proxy, and much more manageable, variable for measuring pollutant emissions. This is the case not only with the currently generated but also the expected emissions, because such classification of stickers takes into account, thus far, vehicle pollutant emissions and some characteristics like model-year, e.g., a vehicle model-year 1990 and earlier can not obtain a sticker “zero” at all. With this dataset there is no way to know if the motorist has two or more vehicles, i.e., it is possible that among the tested vehicles some have owners that also drive other vehicles. Although such information is relevant, in this part of the analysis there is no problem to ignore this issue. Table 4.1 lists and classifies the variables.

Table 4.1 List of variables from the VVP dataset

No.	*Name*	*Type*	*Description*	*Control*	*Analysis*
1	numberplate	String	Vehicle’s plate	Yes	
2	pz (DZ#)	Numeric*	Owner’s postal zone (postal code)	Yes	Yes
3	km	Numeric	VKT until the verification date	No	Yes
4	manuf (DM#)	Numeric*	Car manufacturer (e.g., Ford)	Yes	Yes
5	brand	Numeric*	Car brand (e.g., Focus)	Yes	
6	mody (agecar)	Numeric	Model year		Yes
7	catal (DC_#)	Numeric*	If the car has catalytic converter (1) or not (0)	Yes	Yes
8	gvw (DW)	Numeric*	Gross vehicle weight	No	Yes
9	stick (DS_#)	Numeric*	Kind of obtained sticker	No	Yes

*The number is a dummy variable and depends on qualitative or categorical description

[11] The sticker “double zero” (which actually would represent the least polluting vehicle) is not included in the sample: less than 1% of cars in every inspection got it, because actually during the years 2003 and 2004, the above mentioned required technology was not included in all brand-new models, for example.

The number of kilometres travelled for each corresponding vehicle is linked with the license plate number. That is, as mentioned above, the analysis is carried out only for those vehicles whose plates and, more importantly, odometer figures are in the four datasets. Both the number of kilometres registered in the dataset (i.e., km1, km2, km3, km4, for kilometres registered in every of the four consecutive verifications) and the difference between each two consecutive periods are considered (i.e., km12, km23 and km34, for the kilometres travelled between first and second inspections, second and third inspections, and third and fourth inspections, respectively). The analysis regresses the kilometres travelled between 6-month periods (i.e., km12, km23 and km34), where the kilometres are divided by 1000. The days of difference between inspections is on average 180, 174 and 169, respectively, thus, the VKT accumulated between periods corresponds on average to a period of roughly six months (i.e., 30 days per month).

The Distrito Federal has a total of 2,397 postal zones (pz), or postal codes, which are numbered according its 16 *delegaciones* (i.e. 1xxx, 2xxx,..., 15xxx and 16xxx), Hence, the postal zones (where the motorists live) are grouped (i.e., as dichotomic variables, e.g., DZ1=1 if the motorist is from North, otherwise 0) in five zones: North (with 15% of pz's), South (28%), Centre (14%), East (23%) and West (20%), that is, DZ1, DZ2, DZ3 and DZ4, respectively (i.e., there is no DZ5 variable in the regression because when all DZ's are equal to zero, then the car is from the West; but it is included in descriptive statistics). In this way, variables are included regarding not only the residential zone of the motorist but also, to some extent, his/her income level (i.e., a proxy variable that associates address with income level[12]). Thus, there are in the sample: 19.2% motorists[13] from the North, 22.4% from the South, 30.2% from the Centre, 14.5% from the East, and 13.7% from the West. As mentioned above, there are as also sub-samples corresponding to each zone.

[12] In general, it is possible to differentiate the income level according to the zone where the individual is living, e.g., inhabitants of *delegación* Tlalpan have on average a greater income than inhabitants of *delegación* Tlahuac, or, inhabitants from the South have greater income levels than those from the East. Again, this is a proxy variable and of course very debatable. Also, the vehicle itself can be used as a signal of the income level of the motorist.

[13] As noted above, I assume that there is one vehicle per motorist: the interest in this part is to know, in broader terms, to what extent some factors like vehicle model year and sticker, and residential zone are related with the kilometres driven.

Manufacturer, brand and model-year are the three variables for vehicles' (external) physical characteristics. Only the manufacturer (manuf) and model-year (mody) variables are included in the analysis (i.e., to see their relation with VKT). The brand helps only to group and describe the dataset; that is, it is considered that the manufacturer variable is sufficient to analyse to what extent the kind of automobile indeed matters for the kilometres that a motorist drives. The vehicle model-year is included in the analysis as "age of the car" (agecar), e.g., if the vehicle is model 2003 then its age is 1 year (there are no 2004 model-year vehicles in the sample), and it is assumed constant during the four periods[14]; also, as the age increases, vehicle use decreases after a certain point, thus age and age squared (sqagecar) are used in order to take into account this non-linear relation of the age. The average age of the sample is eight years.

Additionally, regarding vehicle characteristics, catalytic converter (DC) and gross vehicle weight (DW) are further explanatory variables for the number of kilometres travelled. If the vehicle has catalytic converter DC=1, otherwise 0; there are four DC's: DC_1, DC_2, DC_3 and DC_4, according to the test period (but of course only one is included in each regression). The gross vehicle weight falls in two ranges: between 2,728 and 3,856kg (DW=0) and greater than 3,856kg (DW=1)[15].

There are three types of stickers: sticker "zero" (stick=1), sticker "one" (stick=2), and sticker "two" (stick=3)[16]. In order to include these possibilities in the regression, there are two dummy variables: DS1 and DS2, where DS1=1 if the vehicle has a sticker "one", otherwise 0; DS2=1 if the vehicle has a sticker "two", otherwise 0 (thus, if both are equal to 0 the vehicle has a sticker "zero": it has no restrictions on driving). For each 6-month test, the variables are named in this way: DS1_1 and DS2_1 for first period; DS1_2 and DS2_2 for the second period (both from 2003); and DS1_3 and DS2_3 for the third one (i.e., the first half of 2004).

[14] Taking into account that the difference between periods is only six months, it is a sensible assumption about the age. However, for extensive periods of time, more than the age of the car, it would be better to have the depreciation of the car and then to see how such feature impacts on the use of the car.

[15] From the sample, only 1.7% vehicles have a gvw greater than 3856kg.

[16] As it was explained above, sticker "zero" entitles a vehicle to be driven on all seven days of the week, sticker "one" bans a vehicle from being driven one day per week, sticker "two" bans two days, and for all these possibilities the vehicle must be inspected every semester.

Finally, the manufacturer variable (manuf) is included in the analysis as a dummy variable (DM). Manufacturers are placed in nine groups: 1) Chrysler/Dodge, 2) Ford, 3) Chevrolet (General Motors), 4) Nissan, 5) Renault and Peugeot, 6) Volkswagen, 7) Mercedes and BMW and Audi, 8) Honda, and 9) "Luxury" (i.e., Jaguar, Land Rover and Volvo). This implies eight dummy variables (DM) where if DM is equal to 1 the vehicle belongs to the respective numbered group, and otherwise has a 0: DM1, DM2, DM3, DM4, DM5, DM6, DM7 and DM8 (i.e., when all are 0 then the vehicle is part of the Luxury group). The sample includes, for every group the following percentage of vehicles: 16.6% (Dodge), 17.5% (Ford), 21.7% (GM), 17.4% (Nissan), less than 1% (Renault and Peugot), 20.7% (VW), 1.5% (Mercedes/BMW/Audi), 3.8% (Honda), and less than 1% (Lux). These and the above mentioned descriptive statistics are presented at length in the Appendix A: Statistical Descriptions. Also, as mentioned above, seven sub-samples were created according to the manufacturer, grouping in one single sub-sample the groups 5, 7 and 9.

2.3 The INE Survey

During the final months of 2005 and beginning 2006 the Environmental Economics Area of the Mexican National Institute of Ecology (INE) conducted a survey aimed at building a database that helps to improve the analysis of cross-demand price elasticities of brand-new automobiles. The objective of the survey was, through eleven different manufacturers[17] and their sales points in Mexico City, to obtain between 15 and 25 questionnaires for each vehicle model (listed in Table 4.2), and to obtain 1500 questionnaires (at a minimum), in order to identify the main buying factors, i.e., consumer preferences, for brand-new automobiles.

The survey, named in this research as the "INE survey", was conceived as a data collection to estimate the economic and environmental impacts of economic instruments applied for improving the environmental performance of brand-new automobiles. Nonetheless, through cooperation with the research team at INE it was possible to modify and include questions regarding the vehicle's usage, i.e., the planned use for the brand-new

[17] Daimler Chrysler, General Motors, Ford, Honda, Mitsubishi, Nissan, Peugeot, Renault, Seat, Toyota and Volkswagen.

auto and the current use of other vehicles owned by the buyer. Thus, the final version of the questionnaire was indeed not only for the INE's research interests but also for the aim of this doctoral thesis. The survey's main purpose and focus was to obtain insight as to consumer preferences regarding the purchase of brand-new automobiles, i.e., the survey takes into account only 2006 model-year vehicles.

Table 4.2 List of kind of cars included in the INE survey

Manufacturer	*Manufacturer Brand**	*Brand*
Daimler Chrysler**	Dodge	Ten different brands, *inter alia* Atos, Neon and Stratus
	Chrysler	Cirrus, Cruiser and Voyager
	Jeep	Cherokee and Liberty
General Motors	Chevrolet	19 different brands, *inter alia* Astra, Chevy and Meriva
	Pontiac**	Matiz and Palio
Ford	Ford	17 different brands, *inter alia* Courier, Fiesta and Focus
Honda	Honda	Accord, Civic and CR-V
Mitsubishi**	Mitsubishi	Lancer and Outlander
Nissan	Nissan	12 different brands, *inter alia* Altima, Platina and Tsuru
Peugeot	Peugeot	P.206 and P.307
Renault	Renault	Clio (2ver) and Megane (2ver)
Seat	Seat	Cordoba and Ibiza (2ver)
Toyota	Toyota	Camry, Corolla, RAV4 and Sienna
Volkswagen	Volkswagen	11 different brands, *inter alia* Derby, Golf and Polo

*This name-category is the correspondent to "manufacturer" in the VVP database.
**not included in the available dataset for this research.

The survey included four sections: characteristics of the purchased vehicle, its planned use (including uses of alternate modes of transport both after- and before-buying the vehicle, and characteristics of already owned autos), payment details, and personal consumer characteristics (including net income). In total the questionnaire includes 15 questions, with a total of 99 variables. The first section includes three questions (27 variables), the second one 9 questions (48 variables), and the third and fourth parts are the remaining four questions (7 variables for payment details and 17 variables for consumer characteristics).

Most of the questions are qualitative with answer-options restricted to single statements (e.g., by selecting the answer from a list of possibilities, or the usual selection between sex 'male' or 'female'), and only four answers are totally open (and not relevant for this research, e.g., "Please mention some extra features of the car"). Hence, those 99 variables are the sum options given with the closed questions (representing, for example, a column in a datasheet). Finally, 764 questionnaires were available for this research, for logistical reasons and reasons of data confidentiality[18]. Table 4.3 indicates how many questionnaires corresponded to each manufacturer.

Table 4.3 Number of questionnaires for each manufacturer

Manufacturer	*Number of questionnaires*
(1) General Motors	137
(2) Ford	36
(3) Honda	215
(4) Nissan	22
(5) Peugeot	66
(6) Renault	13
(7) Seat	36
(8) Toyota	6
(9) Volkswagen	233

2.4 The INE Survey Variables

In total the survey for the analysis includes 27 variables and 533 questionnaires; net monthly income was only reported for this number of households. That is, the analysis does not take all sections and variables of the original survey: it selects only the relevant parts for this case study. Table 4.4 lists the included variables.

[18] That is, only thanks to this mentioned closer cooperation with the INE's research team it was possible to get some data, taking into account those personal data included in the survey and related Mexican legal aspects.

Table 4.4 List of variables from the INE survey

Name	*Description*	*Features*
ID	ID number of the questionnaire	Control number
manuf	Manufacturer (e.g., VW)	9 categories (see Table 4.3)
brand	Car brand (e.g., Golf)	Only to control data consistency
DPF	Payment form	3 categories: (1)single payment; (2)financing; (3)self-financing
price*	Price of the car (in euros)	
DGI1	Degree of importance for 'price' factor	3 categories: "indifferent" (1), "more or less" (2), "very important" (3)
DGI2	Degree of importance for 'engine's power' factor	idem
DGI3	Degree of importance for 'comfort' factor	idem
DGI4	Degree of importance for 'security' factor	idem
DGI5	Degree of importance for 'related expenses' factor (e.g., taxes, insurance)	idem
DGI6	Degree of importance for 'environmental performance' factor	idem
DGI7	Degree of importance for 'fuel consumption' factor	idem
DGI8	Degree of importance for 'status' factor	idem
DU	Planned use of car	Five categories (according to the main use): work (1), school (2), work and school (3), home activities (4), holidays (5)
FT	Frequency of transportation	Daily (=1) or no-daily (=0)
FTH	Frequency of transportation per hour (intensity of travel)	3 categories: small (y*<3hrs), medium (3≤y*<6hrs), big (6≤y*)
DPTU	Public transport use before buying the car	Yes(1) or no(0)
ECU	Expected car use (i.e., for the new one)	Yes(1) or no(0), which means public transport use
DTNC	Total number of cars (including the new one)	One(1), two(2) or more than two (3)
HAGE	Household age	
DMS	Marital status	(1) Single (including widowers, divorcés) or (0) with couple (including married or living together)
DSX	Sex	Male (0) or female (1)
DSI	Source of income	(1) Self source (e.g., employers) or (0) from-others (e.g., employees and students)
DEDUC	Years of education	3 categories: less than high school (1), high school but less than university degree (2), university degree (3)
HS	Household size	≥ 1 (living alone)
DHK	Household with kids/teens	Dummy variable
INC*	Household net monthly income (in euros)	

*Exchange rate: €1=15Mexican pesos, Aug 2007 (which was the same one year ago).

Those variables beginning with 'D' are dummy variables (also *manuf* is included). As noted above, the vehicle model-year is 2006, and the price is as reported by the buyer; the final price depends on the payment type: normally it increases when payments are made through finance plans. The variable DPF takes into account this difference in payment forms; the difference between financing and self-financing is that the former implies a large down payment followed by monthly instalments, and the latter only monthly instalments.

The "degree of importance (DGI)" variables are the answers to the question: "Select the degree of importance given to the following vehicle characteristics". That is, to what extent the particular characteristic was important when the buyer was selecting and buying the automobile. For this research I selected eight characteristics. Another like design, the brand itself, colour or brakes, were not taken into account because they were not considered relevant for vehicle usage (though they may indeed be relevant when purchasing a vehicle). The planned use of the vehicle (DU) was the first item in the section about vehicle usage. The question was: "What will be the main use of the vehicle? Please select three options in order of importance". The motorist's manner of response did not always coincide with this intent, and there were surveys filled out with only "crosses" instead of ranking; thus, the answers were managed in such way that at the end five categories were generated and the answers grouped (trying to follow the degree of importance: i.e., if the buyer selected "work" and then "holidays", then the answer was classified as "work"). Most responses as to planned vehicle use, according this management of information, are for work (54.2%) and "work and school" (25.7%); there are yet interesting outputs, as stated in the next section, even for this kind of classification.

The three dependant variables for the regressions are: expected car use (ECU), frequency of transportation (FT), and frequency of transportation per hour (FTH). The three of them are discrete variables: ECU and FT are dichotomic and FTH includes three possible categories. ECU was the answer for the question: "Are you going to use public transport after buying the vehicle? Which type?". Again, in this part of the survey it was asked to give the number of times (per week), but not all the buyers answered according to instructions[19],

[19] It was not a personal interview: the survey was answered (i.e., filled) directly by the buyer.

thus, the information must be grouped. The frequency of travel (FT) was grouped as well: "How frequently are you going to use the vehicle?" Daily (FT=1) and FT=0 if "Every 2-3days", "Once a week" or "Very seldom" were responded, and in this way it was possible to have a better base for the estimation model (i.e., 13% with FT=0, and 87% with FT=1). Lastly, FTH was an open question: "Approximately, how many hours per day are you going to use the vehicle?" The answers were multiple so it was necessary, in order to deal with the information, to group in three categories: less than 3 hours, between 3 and 6 hours, and more than 6 hours (i.e., low, medium or high intensity of travel, respectively)[20].

The use of public transport was treated with the above mentioned question and with the following: "Number of times the buyer travelled with other means of transport before buying the vehicle?" Six options were available and, as with other questions, in order to deal better with the information (and taking into account the disparity among the answers) the answers were grouped in two possible answers: public transport user negative or positive (i.e., the DPTU variable). The following question in the survey regards the number of automobiles that already the buyer has, with three possible answers (none, one, more than one), while the DTNC (total number of cars) variable also includes the newly purchased automobile such that the final options were: one, two, more than two.

And finally, there are the personal characteristics. Some of them had to be grouped, like the source of income (DSI) and years of education (DEDUC). Questions about family members were given in two parts: the number of people living in the same house (i.e., household size) and how many of them are children or teenagers (then the buyer was classified as having or not having children/teenagers). The descriptive statistics of these above mentioned variables, as in the case of the VVP dataset, are presented in Appendix A: Statistical Descriptions.

[20] This is why this variable is not at all an ordered one, and thus modelled trough an ordered logit model. It is modelled with a multinomial logit.

3. ESTIMATION RESULTS

The following paragraphs present and explain the results, and indicate relevant implications for this part of the research (taking into account what has been reviewed and analysed so far). First the VVP dataset is presented, then the INE survey. The ordinary least squares (OLS) method was used for VVP dataset analysis, while logistic and multinomial logistic regression methods were used for the INE survey analysis. Because of the data characteristics in both sets (i.e., expected heteroscedasticity), the regressions were estimated with the Huber/White/sandwich estimator of variance, in order to have consistent standard errors (i.e. robust standard errors). On the other hand, there was no evidence for problems like autocorrelation and multicollinearity.

3.1 Results from the VVP-dataset

In order to introduce the results from the econometric regressions, first, I revise the correlations between age of the vehicle (agecar) and kilometres travelled (until the date of inspection and during 6 month periods: km1, km2, km3, km4 and km12, km23, km34, respectively). The aim of doing this is to find any kind of pattern among the data: Is there any relation between vehicle age and VKT? What is it? According to theory and the literature review, I expect that there is indeed a positive relation. Table 4.5 lists the correlation coefficients.

Table 4.5 Correlations (from the VVP dataset)

		AGECAR	KM1	KM2	KM3	KM4	KM12	KM23	KM34
AGECAR	Pearson Correlation	1,000	,230**	,342**	,413**	,399**	,226**	,259**	,248**
	Sig. (2-tailed)	,	,000	,000	,000	,000	,000	,000	,000
	N	12997	12997	12997	12997	12997	12997	12997	12997
KM1	Pearson Correlation	,230**	1,000	,742**	,515**	,246**	-,118**	-,026**	,007
	Sig. (2-tailed)	,000	,	,000	,000	,000	,000	,004	,396
	N	12997	12997	12997	12997	12997	12997	12997	12997
KM2	Pearson Correlation	,342**	,742**	1,000	,762**	,394**	,578**	,071**	,046**
	Sig. (2-tailed)	,000	,000	,	,000	,000	,000	,000	,000
	N	12997	12997	12997	12997	12997	12997	12997	12997
KM3	Pearson Correlation	,413**	,515**	,762**	1,000	,559**	,502**	,700**	,112**
	Sig. (2-tailed)	,000	,000	,000	,	,000	,000	,000	,000
	N	12997	12997	12997	12997	12997	12997	12997	12997
KM4	Pearson Correlation	,399**	,246**	,394**	,559**	1,000	,283**	,427**	,887**
	Sig. (2-tailed)	,000	,000	,000	,000	,	,000	,000	,000
	N	12997	12997	12997	12997	12997	12997	12997	12997
KM12	Pearson Correlation	,226**	-,118**	,578**	,502**	,283**	1,000	,136**	,059**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,	,000	,000
	N	12997	12997	12997	12997	12997	12997	12997	12997
KM23	Pearson Correlation	,259**	-,026**	,071**	,700**	,427**	,136**	1,000	,122**
	Sig. (2-tailed)	,000	,004	,000	,000	,000	,000	,	,000
	N	12997	12997	12997	12997	12997	12997	12997	12997
KM34	Pearson Correlation	,248**	,007	,046**	,112**	,887**	,059**	,122**	1,000
	Sig. (2-tailed)	,000	,396	,000	,000	,000	,000	,000	,
	N	12997	12997	12997	12997	12997	12997	12997	12997

**. Correlation is significant at the 0.01 level (2-tailed).

As it is expected, there is a very statistically significant positive correlation between vehicle age and its kilometres travelled. That is, as the vehicle ages the kilometres travelled increases (e.g., by comparing the coefficients of every period of time, km1, km2, km3 and km4). This relation is small for the first period of time (i.e., km1) and for the kilometres travelled during the six month intervals (i.e., km12, km23 and km34): 0.230, 0.226, 0.259 and 0.248, respectively; and medium for the second, third and fourth periods (i.e., 0.342, 0.413 and 0.399, respectively). Likewise, the correlation between kilometres registered at every inspection period (e.g., km1 and km2, km3, km4) is positive with respect to direction, but it decreases with the time: 0.742, 0.515 and 0.246, for the first semester; 0.762 and 0.394 for the second one; and 0.559 for the third one.

Finally, the relation between the kilometres travelled up until the date of inspection (km1, km2, km3, km4) and kilometres travelled between inspections (km12, km23, km34) shows a very interesting pattern. For the first period, the kilometres travelled up until the inspection date have a very small correlation with those travelled during next 6 months periods (and actually negative for the first two: -0.118, -0.026 and 0.007, respectively); the second period (km2) has, first, as expected (i.e., how many kilometres the vehicles have been driven up until the date of inspection is related with the distance travelled in the previous period), a medium correlation (0.578) but the impact decreases to near zero in the subsequent 6 month periods; the third period (km3), again, has an expected positive and decreasing correlation with the previous first two periods (km23 and km12: 0.7 and 0.502, respectively), but becomes very low in the subsequent period (0.112). The final period (km4) shows better the pattern among periods: how many kilometres are driven up until a given period of time has a decreasing relation with how much was driven during previous 6 month periods and a very low relation with subsequent 6 month periods. That is, the total number kilometres travelled prior to period N has indeed a strong positive correlation with the distance travelled between period N and N-1, N-2, N-n periods, but this relation decreases in strength (as n increases), and also this total distance travelled has no heavy impact on the following six month periods.

Thus, there is room to think about which other factors, besides age and previous kilometres driven, could explain vehicle use. Certainly, by looking at the vehicle age, one can expect to some extent that the vehicle has been used in a certain way (e.g., the average expected kilometres per year that auto manufacturers set for, say, inspection or service) and/or how it will be used (e.g., if it is very old then the use decreases); in the same way, by observing the odometer, one can explain more or less the intensity the vehicle has been driven so far, but not very much about how (and how much) it will be driven.

The econometric regressions go one step further than correlation figures, and present to what extent the distance travelled is influenced by the vehicle age and other factors. The method I use for the econometric model, taking into account the available information and the aims of the tool, is the ordinary least squares method (OLS). In particular, the OLS-regression model includes one dependant variable (VKT over six months, i.e., between inspections/periods: *km12*, *km23* and *km34*) and eight kinds of independent variables (vehicle age "*agecar*", square of the age "*sqage*", kilometres driven before the analysed period "*km#*", a dummy variable for zone, a dummy variable for the kind of the sticker, a dummy variable for the kind of the manufacturer, a dummy variable for vehicle weight, and a dummy variable for catalytic converter), and the constant term. Regarding the five dummy variables, there are four for the zone (*dz1, dz2, dz3, dz4*), two for the sticker (*ds1_#* and *ds2_#*), eight for manufacturer (*dm1, dm2, dm3, dm4, dm5, dm6, dm7* and *dm8*), one for weight (*dw*), and one for catalytic converter (*dc_#*), where # is the number of the period (1, 2, 3 or 4).

The first regression for every dataset (i.e., in total there are 13: five from geographical region, seven from manufacturer, plus the general one) and for each dependant variable (i.e., *km12*, *km23* and *km34*) included all the variables. By using a stepwise regression method with backward elimination and forward selection of variables, the more suitable specified model is selected. There was no single form (i.e., pre-selected independent variables), and for every regression the purpose was to get the best specified model, taking into account that the models are not for forecasting purposes (i.e., the concern is not to provide accurate predictions). The aim is to identify possible factors causing the variation in the particular dependant variable. Tables 4.6-4.10 summarize the results (coefficients and significance) of these regressions; table 4.10 lists only if there is significance and if it is positive or negative.

Table 4.6 Determinants of VKT during one semester, OLS regressions

Variable	*Period I*	*Period II*	*Period III*
Age of the car	3.7585 (.3230)*	1.6596 (.2199)*	5.8643 (.9239)*
Age squared	-.0838 (.0126)*	n.s.	-.0629 (.03352)***
Km1	-.00018 (.000017)*	-.00017 (.00002)*	-.00011(.00004)*
Km2	N.I.	.00008 (.00002)*	-.00021 (.00004)*
Km3	N.I.	N.I.	.00015 (.00003)*
DZ1	.2510 (.9124)	n.s.	n.s.
DZ2	1.7945 (.9823)***	n.s.	n.s.
DZ3	.5619 (.8329)	n.s.	n.s.
DZ4	1.5287 (1.043)	2.3856 (1.3251)***	n.s.
DM1	n.s.	n.s.	n.s
DM2	n.s.	n.s.	n.s
DM3	n.s.	n.s.	n.s
DM4	n.s.	n.s.	n.s
DM5	n.s.	n.s.	n.s.
DM6	n.s.	n.s.	n.s.
DM7	n.s.	n.s.	n.s.
DM8	n.s.	n.s.	n.s.
Sticker 1 in PI	5.4341 (1.7206)*	N.I.	N.I.
Sticker 2 in PI	2.8752 (2.1610)	N.I.	N.I.
Sticker 1 in PII	N.I.	4.9591 (2.737)***	N.I.
Sticker 2 in PII	N.I.	8.0914 (2.885)***	N.I.
Sticker 1 in PIII	N.I.	N.I.	4.8674 (5.6627)
Sticker 2 in PIII	N.I.	N.I.	28.6583 (6.553)*
Weight	-2.9919 (2.343)	n.s.	n.s.
Catalytic in PI	.2946 (2.0894)	N.I.	N.I.
Catalytic in PII	N.I.	n.s.	N.I.
Catalytic in PIII	N.I.	N.I.	n.s.
constant	3.5205 (1.235)*	3.2480 (1.1218)*	9.4587 (3.3462)*
Prob>F	0.0000	0.0000	0.0000
R^2	0.1009	0.0804	0.0702
Root MSE	32.999	44.775	124.36

Notes: a) Dependant variable: number of kilometres travelled during the inspections, divided by 1000 (km12, km23 and km34); b) The variables km1, km2 and km3 are the number of kilometres travelled up until the day of inspection; c) Number of observations: 12997; d) Robust standard errors in parentheses; e) N.I. means not included; and n.s. not significant (and not reported in order to facilitate reading); f) Statistically significant at the: ***10%, **5% and *1% level.

Table 4.7 Determinants of VKT by zone (North and South), OLS regressions

Variables	*North*			*South*		
	I	II	III	I	II	III
Age of the car	3.730* (.589)	2.822* (.764)	3.531* (.960)	1.110* (.375)	1.841* (.457)	5.621* (2.069)
Age squared	-.084* (.021)	-.059** (.027)	n.s.	n.s.	n.s	n.s.
Km1	-.0001* (.00004)	-.0003* (.00006)	n.s.	-.0001* (.00002)	-.0001* (.00004)	n.s.
Km2	N.I.	.0001* (.00006)	-.0002** (.0001)	N.I.	.00007*** (.00004)	-.0002* (.00009)
Km3	N.I.	N.I.	.0001* (.00006)	N.I.	N.I.	.0001* (.00007)
DM1	n.s.	n.s.	n.s.	7.639* (2.101)	n.s.	n.s.
DM2	n.s.	n.s.	n.s.	10.904* (2.203)	n.s.	n.s.
DM3	n.s.	n.s.	n.s.	12.028* (1.995)	5.158* (2.009)	n.s.
DM4	n.s.	n.s.	n.s.	14.102* (2.180)	n.s.	n.s.
DM6	n.s.	n.s.	n.s.	10.874* (2.585)	n.s.	n.s.
DM8	n.s.	n.s.	n.s.	8.185* (1.810)	n.s.	n.s.
Sticker 1 in PI	n.s.	N.I.	N.I.	19.399* (4.418)	N.I.	N.I.
Sticker 2 in PI	n.s.	N.I.	N.I.	13.158** (6.370)	N.I.	N.I.
Weight	n.s.	-11.382* (4.365)	n.s.	n.s.	n.s.	n.s.
Catalytic in PII	N.I.	-17.337* (6.523)	N.I.	N.I	-13.842* (5.173)	N.I.
Catalytic in PIII	N.I.	N.I.	n.s.	N.I.	N.I.	-44.710** (22.504)
constant	2.991** (1.514)	16.907* (7.149)	14.929* (5.025)	4.493* (1.536)	13.715* (5.787)	51.909** (24.041)

Table 4.7 Determinants of VKT by zone, OLS regressions (continuation)

	NI	NII	NIII	SI	SII	SIII
Number of observations	2501	2501	2501	2908	2908	2908
Prob>F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R^2	0.0831	0.100	0.0604	0.1041	0.0996	0.0854
Root MSE	30.634	44.799	115.86	38.73	39.974	123.56

Notes: a) Dependant variable: number of kilometres travelled during the inspections, divided by 1000 (km12, km23 and km34); b) The variables km1, km2 and km3 are the number of kilometres travelled up until the day of inspection; c) Robust standard errors in parentheses; d) N.I. means not included; and n.s. not significant (and not reported in order to facilitate reading); e) Statistically significant at the: ***10%, **5% and *1% level.

Table 4.8 Determinants of VKT by zone (Centre), OLS regressions

Variables	*Centre*		
	I	*II*	*III*
Age of the car	3.808* (.573)	1.694* (.426)	4.009* (.772)
Age squared	-.087* (.025)	n.s.	n.s.
Km1	-.0002* (.00002)	-.00009* (.00002)	n.s.
Km2	N.I.	n.s.	-.00018** (.00008)
Km3	N.I.	N.I.	.00011** (.00005)
DM3	n.s.	n.s.	13.609** (5.393)
Sticker 1 in PI	8.064* (3.146)	N.I.	N.I.
Sticker 2 in PI	n.s.	N.I.	N.I.
Sticker 1 in PII	N.I.	10.078*** (5.71)	N.I.
Sticker 2 in PII	N.I.	n.s.	N.I.
Sticker 1 in PIII	N.I.	N.I.	n.s.
Sticker 2 in PIII	N.I.	N.I.	39.219* (11.662)
constant	5.392* (1.734)	4.334* (2.016)	11.992** (5.250)
Number of observations	3927	3927	3927
Prob>F	0.0000	0.0000	0.0000
R^2	0.1172	0.0742	0.0759
Root MSE	31.024	44.134	129.13

Notes: a) Dependant variable: number of kilometres travelled during the inspections, divided by 1000 (km12, km23 and km34); b) The variables km1, km2 and km3 are the number of kilometres travelled up until the day of inspection; c) robust standard errors in parentheses; d) N.I. means not included; and n.s. not significant (and not reported in order to facilitate reading); e) Statistically significant at the: ***10%, **5% and *1% level.

Table 4.9 Determinants of VKT by zone (East and West), OLS regressions

Variables	*East*			*West*		
	I	II	III	I	II	III
Age of the car	3.157* (.685)	1.450** (.7532)	4.707* (1.153)	1.552* (.4942)	2.077* (.390)	3.830* (.839)
Age squared	-.0694* (.025)	n.s.	n.s.	n.s.	n.s.	n.s.
Km1	-.0001** (.00005)	-.0001* (.00003)	n.s.	-.0001* (.00002)	-.0001* (.00003)	-.0003* (.0001)
Km2	N.I.	n.s.	-.0002* (.00008)	N.I.	n.s.	n.s.
Km3	N.I.	N.I.	.0001*** (.00006)	N.I.	N.I.	.0002* (.00009)
DM1	n.s.	n.s.	20.029* (7.721)	n.s.	n.s.	n.s.
DM2	n.s.	n.s.	31.180* (8.191)	n.s.	n.s.	n.s.
DM3	n.s.	n.s.	27.573* (7.018)	n.s.	n.s.	n.s.
DM4	n.s.	n.s.	29.014* (7.835)	n.s.	n.s.	n.s.
DM5	n.s.	n.s.	144.866*** (82.197)	n.s.	n.s.	n.s.
DM6	n.s.	n.s.	21.686* (7.870)	n.s.	n.s.	n.s.
Sticker 2 in PI	9.091** (4.600)	N.I.	N.I.	n.s.	N.I.	N.I.
Sticker 1 in PII	N.I.	17.646*** (10.211)	N.I.	N.I.	n.s.	N.I.
Sticker 2 in PIII	N.I.	N.I.	28.73*** (17.052)	N.I.	N.I.	n.s.
Weight	n.s.	n.s.	n.s.	-8.217* (3.963)	n.s.	n.s.
Catalytic in PII	N.I.	-21.311*** (11.756)	N.I.	N.I.	n.s.	N.I.
constant	4.376** (1.937)	29.546** (14.646)	-10.576** (5.321)	11.974* (2.829)	4.522* (2.152)	14.527* (4.776)

Table 4.9 Determinants of VKT by Zone, OLS regression (continuation)

	EI	*EII*	*EIII*	*WI*	*WII*	*WIII*
Number of observations	1888	1888	1888	1773	1773	1773
Prob>F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R^2	0.0862	0.0781	0.0839	0.1105	0.0817	0.0534
Root MSE	34.627	54.739	126.46	28.154	41.022	123.45

Notes: a) Dependant variable: number of kilometres travelled during the inspections, divided by 1000 (km12, km23 and km34); b) The variables km1, km2 and km3 are the number of kilometres travelled up until the day of inspection; c) robust standard errors in parentheses; d) N.I. means not included; and n.s. not significant (and not reported in order to facilitate reading); e) Statistically significant at the: ***10%, **5% and *1% level.

Table 4.10 Determinants of VKT by manufacturer, OLS regressions

variable	*M1*	*M2*	*M3*	*M4*	*M6*	*M8*	*M579*
Age of the car	Y Y Y	Y Y Y	Y N Y	Y Y Y	Y Y Y	Y -Y -Y	-Y -Y -Y
Age squared	-Y N N	-Y N N	-Y Y N	-Y N N	-Y N -Y	N N N	N Y N
Km1	-Y -Y N	-Y -Y N	-Y –Y N	Y -Y N	-Y -Y -Y	-Y N N	Y N Y
Km2	X Y -Y	X N -Y	X Y N	X Y N	X Y -Y	X Y -Y	X Y N
Km3	X X Y	X X Y	X X Y	X X Y	X X Y	X X Y	X X Y
DZ1	N N N	N N N	N N N	N N N	N N N	N Y N	N N N
DZ2	N N N	N N N	Y Y N	N N N	N N N	N Y N	N N N
DZ3	N N N	N N N	N N N	N N N	N N N	N Y Y	N N N
DZ4	N N N	N -Y N	N Y N	N N N	N N N	N N N	N N N
Sticker1 in PI	N X X	Y X X	Y X X	N X X	Y X X	N X X	-Y X X
Sitcker2 in PI	N X X	N X X	N X X	N X X	N X X	N X X	NXX
Sticker1 in PII	X N X	X N X	X N X	X N X	X N X	X N X	X -Y X
Sticker2 in PII	X N X	X N X	X N X	X N X	X Y X	X N X	X N X
Sticker1 in PIII	X X N	X X N	X X N	X X N	X X N	X X N	X X N
Sticker2 in PIII	X X Y	X X N	X X N	X X N	X X N	X X N	X X -Y
Weight	N Y N	N N N	-Y N N	N N N	N N N	N N N	N N N
Catal. in PI	N X X	N X X	N X X	N X X	N X X	N X X	N X X
Catal. in PII	X N X	X N X	X N X	X Y X	X N X	X N X	X N X
Catal. in PIII	X X N	X X -Y	X X N	X X N	X X N	X X N	X X N
Number of obs.	2160	2278	2820	2263	2688	499	232

Y: it is significant; N: not significant; X: not included; (-)negative coefficient; ordered by period (i.e., I II III).
Notes: a) Dependant variable: number of kilometres travelled during the inspections, divided by 1000 (km12, km23 and km34); b) The variables km1, km2 and km3 are the number of kilometres travelled up until the day of inspection; c) in every regression there was a significant constant.

The results show those variables that seem to have an impact on the kilometres travelled during the six month periods. However, this impact is not precisely indicated by the numerical coefficients because the models (and the available variables), as noted above, are not fit for forecasting purposes. The coefficients only indicate in broader terms the extent of the impact. The results do offer one very significant output: the impact of the HNC program on the use of automobiles. There is no real impact and, more importantly, the program does not help reduce automobile usage: it induces automobile usage. The next section provides other factors that offer further explanation about automobile usage.

3.2 Results from the INE survey

Many factors remain to be included in a model regarding automobile usage. The INE survey allows this by reporting (more) qualitative information related to the issue. Three dependant variables are the axis of three regressions: expected car use (ECU), frequency of transportation (FT) and frequency of transportation per hour (FTH). The first two have only two outcomes each, and the third one has three, thus, the first two regressions are estimated through logit models and the third one using a multinomial logit model. The independent variables are the same for the three models. Following Table 4.11 and 4.12 summarizes the results (4.11 presents the results for the ECU and FT variables).

Table 4.11 Logit model of the determinants of vehicle use (ECU and FT)

variables	*I. ECU as dependant variable*	*II. FT as dependant variable*
Price	n.s.	n.s.
Income	n.s.	n.s.
Household age	n.s.	n.s.
Household size	n.s.	n.s.
DGI1	n.s.	n.s.
DGI2	n.s.	n.s.
DGI3	n.s.	n.s.
DGI4	n.s.	n.s.
DGI5	n.s.	n.s.
DGI6	n.s.	n.s.
DGI7	n.s.	dgi7_2: 1.636** (.736) dgi7_3: 1.477** (.6563)
DGI8	n.s.	dgi8_2: -.8891* (.4706)
DU	du2: -.9585* (.4015)	du3: .6939*** (.4267) du5: -1.604* (.4424)
DPTU	-2.720* (.2830)	-.6594** (.3085)
DTNC	dtnc2: 1.186* (.4505) dtnc3: .9015* (.3298)	dtnc3: -.6446** (.3443)
DMS	.6104* (.2858)	.6164** (.34760)
DSX	n.s.	n.s.
DSI	n.s.	n.s.
DEDUC	n.s.	n.s.
DHK	n.s.	n.s.
DPF	n.s.	n.s.
Manufacturer	m2: 1.351* (.5298) m5: 1.107* (.5078) m7: 1.553* (.7526) m9: .8258* (.3598)	n.s.
Constant	.4061 (.5373)	2.661** (1.165)
Number of observations	533	533
Prob>chi2	0.0000	0.0002
Pseudo R^2	0.2928	0.1422

Notes: Robust standard errors in parentheses; n.s. means not significant (and not reported in order to facilitate reading); statistically significant at the ***10%, **5% and *1% level.

Table 4.12 Multinomial model of the determinants of vehicle use (FTH)

variables	*III. FTH as dependant variable*	
	Group 0 (small intensity)	Group2 (big intensity)
Price	n.s.	n.s.
Income	n.s.	n.s.
Household age	n.s.	n.s.
Household size	n.s.	n.s.
DGI1	n.s.	n.s.
DGI2	n.s.	n.s.
DGI3	n.s.	n.s.
DGI4	n.s.	n.s.
DGI5	dgi5_3: -.7146*** (.4248)	n.s.
DGI6	n.s.	n.s.
DGI7	n.s.	n.s.
DGI8	n.s.	n.s.
DU	du2: .7545*** (.4194)	n.s.
DPTU	n.s.	n.s.
DTNC	dtnc3: .5517** (.2559)	dtnc2: .7235** (.3307)
DMS	.4016*** (.2362)	n.s.
DSX	n.s.	n.s.
DSI	n.s.	.7490* (.2726)
DEDUC	n.s.	n.s.
DHK	n.s.	n.s.
DPF	n.s.	dpf2: -.6036* (.2875)
Manufacturer	n.s.	M2: 1.172** (.5993) m4: 1.759* (.6699) m5: 1.213* (.4925 m7: 1.7715* (.6588) m8: -32.744* (.8027)
Constant	-.6424 (.7312)	-1.0869 (.7392)
Number of observations		533
Prob>chi2		0.0000
Pseudo R^2		0.0794

Notes: Robust standard errors in parentheses; n.s. means not significant (and not reported in order to facilitate reading); the base group is the 1 category (i.e., medium intensity of use); Statistically significant at the ***10%, **5% and *1% level.

In this case, the results give more information about the causes of using the vehicle or not and its intensity of use. The model is not intended for predictive purposes, but it does offer some other explanatory factors about vehicle usage. The more important results from these models are that numeric variables like income or vehicle purchase price do not explain vehicle usage, the behaviour of people in this particular issue. Such behaviour seems to be better explained by attitudes (e.g., alternative use of public transport) or personal attributes (e.g., being single or married), and not precisely by economic factors or the vehicle itself (to some extent). Further discussion, and the relevance, of the above mentioned results is presented in the following chapter.

4. SUMMARY

This chapter presented the results of the empirical evidence. This evidence was generated in two stages. The econometric tool consisted in three regression models: linear (for the first stage), logit and multinomial logit (for the second stage). Given the quantity of possible variable coefficients and the restricted use of the models for forecasting, the focus was on the possible relation between variables, its direction and the magnitude of these relations. Two datasets, each corresponding to one stage of analysis, were used and each one contributed significantly to the total evidence. The Vehicle Verification Program shows the magnitude of impact that already implemented instruments have had for controlling vehicle use, and the INE survey supplements with related information. Thus, the resulting models do not have forecast purposes but their application helps to look beyond the common approach by taking into account that which was suggested in the theoretical revision, i.e., transportation is an activity that involves inputs and outputs with a collection of characteristics.

Chapter 5

Implications of the Results

"What is the city but the people?" (William Shakespeare)

"Every person has the right to live in an environment that is suitable for his/her development and wellbeing." (Included in Article 4, 'Chapter I: About Individual Guarantees', of the Mexican Constitution)

"Too many laws are made, and too few examples given." (Saint-Just)

1. Introduction

In order to discuss the results presented in the previous chapter, this chapter presents a framework that includes relevant findings from other studies. In particular, a theoretical model is introduced to guide the discussion, and two more studies about the case of Mexico City are drawn into the discussion. The aim of this chapter is not only the discussion of the results but also, by relating them to other studies and the existing policies, to supplement the theoretical aspect and to nourish the empirical evidence. In the next two sections the discussion of the results is further contextualized through the review of, on the one hand, related studies regarding automobile use and air pollution, and, on the other hand, the current policies that tackle the issue.

This chapter continues the empirical part of the research and discusses its findings in light of relevant results from other related socioeconomic studies. Thus, the discussion is presented in two levels: first, the implications are seen through both sociological and economic approaches, which are introduced by related case studies; the second level is the discussion of the current policy actions and their relation with this research's findings.

The chapter includes three more sections: the following section presents results from the research and relevant sociological and economic studies; section three compares the results with the existing policy actions, and section four provides a summary.

2. RESULTS FROM THE RESEARCH AND PREVIOUS RELEVANT STUDIES

Studies with a sociological focus that have taken up the case of air pollution in Mexico City have been few and far between; in this research I refer to one such study by Mercado-Doménech *et al.* (2001), which had the goal of evaluating the cognition, perception and ways to cope with the air pollution problem among the residents of Mexico City. Additionally, Axhausen (2002) and Hanson (1982), in their conceptual discussion of spatial factors, are discussed at the close of the following sub-section. The first sub-section opens with a general model by Chapin (1974) for explaining activity patterns and that will guide the analysis of the mentioned studies and help frame discussion of the research's results.

The second sub-section presents the results with an economic focus. The discussion of vehicle use begins by reviewing the case study from Dix *et al.* (1983), and it ends with the results presented by De Souza (1999) about an analysis of household transportation use and urban air pollution in Mexico City. Lastly, the third sub-section closes with the findings of this research.

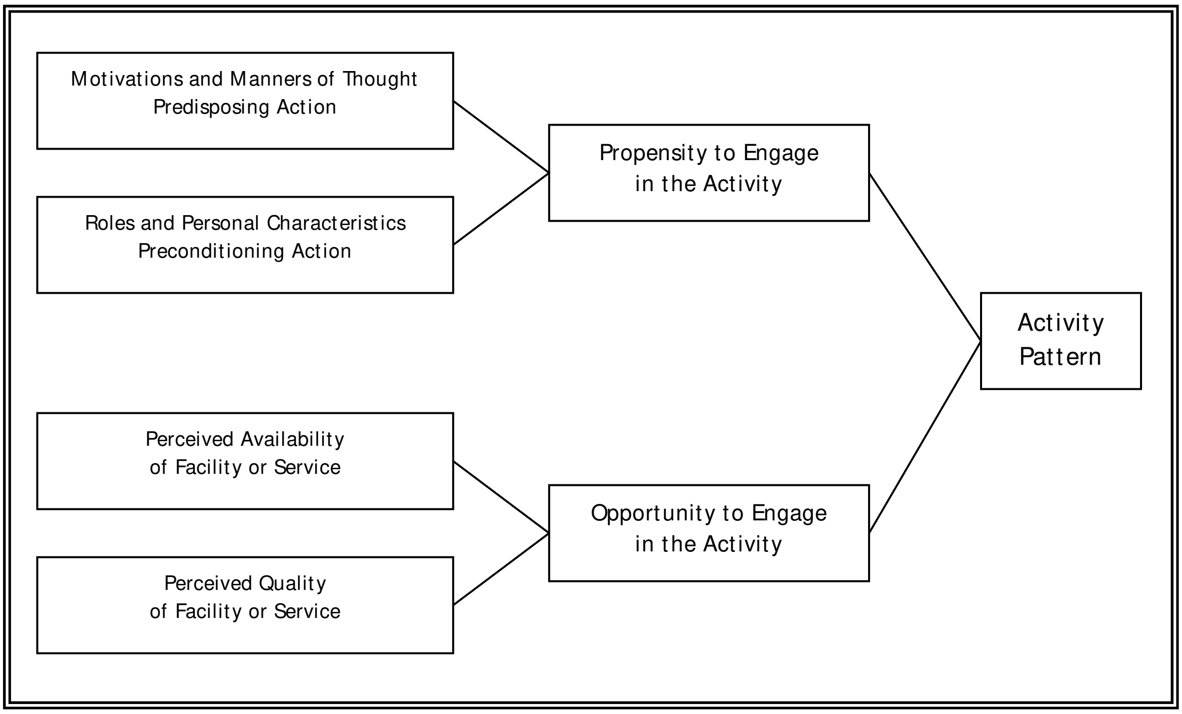
2.1 Sociological studies

The study of human patterns of activity seeks to describe the living patterns of a city, how people play out different routines, assume different roles, and possess different predispositions to do things in particular ways; the underlying assumption is that activity and the environment influence each other. From the realm of economic behaviour studies, Becker (1965), for example, suggests that by treating time as a resource that can be traded off with money, some fruitful insights can be gained in household activity choices[1]. Although not radically different from the view taken by economists, the alternative view concerns choice in a social context. In such social contexts people's activities in the urban scene are conceived of as the result of a complex and variable mix of incentives and constraints serving to mediate choice, with some activities directly traceable to positive choices, and some attributable to negative choices in the sense that constraints overshadow opportunities for choice (Chapin 1974). Figure 5.1 represents the behavioural sequence that serves as a point

[1] Choice is examined first under conditions where time and goods are treated in fixed proportions and then under conditions where substitutions are made between time and goods.

of departure in developing the analysis for this section. It indicates the contingencies that lead to patterns of activity and suggests the general breadth that approaches to the study of human activity systems can take.

Figure 5.1 General model for explaining activity patterns



Source: Chapin 1974

The output of the model refers to an "activity pattern", which signifies the tendency for a population to behave similarly[2]: that is, in this research, private motorists using their autos (i.e. travelling with autos as the activity). Next, instead of viewing the behavioural sequence entirely as a "demand" phenomenon, the consummation of an activity is seen as dependant on considerations of "supply" as well. In other words, the diagram states that an activity pattern is contingent not only on a propensity or readiness to engage in the activity, but also on there being an opportunity to engage in that activity in the sense that a facility, service, or other instrumental means is available which permits the activity to take place.

[2] In a pure model of individual behaviour, an "act" is an episode of behaviour discrete to an individual. The motivations attributable to an act of individual behaviour tend to become less salient when acts are grouped into activity classes, but by grouping acts and dealing with more generic forms of activity, it is possible to begin to define behaviour patterns that are common to whole groups of people (Chapin 1974).

Further toward the left-hand side of Figure 5.1, the framework posits for each of these two requisites at least two antecedent sets of factors. In the upper branch, the diagram signifies that the propensity to engage in an activity is determined by a set of energizing factors (motivations and ways of thinking predispose actions) and a set of constraining factors (roles and personal characteristics preconditioning action). Likewise, the opportunity to engage in the activity is seen as a function of the existence of a favourable situation for the activity to occur. That is, it is a function of access to the requisite facilities or services in sufficient quantity and in locations sufficiently convenient to permit the level of use indicated by the propensity to engage in the activity reflected in the upper branch of the diagram. However, it is also dependent upon a sufficient and acceptable quality of facility or service, so as not to discourage said level of use.

Not shown in Figure 5.1 are the resultant satisfaction (or dissatisfaction) that materializes and the feedback to the motivational and 'way of thinking' components that affects the predisposition of the population segment to continue or discontinue the activity. Also not shown is the larger general system context that affects the opportunity circuit: the existence of economic, social and political institutions necessary to supply the opportunities; the existence of organizations with a disposition to provide these opportunities; and the general compatibility of the facilities or services provided with the perceived need for access and service quality. Also not shown are the external influences (technological change, cultural change and so on) that go with an open system view of the model[3].

By using the study of Mercado-Doménech *et al.* (2001), this research focuses on the upper part of the above proposed model: what have been the thoughts, manners and cognition of the people in Mexico City regarding the problem of air pollution, and how all this together has impacted behavioural patterns. The study includes private motorists as part of this population, thus part of its results are relevant for this research. For example, the authors mention the known fact, and important critique since the very beginning, that the HNC program instigates a second vehicle for many households and, above all, intensive

[3] Furthermore, although not stated, there are two basic assumptions: first, activity patterns of the metropolitan community vary with the cultural makeup of the community; and second, they vary with the community's context of social structure and its sub-cultural spheres of influences (Chapin 1974).

vehicle use (i.e., more trips and VKT) by other members of the family (and not only the principal driver) in order to take advantage of having the extra vehicle, even when the household interviewee reported him/herself as informed about the air pollution problem. In other words, the propensity to travel by automobile seems to have increased because of the new situation generated by the HNC program and, at the same time, there were not enough disincentives (i.e., the those above mentioned external influences) to automobile travel.

The general conclusion of this mentioned study is that there is indeed a perception that the city has "bad" or "very bad" air quality. Likewise, residents think that the Centre is the most polluted zone, whereas according to official figures the most polluted zones are the Southwest and Northeast. This misperception is explained by the meaning of the Centre to the population: it is there where historically political and social activities have been concentrated. On top of that, authors conclude that there is a mismatch between the official information and the perception of the problem. Motivations and ways of thinking respond to ideas without an objective and sound understanding of the problem. That is, these ideas reflect individuals not having rational contact with the situation, and that expectations and beliefs are very much what determine the cognition of the situation.

Regarding the source of pollution, 50% of the population answered that factories are the main source and only 25% think that the autos are the main source[4]. Consequently, there are responses on the order of 60% saying 'do nothing' despite having reported air pollution as being high. In other words, there is a slanted vision of social responsibility (for the problem of air pollution). Likewise, programs like HNC and the VVP are not seen as the best options for controlling air pollution, but rather as restrictions: as impositions. An additional interesting result was that individuals with more education and vehicles tend to be more willing to participate (in programs against air pollution), but also they ask for more detailed information about the implications (there is actually no total willingness to sacrifice comfort like vehicle use[5]).

[4] As it was noted in Chapter 2, transportation sector is actually the main source of air pollution.

[5] The study includes one statement which says: "We must restrict the use of autos even this action can be a sacrifice". 73% disagree and only 10% agree.

In general, the authors conclude that personal characteristics and not objective information determine the perception of air pollution. Also, there is a generalized idea that the origin of and solutions to air pollution are difficult to explain because the city is so 'big' and 'complex'. Furthermore, the widespread thought is that pollution comes from 'others' (e.g., factories) and not because of 'our' habits (e.g., vehicle use). Hence, most of the population is not willing to sacrifice comfort; participation is limited to the fulfilment of programs. However, people are generally willing to take part in programs if provided better information about the problem and, above all, the direct and observable implications.

On the other hand, Axhausen (2002) and Hanson (1982) argue that the spatial dispersion of social networks in combination with the choices of residential location were, and will remain, the main factor in the observed increases in VKT. In particular, Hanson assesses the role of spatial and sociodemographic factors in explaining each of a number of different aspects of travel (e.g., frequency of travelling, disperseness of destinations visited); the results show that for most dimensions of travel activity patterns, sociodemographic descriptions explain more variance than do spatial descriptors, which, in most of the equations, account for a very small proportion of the total variance. That is, the results demonstrate that sociodemographic and particularly the role-related factors (gender, household size, employment status, marital status and age) remain important in explaining most of the aspects of travel even when the effects of relative location have been controlled. Hence, in Hanson's findings the sociodemographic factors are more important than locational factors in explaining travel behaviour; nevertheless, spatial variables were found to be significant in explaining a number of dimensions of travel: the individual's location within the city plays a relatively minor role in explaining travel frequency but plays an important role in explaining travel distances[6].

Twenty years later, Axhausen (2002) directs attention to the spatial and social structure of traveller's social networks, and argues that an understanding of such issues is crucial for the assessment of the further dynamics of overall transport consumption. That is to say, for a given number of common activities the locations of friends, family and

[6] Distance is the first recurrent perspective from a transport point of view, but frequency the second.

colleagues determine the amount of kilometres travelled (especially for leisure activities). This total VKT is due not only to the distance between social destinations, but also to the frequency of such trips. If we accept the idea that the size of the activity space (of a one's everyday environment) determines the consumption of transport services (including those self-produced, by walking or driving), then increasing trips and distances have far reaching and permanent effects: this creates a dynamic which cannot be reversed, given, as Axhausen says, the investments people make into their work, family and friendships. Above all, home, work, ownership of the means to mobility, and social network membership, concludes Axhausen, interact and depend on each other; the further trajectory of these interactions determines to a large extent the shape of future personal travel. To summarize, the exact form of activities depends on the 'personal world' of the traveller: one's mental map, activity repertoire and knowledge space are the three ways of seeing this personal world[7].

2.2 Economic studies

The study of Dix *et al.* (1983) provides, according to the authors, a basis for providing traffic forecasting and local models of traffic generation. They demonstrate marked differences among households in the intensity of vehicle usage at various times of the day and for different activities; one feature of the analysis is the way in which households are distinguished: the main variable is the stage in family cycle. Through extensive descriptions, the study answers how autos are used for each of four main categories of activity (i.e., work, education, shopping, and 'free time' activities). Additionally, the study discusses a topic which links the social with the economic aspect of vehicle use: driving costs, that is, how these costs vary between different types of vehicle-users, and what processes of adaptation have occurred in response to past changes in the various costs associated with driving[8].

The case study of Dix *et al.* is Coventry, in the heart of West Midlands, England. There, as the study reports, most of the owner-drivers perceived petrol prices as having increased, yet responses involved very little reduction in vehicle use; these meant mainly more

[7] The mental map focuses on spatial relations and the generalised costs of travel; the activity repertoire describes the kind and form of possible activities and their generalised costs and qualities; and knowledge space emphasises the possible locations of different types of activities.
[8] Such costs do not include, according to the study's approach, environmental costs or traffic congestion.

economical driving techniques rather than suppressing trip-making habits. Instead, efforts were concentrated on reducing expenditures on fixed-cost items by delaying automobile replacements, changing to smaller vehicles, reducing insurance coverage, deferring driving lessons for other household members, and opting for a moped rather than a second auto. Furthermore, certain economically paradoxical behaviours were evident; one very common reaction was the reported maximisation of vehicle usage in order to justify high and increasing costs of ownership, which applied particularly to otherwise little-used second automobiles[9]. The importance of ‘money illusion’ in a period of price inflation is also apparent, and some special reasons for misperceptions of petrol price changes are noted.

In particular, regarding the awareness of costs of operation, those with the most definite and quantified concepts of the variable costs of vehicle usage are those who drove company cars and received a mileage allowance. At the other extreme, in the case where a private vehicle is used by several drivers, each driver often has no notion of fuel input or expenditure, or of the kilometres driven by the others, and none could estimate the total use or total expenditure. Between these extremes is the private motorist who is the exclusive driver of a vehicle: he/she usually has some quantified idea of average running costs, although these are measured in different ways (e.g., ‘about x pounds a week’, ‘about y litres a week’). The authors suggest three general rules: i) to the extent that drivers do consider running costs, their estimates are based on petrol costs only (i.e., they do not include maintenance or depreciation[10]); ii) only regular and frequent journeys, notably work commutes, have any perceived monetary costs attached to them (but costs per kilometre calculations are apparently quite unnatural, and moreover many drivers have to put considerable thought into questions about distance, in kilometres, of the trips they regularly make); iii) costs of a marginal trip are only estimated in exceptional circumstances, most typically for long-distance recreational trips.

[9] It is reported as well how company-cars complicate the picture of adaptations towards cost changes because increasing numbers of ‘household’ vehicle users feel themselves insulated from market price effects by the actions of their firms. Likewise, company-financing is changing vehicle use and traffic patterns by affecting household vehicle-ownership decisions as well as those concerning vehicle use itself.

[10] Parking charges affect choice of destination, but not the decision to make the trip or the choice of mode.

Regarding responses to changing usage costs, as noted above, the favourite and most frequently mentioned responses (in the study) were those that involved no reduction in travel (in the face of rising costs of vehicle use, i.e., increased petrol prices). The only short-term measure involving definite reduction in trip making was cutting out pleasure driving (i.e., no longer 'going for a drive just for the fun of it')[11]. Thus, Dix *et al.* summarize, perceived increases in fixed costs of driving have led to minimal reductions in usage, but do eventually lead to reductions in expenditure on fixed-cost items themselves. Perceived increases in usage costs (which for the most part mean petrol costs) results as well in minimal reductions of usage; the delayed response is reducing fixed costs, while non-driving expenditures are reduced in the interim. In other words, such results suggest that demand for petrol is fairly inelastic (except for leisure journeys); fixed costs appear to be the most important component in driver perceptions of driving costs.

Regarding the costs born by motorists, Litman (1999) revises and proposes eleven specific strategies to create more optimal pricing and markets; that is, according to the author, current high levels of vehicle usage are partly the result of mispricing and market distortions. Hence, new pricing techniques and increasing concern over external costs justifies increased emphasis on marginal and full-cost pricing and efforts to eliminate market distortions.

Such strategies, Litman says, are expected to significantly increase the perceived cost of motor vehicle use while reducing both fixed vehicle costs and externalities, increasing consumer choice, and reducing market distortions. The analysed strategies are weight-distance charges, distance-based vehicle insurance, emission charges, road/congestion pricing, parking, fuel taxes, fines and fees, land-use development patterns, least-cost transportation planning, ownership alternatives, and company cars. Accordingly, with the optimal pricing there is an important shift of some internal-fixed and external costs to

[11] Although, some respondents said that they were generally more careful about how they used the vehicle, this probably reflect, as Dix *et al.* remark, a change in attitude rather than in behaviour.

internal-variable costs (i.e., short-term costs that vary with the amount of travel and directly affect trip decisions[12]).

The author's discussion of travel behaviour is only presented through the estimation of travel reduction according to estimated long-run elasticities for total vehicle travel with respect to fuel prices. With said pricing scheme, a 35-60% reduction in motor vehicle travel is expected over the long-term. Thus, it is assumed that the reported elasticities with respect to fuel price will remain the same after the mentioned shift to internal-variable costs. There is room to question this assumption given the reported concern (in empirical studies), for example, regarding air pollution and the real changes when motorists face pollution (emission) fees.

In other words, results like those mentioned above assume that the activity pattern (i.e., travel behaviour) is merely the output of an interaction between the pattern itself and its cost (the last box of the figure 5.1 and an associated monetary term). There is an omission in the analysis: to what extent does the pricing scheme change not only the activity pattern but also, and more importantly, the mechanisms behind the pattern.

Lastly, De Souza (1999) considers the potential pollution impacts of consumer intentions; he focuses on one particular indicator of consumption patterns: transportation use[13]. De Souza presents the results of a comparative case-study analysis of the impact of household transportation use on urban air pollution; the case studies were conducted in three cities (i.e., Bangkok, Washington DC, and Mexico City)[14]. The researchers found that *inter alia* high income and education levels translated into increased household pollution levels in these cities. According to the researchers, motorisation (defined as vehicle ownership) rises in response to urbanisation, and in turn causes air pollution to increase.

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[12] As it can be seen, in theory the variable costs are those that are expected to modify decisions, but according to studies like the one previously mentioned (Dix *et al.* 1983), fixed costs tend to be, in practice, more important.

[13] In particular, three questions guide the study: "how does consumption vary among households?"; "what are the environmental implications of current household transportation use?"; and "how conscious is the public about the links among household size, consumption, and the environment?".

[14] Respectively, three teams from three different institutes (i.e., Mahidol University, Thailand; Colegio de México, Mexico; and ICF Kaiser International Inc., USA) conducted and wrote the initial studies.

More importantly, the authors mention that foremost among the factors behind the urbanisation and motorisation are demographics (i.e., more households, changing household structure, and increasing household incomes have led to a rise in the number of automobiles)[15]. Hence, one result of increasing motorisation is more fuel consumption, which increases pollution.

Nonetheless, the De Souza study uses household expenditure patterns as a proxy for implied pollution impact and, above all, household transportation patterns. For this reason factors like (higher) income can be seen indeed as the "perpetrators" of (high) pollution. As a result, for example, male-headed households, which on average have greater income levels, engage in more polluting behaviour than female-headed households[16]; also, large households spend more money on transportation and, as a result, the report concludes, generate more pollution.

A second part of the De Souza study (which was carried out through focus-group interviews with people from different socioeconomic backgrounds) is a qualitative analysis exploring why urban dwellers make the transportation choices they make; the report concludes that such choices are much more related to the level of awareness of the problem of air pollution among the population. Thus, two major findings were that: i) Mexico City residents perceived various health problems due to air pollution, but they did not regard these as a major concern, that is, people seemed willing to live with air pollution[17]; ii) the perception of personal impact on air pollution varied according to income level: low-income participants did not view themselves as contributing to air pollution in using their recurrent mode of transport (i.e., public), whereas medium- and high-income participants recognized that driving their vehicles does contribute to the problem of air pollution, but they did not

[15] The two other factors (influencing the number of automobiles) according to this study are city design and relative cheapness of autos.

[16] At the same time, with this logic, the authors concluded that spending on public transportation by female-headed households in Mexico City has a negative impact on air pollution because of quantitative (i.e., monetary) reasons: female-headed households relied more on public transportation (i.e., automobile ownership is less common among them) and the number of female-headed households in Mexico City is quite large.

[17] Low-income individuals seemed to be adapting themselves to the situations imposed by the air pollution risks, and medium- and high-income groups saw air pollution as a nuisance because of imposed additional tasks, such as the inspection of engines and triggered driver bans under HNC program.

see it as a major contributor[18]. It was reported that both individualism and consumerism (behaviour) hinder action that could reduce urban air pollution[19], and, on the other hand, that although people perceive that urban air pollution has an adverse effect on health, many urban dwellers continue to use their vehicles out of convenience[20].

2.3 Findings of this Research

The two previous sections presented those findings (from other studies) that point out and remind us of the complexity surrounding the behaviour of private motorists in urban areas. This research also reports results that put further questions about how appropriately the issue of air pollution and private-vehicle use has been understood until now. The quantitative and qualitative work of the research suggests that several structural and behavioural factors determine the level of impact private motorists have on urban air pollution.

From the analysis of VVP dataset, the first question (part of the research's objectives) regarding the driving patterns and differences in the extent of pollution arising from environmentally friendlier driving is answered (assuming that less VKT implies less pollutant emissions).

In the first place, the VVP dataset shows differences with some figures reported by SETRAVI (2005) regarding the mean distance driven by the motorists in Mexico City. According to the VVP dataset (i.e., the final sample used) the mean annual VKT in Mexico City is around 32,000 kilometres per year (see Tables A.1-A.13 of Appendix A), and not the reported figure of 23,300. At the same time, the figure about the average age of the vehicle population, i.e., around 8 years, is less than the 10 years reported by Molina and Molina

[18] Actually, these participants believed that authorities made it appear as if vehicles were the major cause of air pollution.
[19] For example, focus group respondents from Mexico City and Washington DC seemed less committed to taking personal action to tackle the problems of urban air pollution.
[20] According to the report, in all three cities (i.e., Washington DC, Bangkok and Mexico City) vehicle owners were reluctant to give up the use of their vehicles because they believed that public transport was too infrequent, sparse or unsafe. Also, most participants thought that, if air pollution's detrimental effects on health were proven, obvious, and widespread, they would be more willing to change their behaviour; they noted the effectiveness of public information and education initiatives, incentives, and legal and social pressures applied in anti-smoking and household recycling campaigns and recommended using similar tactics in the effort to reduce air pollution.

(2002). Hence, these two differences imply that the trend in Mexico City, and what is in need of reconsideration, is renewal (i.e., decreasing of average age of the vehicle population) of vehicle stock in Mexico City and an increasing distance travelled by motorists. Instead of just statistical descriptions about vehicle age and kilometres travelled, as reported by FIMEVIC (2005), the research not only analysed the correlation between these two variables (see Table 4.5 of the previous chapter), but also obtained further factors that can influence the distances travelled by the private motorists.

Vehicle age is indeed a factor that to a certain extent explains VKT, yet the magnitude of its impact remains unclear. The results conclude that there is a decreasing positive relation over time between vehicle age and VKT; the magnitude of this relation (i.e., the coefficient for vehicle age squared) is medium in comparison with the significance of other variables' resultant coefficients. Next, the inter-period relation does not show any particular trend over the course of all 4 periods; however, in comparison with periods one and two, the third period displays a greater impact of vehicle age on VKT, though this magnitude seems to respond to the amount of VKT for the period, i.e., this period is where the most VKT was registered.

The relation of VKT prior to the day of inspection (i.e., the cumulative VKT) is as the correlation coefficients indicated (see Table 4.5 and its discussion in the previous chapter): the cumulative VKT has a small effect on the VKT per period. Thus, the "historical driving" (i.e., how many kilometres have been driven) can be considered as a minor factor explaining VKT when looking only at the odometer, but such "historical record" has a more significant relation when it is considered together with vehicle age.

Other physical vehicle characteristics considered were the weight and catalytic converters. Both these variables show, when significant, a large impact, but are insufficient in and of themselves to explain VKT. In the case of weight (i.e. gross vehicle weight), the relation is negative, which implies that 'heavy' vehicles are driven less. Yet this relation was significant in only one period of time and for few sub-samples. With reference to catalytic converters, a tool that has played an important role in the policies applied thus far, in general (i.e., from the total sample) only showed a significant and positive relation in the first period, but with a very minor impact on VKT; however, for the sub-samples of zones North, South, East, and manufacturer group two (M2: Ford), the variable has a negative relation: if the vehicle has a catalytic converter, VKT decreases considerably. The result must be seen prudentially, because only one period had this relation, and it actually seems less logical that those vehicles with more opportunity to drive (because, being equipped with catalytic converters, they lack VVP circulation restrictions) and/or better fuel economy would be driven less. The only possible explanation for this relation is that by having a vehicle with a catalytic converter, the motorist is already aware of the impact of driving, and thus prefers to drive less.

The third physical vehicle characteristic considered was the brand, that is, its manufacturer (e.g., Ford or Volkswagen). In general, brand does not have an impact on VKT. However, for the South and East geographical zones (and the Centre, to some extent), some brands were found to have a positive relation with VKT (i.e., if the vehicle is from brand X, it registers more VKT) but, important to mention, this relation was significant only for individual periods of time (i.e., first period for South, and third period for East and Centre). The results are that vehicles from the southern zone have more VKT from the manufacturers Chrysler/Dodge, Ford, Chevrolet, Nissan, Volkswagen and Honda; in the eastern zone this appears for the same manufactures plus Renault and Peugeot (in the Centre, the only manufacturer with a significant impact in this respect is Chevrolet). As with the weight and catalytic-converter variables, this kind of evidence is not strong enough to conclude that brand plays a significant role.

Next, the vehicle owner's zone of residence was significant only in the first period. That is, for the general sample, if the motorist comes from a particular geographical zone, it will show an impact on the VKT. The magnitude is minor, and if we take the coefficients into account, motorists from zones South and East drive more than motorists from other zones. These are the same two zones that emerge where the manufacturer variable has a significant impact on VKT. There is room then to consider the relevance of motorists from these zones.

The last item of research consists in an analysis if the sticker. The output is significant and it helps to reconsider the role of the policy tools that have been applied so far. According to the results, if vehicle circulation is restricted because of programs like the (current) HNC, VKT increases. That is, the tool that is supposed to alleviate the problem of traffic congestion and air pollution is in fact generating more kilometres travelled and more pollution. For the three periods of time, the sticker variable (i.e., if the vehicle has sticker "one" or sticker "two", where both stickers entail a restriction on driving either one day or two days, respectively) is significant and has a positive relation: e.g., vehicles having a sticker "one", in the first period have an average of an extra 5000 VKT more. Such vehicles are driven more intensely. The expected relation should be negative; that is, if there is a restriction, the expected output is decreasing activity, but the results testify that this is not the case for vehicle use in Mexico City. The activity of driving is not responsive to restrictions on it; in a way this case can be compared with the above mentioned situation, in Dix *et al.* (1983), where motorists have a paradoxical behaviour (regarding the price of fuel and vehicle use).

The relation between sticker and VKT is revealing. Among the results, this relation displays relatively large coefficients in almost every regression (although, as noted previously in Chapter 4, the regressions do not have forecast/prediction purposes). In other studies (see Chapter 2: section 4.4) and, even *vox populi*, it is noted that with the HNC program people started to buy second autos and to modify travel patterns, particularly on weekends; the results of this research confirm how vehicle use is more intensive with measures like the restriction on driving one or two days per week. Thus, this sticker-tool is a measure that must be changed or modified in order to reduce VKT. Those motorists that do not have such restrictions drive less. Those who face the restriction drive more.

The second part of the data analysis stems from the INE survey. In comparison with the first part, the INE survey analysis deals with qualitative factors, and it offers access to more information about the attitude of motorists regarding the adoption of environmentally friendlier behaviour (i.e., less vehicle use). As noted in the previous chapter, the more important results from the regressions are that numeric explanatory variables (like income or price) do not explain vehicle use. The behaviour, i.e. vehicle usage, is better explained by attitudes and/or particular personal attributes.

In particular, for the regression model of the determinants of vehicle use and frequency of travel (ECU and FT variables, respectively) and the use of public transport (before buying the brand new auto) displayed, as expected, a negative relation. That is, if the motorist is already a user of public transport, there is less probability that this motorist changes and stops using the public transport in order to use the auto (i.e., to get a "yes" in the ECU variable). There is also a negative relation between transportation by automobile (FT) and use of public transportation: if the motorist is already a user of public transport, the frequency of vehicle use will be less (i.e., to get a "daily" use).

Other variables like the planned vehicle use (DU), the more or less important 'status' factor (DGI8_2), and the total number of vehicles (DTNC) also have a negative relation with VKT. If the vehicle's planned use is mainly for school (e.g., taking the kids to school), less vehicle use is expected; also, the frequency will not be daily if, as expected, the planned use is for holiday purposes. However, there is a positive relation with the frequency if the planned use is for both work and school trips. If the motorist grants 'more or less' importance to the 'status' factor, fewer cases of daily vehicle use are predicted according to the regression model: one then should interpret this result carefully, because if such a 'more or less' scale refers more to the 'less', then this relation is logical, otherwise, if it refers rather to the 'more' level, the output is paradoxical (i.e., the motorist does care about status but does not use the vehicle daily as expected). On the other hand, if the motorist has more than two vehicles (DTNC3), certainly the use of the new vehicle will be less frequent.

The other significant variables have a positive relation, that is, when coinciding with certain features, the household will indeed use the vehicle with greater frequency. First, if the motorist does assign importance to fuel consumption (DGI7) (i.e., 'more or less' or 'very important' as the degree of importance), there is a higher probability of daily vehicle use. That is, the motorist takes the opportunity to drive more if the vehicle has good fuel economy. Next, if the motorist has two or more vehicles in total, as expected, there is an expected vehicle usage (but, as noted above, not so intensive for the new auto if the motorist has more than two vehicles in total). Furthermore, one of the personal characteristic variables is significant in the model: marital status. If the motorist is single, vehicle use is expected to be intensive (i.e., daily). Of the 'manufacturer' variables, some are positively significant in the case of expected vehicle use; that is, if the vehicle is made by Ford, Peugeot, Seat or Volkswagen, there will be more occurrences of "yes". For the case of frequency of use, these factors have no significance.

The multinomial model of the frequency of transportation per hour (FTH) has interesting outputs as well. Here the factors explain the probability of having a low or high intensity of travelling by auto. With this in mind, if the related expenses (e.g., taxes, insurance, etc.) are very important to the motorist, there is a lower probability that he/she will drive less than three hours per day. Thus, the motorist who keeps a tight account of vehicle expenses seems to be an intensive driver, just as those who assign importance to fuel economy: that is the reason why importance is assigned to such factors, because they drive more; in other words, with such a degree of importance, they do not belong to those drivers who use the vehicle less than three hours per day. In comparison, if the intended vehicle is used mainly for school, it is less likely to be used at a low intensity; also, the case is the same when the motorist has more than two vehicles and is single. If that is the case, it can be expected that the motorist drives less than three hours per day.

On the other hand, only three factors are significant in cases of high intensity of travel (i.e., more than 6 hours per day): if the motorist has (only) two vehicles, if the motorist is, for example, an employer or self-employed, and if the vehicle is made by Ford, Nissan, Peugeot or Seat. However, if the vehicle is a Toyota, we expect a lower chance of having a high intensity of travel, according to the regression model. The same occurs with the case where the motorist purchases the automobile with a finance plan rather than in cash. This last issue is certainly logical: as long as the vehicle is not fully owned by the motorist, the intensity of travel is not expected to be high (i.e., more than six hours per day).

3. RESEARCH RESULTS VERSUS CURRENT POLICY ACTIONS

In this section the findings of the research are analysed and linked to the current policy actions in Mexico City. The following paragraphs answer to some extent how and under what conditions it is possible to modify current motorist behaviour by taking into account both the research results and transport management programs implemented thus far. It is indeed clear that motor vehicle emission reductions achieved through improvements in conventional vehicle technology have been largely overwhelmed by increases in the number of vehicles on the streets and, more significantly, VKT; hence these two facts must represent a logical focus for Mexico City's air pollution regulation. In short, an environmentally sustainable pattern of activity (in the case of vehicle use) requires going beyond marginal improvements in conventional vehicle technology.

The current '*Hoy No Circula*' (HNC) program is the tool representing the more important effort to alleviate congestion and pollution problems in Mexico City[21]. Previously, in section 4 of Chapter 2: *The Case of Mexico City*, the particularities of the Mexico City case were reviewed, and it was seen how improving air quality involves not only a variety of technical solutions but also changes in consumer behaviour. The latter of these two ought to give perspective to the HNC program; that is, how does this particular program stimulate behaviour in motorists. As it was noted in the above-mentioned chapter, the program needs to incorporate an evolutionary approach, so that it is constantly and effectively reducing both emissions from the major emitters and kilometres travelled from the motorists who drive most.

The results indicate that the HNC program is not helping to decrease the VKT by the motorists[22]. Being restricted from driving one or two days per week is not an incentive to

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[21] Complementary regulations are more or less constant updated by the Official Mexican Regulations (NOM: *Norma Oficial Mexicana*) regarding maximum pollutant emissions for brand new vehicles and those already circulating, fuels characteristics (e.g., banning lead in the gasoline); the Vehicle Verification Program is part of this effort alongside other programs and policies more focused on public transport (e.g., taxi fleet renovation, Rapid Transit Bus, bus system renovation).

[22] Likewise, Eskeland and Feyzioglu (1995) modelled gasoline consumption as a function of both gasoline prices and income, where gasoline consumption was assumed to be a proxy for total automobile usage. If the HNC program were to have an effect on automobile usage, the demand function would be expected to shift in some way, either by changing the level of consumption without changing the price and income elasticities, changing

reduce vehicle use. On the contrary, according to the results, these kinds of restrictions are incentives to drive more. If we take into account the general model for explaining activity patterns mentioned above (Figure 5.1), the motorist responds to the perceived availability of his/her vehicle, i.e. not having the vehicle one or two days, with a more intensive use of the vehicle. That is, the motorist perception is focussed on the use of the vehicle rather than on the reasons why the vehicle is not available.

However, since June 2004 the HNC program has been updated and, in order to again remove 20% of vehicles from circulation during one day of the week, and not the 8% that was reached by this date (GDF 2004), it incorporates into its criteria (for the kind of stickers that the vehicle can get, in particular the sticker "zero") a 10-year maximum age that a vehicle can have in order to get a sticker "zero" (plus the maximum limits of pollutant emissions applied thus far). That is, one the one hand, with this program modification, more vehicles are restricted and, on the other hand, according to the GDF (2004), there are more incentives to change the vehicle or, in short, to have cleaner vehicles on the streets. With age it is stated that vehicles are driven less, therefore, motorists have two varieties of restrictions: the normative (i.e., HNC program) and the 'natural' (i.e., vehicle age).

By contrast, the findings show how the restrictions are not precisely as assumed. Normative restrictions give an incentive to drive more and the 'natural' restrictions certainly have an impact on VKT: the relation is decreasing but still positive, though it is only one of many other factors that can explain the behaviour of motorists, and these other factors have not been managed by the policy action. Rather than being further restricted according to the current scheme, vehicles could be further classified based on factors other than age and pollutant emissions. The restriction program itself (through the stickers) must still be modified, and the policies must begin to take into account not only the vehicle's being

the elasticities without changing the price level, or by affecting both. Using data from January 1987 through December 1992 the authors determined that there is a substantial change in the gasoline demand function associated with the regulation. Both the price and income elasticities shifted upwards after the regulation's implementation. When data from the post-regulation was inserted into the pre-regulation demand equation it was found that actual demand increased after the policy in all but the first two quarters. Thus, these findings indicated that the regulation actually had a positive influence on gasoline consumption, i.e., automobile usage.

available to be driven (i.e., the vehicle being restricted from circulation during one day) but also the predisposing and preconditioning actions of the motorists.

For example, if we take into account the results from the second part of analysis (i.e., the INE survey), the official programs and policies are not based on the relation between the use of public transport and vehicle use among the motorists. Also, programs to reduce the vehicle use do not include differences between the different motives for driving (e.g., driving because of the school or holidays). Furthermore, the HNC program itself does not take into account, though it would be possible already today, the number of vehicles that the motorists have. The degree of importance that motorists lend to factors like fuel economy and related expenses could very well be part of the framework that any program tries to be put into practice.

Overall, the HNC program does not take into account the personal characteristics of motorists, neither their motivations nor their ways of thinking[23]. The regulation, in its implementation and formulation, is focused on expected technical vehicle improvements; the cultural and urban-structural significance of automobiles has not been recognized. Significant reductions in the negative social, economic and environmental impacts of highly mobile lifestyles require dramatic changes in how people in Mexico City understand mobility itself. Essentially, although measures like the HNC program represent important regulatory policies (including possible innovations), they remain within the dominant vehicle dependence-paradigm.

[23] This fact can be explained in the following way. During restricted days vehicles are not fully utilized, as they are not being used 24 hours per day. Therefore, trips that were to be taken during the restricted day could conceivably be moved to another day. This carries with it the doubly negative effect of inconveniencing the vehicle owner and not reducing automobile usage. Furthermore, changing the time of this trip could actually increase driving if the reason it was preferred to occur on the banned day was for the convenience of location.

4. SUMMARY

This chapter, after discussing factors that motorists consider in their decisions to use their vehicles, has shown that the vehicle-use management program applied thus far in Mexico City (i.e., the HNC) exhibits a significant lack of appropriateness. The program has not captured the multiple factors that can explain the behaviour of private motorists. Some of these factors have been identified using two datasets, the analysis of which is framed by a general model for explaining activity patterns where instead of viewing the behavioural sequence entirely as a 'demand' phenomenon, the consummation of an activity is also seen as dependant on a 'supply' considerations. With this approach as the starting point for the discussion of results, the chapter has demonstrated that: i) sociological context is an intrinsic part of motorist choices regarding vehicle use, rather than being focused on the vehicle itself or on purely economic considerations; ii) perceptions and attitudes influence motorist decisions, and these influences have been better identified and explained under socioeconomic analyses that link qualitative and quantitative issues; and iii) the current situation of the regulation measures in Mexico City, because of their very narrow basis, is not helping to reduce vehicle usage.

CHAPTER 6

CONCLUSIONS: KEY FINDINGS AND RECOMMENDATIONS

"De gustibus non est disputandum." (Latin proverb)

"I have an affection for a great city. I feel safe in the neighbourhood of man, and enjoy the sweet security of the streets." (Henry Hadsworth Longfellow)

"Since consumption is merely a means to human well-being the aim should be to obtain the maximum of well-being with the minimum of consumption." (E.F. Schumacher)

1. INTRODUCTION

Three essential components of the sustainable transportation agenda are grounded upon the relation between transportation, urban air pollution, and household dynamics: economic viability, environmental integrity and social participation. There is no doubt that there are economic, environmental and social components to transportation dynamics; developing countries are faced with the need to increase their energy efficiency to impulse development and raise standards of living, and at the same time to reduce their energy-related pollution.

This dissertation has dealt with environmentally unfriendly consumption in relation to air pollution and use of automobiles in Mexico City. By selecting this city as a case study, the study has investigated the preferences of and constraints on private motorists and their implications for environmental policies and urban development. The dissertation began by describing and analysing the air problem of pollution in large cities and its particular relation with the use of automobiles, taking the case of Mexico City as pertinent for developing urban contexts. A theoretical framework was next incorporated, where activities and final outputs are more important and relevant than the vehicle per se (e.g., its demand), mainly because of the significant environmental impacts of activity patterns. Lastly, the study analyzed factors which could explain private motorist behaviour in Mexico City by using quantitative and qualitative data, and it discussed the findings by relating them to the results of other socioeconomic studies and comparing them with existing policies.

This chapter concludes the study by providing a summary of the key findings (in Section 2) and policy implications (in Section 3) of the preceding chapters. Section 4 describes the limitations of the study and areas for further research.

2. KEY FINDINGS

The private transportation sector in Mexico City is clearly still the largest contributor to urban air pollution; considerable technical improvements (and those regulatory measures based on such technical improvements) have not been able to alleviate the social and environmental problems of motor vehicles; that is, engineering measures alone have been insufficient to minimise air pollution and to attain in the short- or mid-term reductions necessary to comply with recommended limit values related to the protection of public health. Mexico City has developed the most stringent air quality control legislation in Mexico, yet in most respects air quality has not improved; the key question is how to balance the mobility needs of the population with the environmental impacts of transportation activity.

This study confirmed that any set of options must consider both short- and long-term effects on the transportation and environmental systems; also, it underlines that the need for a stronger and more effective connection between transportation and environmental planning is a critical institutional issue. Equally, an integrated policy for transport, land use, and air quality should be designed and adopted at the metropolitan level (i.e., not restricted to the Distrito-Federal area); only the coordinated implementation of measures can sustainably reduce air pollution and effectively prevent or restrict a further increase in vehicle use. However, the local planning tool of integrated traffic development (restricted to the Distrito Federal) is of great importance because it is the only level at which individual traffic planning measures to reduce air pollution can be reasonably coordinated; it would allow for discussion about the effects (of the, e.g., relocation of traffic) on different territorial scales of MCMA and thus allow for a better understanding of the regional implications of policy options.

While neoclassical economic theory suggests that a tax equal to the marginal external damage should be imposed on the source of pollutant emissions, air pollution damages vary substantially according to vehicle type, as well as where, when, and how the vehicle is driven and maintained. Moreover, total emissions are not linked very closely to the total consumption of fuel, and there is the case where better fuel economy encourages the consumption of more fuel and more trips. In Mexico the policy towards private motor vehicles has been to merely encourage them to be less polluting while providing the necessary infrastructure for their increased use. A theoretical framework that puts the activity and not the commodity at the core of the analysis creates a better space for the analysis of pollution control and transportation.

Consequently, policymakers should bear in mind socioeconomic factors when developing specific policies and when projecting how those policies might be received. The results of the qualitative analysis show that sociological factors influence the probability of contributing to air pollution through intensive transportation use (i.e., more VKT). This brings us to the need to inform the public about the impact of transportation choices; the HNC program has not served this purpose and it has actually contributed to increased vehicle use. Qualitative analysis (i.e., INE survey) helped to understand some behavioural factors that contribute to urban air pollution, whereas the analysis of VVP data provided insight into the structural factors that influence the vehicle use and contribute to urban air pollution.

The most important results from the applied regression models are that factors like income or purchase price do not explain vehicle use. This particular behaviour is explained better by attitudes or personal attributes and not precisely by economic factors or the vehicle itself. Also, regarding the total vehicle stock, a trend of renewal (i.e., decreasing of average age of the vehicle population) and an increasing distance travelled were revealed. The analysis found that vehicle age is indeed a factor that explains VKT to a certain extent, though the magnitude of the impact is not yet fully clear. Other physical characteristics like weight, being equipped with a catalytic converter, and brand showed a limited impact on the kilometres travelled. Also touched upon was the fact that the relation between geographical zone of residence and number of kilometres driven is still in need of further investigation.

The above mentioned limited role of the HNC program was evident by revealing its counter-intuitive effects with respect to traffic congestion and air pollution. That is, the activity of transportation by motor vehicle has not responded to restrictions placed upon it: motorists without such restrictions drive less and those who face restrictions on circulating one or two days per week drive more. In general, motorist perceptions are focused on the vehicle use rather than in the reasons why the vehicle is actually being restricted.

The link between the use of public transport and private transport was evident with, for example, the fact that if motorists are already more or less recurrent users of public transport, they will use recently bought vehicles with less frequency. Purposes for having the vehicle (e.g., going to work or to school), the number of vehicles that the motorist has, the degree of importance to factors like fuel-economy and associated expenses were also seen as important factors.

The HNC program does not currently take into account the personal characteristics of the motorist, neither their motivations nor their ways of thinking. The cultural and urban-structural significance of automobiles has not been recognized. Indeed, the auto itself could be further classified rather than being restricted and classified purely by age and pollutant emissions. The HNC program and its mechanisms of action still must be modified so as to take into account not only the vehicle's being available to be driven but also the predisposing and preconditioning actions of motorists.

The applied approach demonstrated that i) the sociological context is an intrinsic part of motorist choices regarding vehicle use, ii) perceptions and attitudes influence motorist decisions, which are better analysed under socioeconomic studies that link qualitative and quantitative issues, and iii) the current regulatory measures in Mexico City, because of their very narrow basis, do not help to reduce vehicle use.

Altogether, the sustainability of any environmental policy related to the vehicle use depends in great measure on the level of citizen awareness and the active and informed participation of stakeholders. Therefore, permanent changes in attitudes and behaviour require the development of an environmentally conscious culture and the improvement of education. Ultimately, Mexico City requires a serious reorientation of its transportation system that goes beyond the current focus on automobile-dependency. People no longer view the auto as a glamorous symbol of progress, wealth, and individual freedom; they have developed relations with their vehicles which revolve around function and use rather than simple ownership.

3. PROPOSED POLICY OPTIONS

In general, since we expect continued economic growth in Mexico City, which will drive transport demand still higher, creating a transport system in proper balance with the environment will be only achievable through a concerted and integrated implementation of technological and important social policy options. Policies directed toward attracting people away from autos and toward less polluting modes of transport are in need of leveraging. Such a mixed strategic approach could, for instance, combine improvements in the public transportation system with incentives to encourage alternatives like walking and cycling, including measures such as carpooling and high-occupancy vehicle lanes.

Also, increased emphasis should be placed on preventive measures in the design of strategies aimed at improving air quality; delays in tackling the air pollution problem may create the need for more drastic measures in the future. Among other measures, carpooling (as above mentioned), more park-and-ride spaces and bike paths can be encouraged at the same time as negative incentives such as banning vehicular traffic in certain areas of the city (e.g., the 'historical-central' part) and limiting parking options. In addition, given the limited possibilities for reducing pollution through the improvement of conventional engines or fuels, innovative regulatory measures based on the behavioural aspects of motorists can be included. In this sense, information obtained from the VVP program can be used to start tax schemes based on observed behavioural issues.

Regarding the departure from automobile-oriented transport, policies will need to go beyond their historical focus on technology-centred measures (e.g., improvement of fuels); also, policymakers, automobile manufacturers and the public need to replace the current automobile paradigm with a notion of “multi-mobility” that sees the auto only as one of a variety of mobility forms. For example, one can consider social innovations such as ride-sharing services, mobility centres and collective taxis.

In conclusion, in any set of proposed policies, it is important to consider the cost-effectiveness of the various strategies and the differential impacts on various stakeholders in Mexico City. While much is known, much is still clouded by lack of understanding of and data about the driving factors and forces.

4. OUTLOOK FOR FURTHER RESEARCH

The study illustrated the value of linking socioeconomic and environmental phenomena; that is, future studies should keep examining urban pollution from a multidisciplinary perspective, encompassing social, political, and economic aspects, such that a greater variety of possible factors are able to inform policy decision making; at the same time, these factors should help to develop pertinent indicators, above all in scenarios where decoupling economic growth from energy consumption and emissions is still a more or less manageable task, i.e., those more important urban centres of emerging countries (in the case of Mexico, Guadalajara and Monterrey are cities facing the trends that Mexico City experienced decades ago).

There are fundamental questions about how cities like Mexico City want to live in the future; the answer requires an examination of the basic nature of industrial production, distribution and consumption in the city. Because the urban and spatial structures of such cities have been fundamentally shaped by the automobile, transportation policy research must go beyond the purely technological issues of mobility to address more questions of social organization (and, even more importantly, political and psychological schemes). This entails research on how changes in, for example, work schedules can help to mitigate congestion during rush hours and to switch means of transportation (e.g., less vehicle usage).

Likewise, exploring the possible trade-offs between information travel and human travel (e.g., telecommuting) could open up new options in public policy. In general, taking into account that there are many stakeholders involved in automobile-related activities (i.e., not only private motorists but also manufacturers, oil-companies, road-construction firms and government), and that some of them are potential (and certainly powerful) losers from reductions in vehicle use, much more information regarding incentives about vehicle usage must assume a central role in further research.

Moreover, there is a big need to start linking public transport with private transport, taking into account that improving public transport services includes expanding them by adding alternatives centred on automobiles, i.e., adopting the auto as a component of competitive services. The demand for transport is becoming more individualized because, for example, it no longer follows collective schedules; such mentalities necessarily complicate route combinations (based on, say, bus use) and work to position automobiles as the ideal means of transport for many people. Therefore, more research has to be done on how future successful provision of public transport will have to expand the traditional spectrum by including automobiles as components that can be calculated and marketed quite separately; to what extent, for example, can car sharing mean the organized joint utilization of autos for Mexican residents? Future economic studies should strive to include these other policy options.

In brief, the existence of knowledge about the causes and consequences of pollution does not imply that this knowledge will automatically be translated into solutions to existing problems: political will and competence should transform the best available knowledge into action. Further studies must attempt to consider political aspects directly and simultaneously into their analysis framework.

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APPENDIX A

STATISTICAL DESCRIPTIONS[*]

A.1 Descriptive statistics VVP dataset

A.1.1 For the entire sample

Table A.1 Descriptive Statistics for VVP dataset

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	12997	1	39	7,89	5,852
km1	12997	20	904655	52544,23	42351,774
km2	12997	1182	923420	69454,95	51536,024
km3	12997	2610	932107	84678,51	71950,645
km4	12997	3395	999999	130923,89	154519,087
km12	12997	,506	901,078	16,91072	34,789671
km23	12997	,500	851,752	15,22356	46,681218
km34	12997	,500	947,973	46,24538	128,927706
Valid N (listwise)	12997				

A.1.2 By Zone

Table A.2 Descriptive Statistics for North zone (Z1) population

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	2501	1	38	7,71	5,826
km1	2501	25	732903	52766,68	43766,230
km2	2501	1993	856326	68612,97	51657,321
km3	2501	4182	917975	83853,64	73076,621
km4	2501	7803	997852	124900,25	146707,690
km12	2501	,509	567,532	15,84629	31,972483
km23	2501	,527	682,286	15,24067	47,183773
km34	2501	,519	947,973	41,04661	119,384085
Valid N (listwise)	2501				

[*] Source for every table: Author's calculations, using SPSS 12.0 for Windows.

Table A.3 Descriptive Statistics for South zone (Z2) population

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	2908	1	39	7,89	5,765
km1	2908	25	647290	52238,20	41385,187
km2	2908	1928	923420	70207,85	54320,893
km3	2908	2796	932107	85062,34	71910,201
km4	2908	3395	999999	131242,18	155251,841
km12	2908	,506	901,078	17,96964	40,835211
km23	2908	,500	688,322	14,85449	42,026758
km34	2908	,500	903,155	46,17984	129,019108
Valid N (listwise)	2908				

Table A.4 Descriptive Statistics for Centre zone (Z3) population

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	3927	1	39	8,01	5,900
km1	3927	20	904655	52832,51	42357,731
km2	3927	1321	909862	69681,48	49494,015
km3	3927	3128	913693	84547,92	69423,740
km4	3927	4429	999651	133559,92	157225,614
km12	3927	,522	737,129	16,84897	32,997456
km23	3927	,507	788,580	14,86643	45,843671
km34	3927	,500	922,375	49,01201	134,193270
Valid N (listwise)	3927				

Table A.5 Descriptive Statistics for East zone (Z4) population

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	1888	1	39	7,80	5,840
km1	1888	43	572223	52472,45	42747,885
km2	1888	2451	898910	69875,36	54517,830
km3	1888	7497	914321	86993,78	80991,430
km4	1888	8521	998574	135167,28	161383,689
km12	1888	,557	672,167	17,40291	36,176065
km23	1888	,532	851,752	17,11841	56,951058
km34	1888	,514	895,231	48,17350	131,705953
Valid N (listwise)	1888				

Table A.6 Descriptive Statistics for West zone (Z5) population

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	1773	1	39	7,97	5,935
km1	1773	32	545454	52170,28	41485,929
km2	1773	1182	621458	68458,34	47726,069
km3	1773	2610	691232	83036,31	65399,771
km4	1773	3728	985254	128541,64	150356,455
km12	1773	,519	430,034	16,28806	29,810636
km23	1773	,519	635,689	14,57797	42,760261
km34	1773	,507	885,451	45,50532	126,744728
Valid N (listwise)	1773				

A.1.3 By Manufacturer

Table A.7 Descriptive Statistics for Chrysler and Dodge (M1) cars population

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	2160	1	39	8,08	5,901
km1	2160	46	265988	53849,70	38091,077
km2	2160	1321	758701	70476,68	46068,796
km3	2160	3128	869812	86890,96	67824,453
km4	2160	5386	972181	132658,82	149630,245
km12	2160	,506	528,180	16,62699	32,153698
km23	2160	,505	632,355	16,41427	47,704268
km34	2160	,547	887,065	45,76786	124,525955
Valid N (listwise)	2160				

Table A.8 Descriptive Statistics for Ford cars (M2) population

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	2278	1	39	8,49	5,853
km1	2278	25	904655	55445,29	46362,651
km2	2278	3026	909862	72191,01	54493,909
km3	2278	3789	913693	87062,79	71467,300
km4	2278	4429	987948	130508,68	151751,717
km12	2278	,522	737,129	16,74572	35,762857
km23	2278	,507	688,322	14,87178	43,959999
km34	2278	,500	904,526	43,44589	125,684320
Valid N (listwise)	2278				

Table A.9 Descriptive Statistics for Chevrolet (M3) cars population

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	2820	1	36	6,51	4,096
km1	2820	36	572223	51221,31	37270,321
km2	2820	1182	668423	66309,89	42839,510
km3	2820	2610	878562	79049,42	59965,636
km4	2820	3728	997852	120313,96	140165,691
km12	2820	,519	531,135	15,08858	28,209001
km23	2820	,512	790,015	12,73953	37,934251
km34	2820	,500	922,375	41,26454	121,258806
Valid N (listwise)	2820				

Table A.10 Descriptive Statistics for Nissan (M4) cars population

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	2263	1	34	7,17	4,642
km1	2263	25	647290	54482,78	47451,887
km2	2263	1993	688479	71878,91	56153,877
km3	2263	2796	865472	86149,94	76398,989
km4	2263	3395	999999	127098,18	150276,621
km12	2263	,509	643,815	17,39614	34,990982
km23	2263	,527	788,580	14,27103	44,355074
km34	2263	,507	916,132	40,94824	121,331071
Valid N (listwise)	2263				

Table A.11 Descriptive Statistics for VW (M6) cars population

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	2688	1	39	10,01	7,668
km1	2688	43	545454	52762,37	45477,232
km2	2688	2145	923420	72996,86	59070,156
km3	2688	8180	932107	93179,18	86624,863
km4	2688	11067	999651	157842,05	183821,038
km12	2688	,506	901,078	20,23449	42,270619
km23	2688	,500	851,752	20,18232	61,616098
km34	2688	,513	947,973	64,66287	154,069227
Valid N (listwise)	2688				

Table A.12 Descriptive Statistics for Honda (M8) cars population

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	499	1	8	4,57	1,346
km1	499	45	120025	41256,14	23843,975
km2	499	5548	142705	52002,74	24536,179
km3	499	6205	162316	58625,66	25951,073
km4	499	6845	944699	79720,10	89606,284
km12	499	,553	109,077	10,74661	14,335889
km23	499	,558	53,132	6,62292	4,815469
km34	499	,501	857,912	21,09444	84,535656
Valid N (listwise)	499				

Table A. 13 Descriptive Statistics for Renault-Peugeot/Mercedes-BMW-Audi/Lux (M579) cars pop.

	N	Minimum	Maximum	Mean	Std. Deviation
agecar	289	1	35	6,79	6,362
km1	289	20	258689	35110,51	29245,936
km2	289	4130	652152	49150,19	53553,617
km3	289	6421	654654	58673,10	59895,177
km4	289	8303	835002	92759,92	121145,145
km12	289	,513	586,929	14,03968	45,931323
km23	289	,519	257,932	9,52291	22,954193
km34	289	,530	780,788	34,08682	103,148712
Valid N (listwise)	289				

A.2 Frequency Tables VVP dataset

A.2.1 For the entire sample

Table A.14 Sticker (after inspection) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	10157	78,1	78,1	78,1
	2	881	6,8	6,8	84,9
	3	1959	15,1	15,1	100,0
	Total	12997	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.15 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	10146	78,1	78,1	78,1
	2	857	6,6	6,6	84,7
	3	1994	15,3	15,3	100,0
	Total	12997	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.16 Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	10093	77,7	77,7	77,7
	2	827	6,4	6,4	84,0
	3	2077	16,0	16,0	100,0
	Total	12997	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.17 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	9779	75,2	75,2	75,2
	2	1115	8,6	8,6	83,8
	3	2103	16,2	16,2	100,0
	Total	12997	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.18 Gross Vehicle Weight (DW)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	12780	98,3	98,3	98,3
	1	217	1,7	1,7	100,0
	Total	12997	100,0	100,0	

*DW=0 between 2728kg and 3856kg; DW=1 more than 3856kg

Table A.19 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	1910	14,7	14,7	14,7
	1	11087	85,3	85,3	100,0
	Total	12997	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.20 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	1970	15,2	15,2	15,2
	1	11027	84,8	84,8	100,0
	Total	12997	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.21 DC in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	2014	15,5	15,5	15,5
	1	10983	84,5	84,5	100,0
	Total	12997	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.22 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	2021	15,5	15,5	15,5
	1	10976	84,5	84,5	100,0
	Total	12997	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.2.2 By Zone

A.2.2.1 North zone (Z1)

Table A.23 Sticker (after inspection) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1974	78,9	78,9	78,9
	2	167	6,7	6,7	85,6
	3	360	14,4	14,4	100,0
	Total	2501	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.24 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1969	78,7	78,7	78,7
	2	165	6,6	6,6	85,3
	3	367	14,7	14,7	100,0
	Total	2501	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.25 Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1953	78,1	78,1	78,1
	2	154	6,2	6,2	84,2
	3	394	15,8	15,8	100,0
	Total	2501	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.26 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1910	76,4	76,4	76,4
	2	198	7,9	7,9	84,3
	3	393	15,7	15,7	100,0
	Total	2501	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.27 Gross Vehicle Weight (DW)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	2463	98,5	98,5	98,5
	1	38	1,5	1,5	100,0
	Total	2501	100,0	100,0	

*DW=0 between 2728kg and 3856kg; DW=1 more than 3856kg

Table A.28 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	351	14,0	14,0	14,0
	1	2150	86,0	86,0	100,0
	Total	2501	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.29 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	364	14,6	14,6	14,6
	1	2137	85,4	85,4	100,0
	Total	2501	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.30 DC inS3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	368	14,7	14,7	14,7
	1	2133	85,3	85,3	100,0
	Total	2501	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.31 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	380	15,2	15,2	15,2
	1	2121	84,8	84,8	100,0
	Total	2501	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.2.2.2 South zone (Z2)

Table A.32 Sticker in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2289	78,7	78,7	78,7
	2	181	6,2	6,2	84,9
	3	438	15,1	15,1	100,0
	Total	2908	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.33 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2287	78,6	78,6	78,6
	2	177	6,1	6,1	84,7
	3	444	15,3	15,3	100,0
	Total	2908	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.34 Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2287	78,6	78,6	78,6
	2	163	5,6	5,6	84,3
	3	458	15,7	15,7	100,0
	Total	2908	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.35 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2199	75,6	75,6	75,6
	2	254	8,7	8,7	84,4
	3	455	15,6	15,6	100,0
	Total	2908	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.36 Gross Vehicle Weight (DW)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	2852	98,1	98,1	98,1
	1	56	1,9	1,9	100,0
	Total	2908	100,0	100,0	

*DW=0 between 2728kg and 3856kg; DW=1 more than 3856kg

Table A.37 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	421	14,5	14,5	14,5
	1	2487	85,5	85,5	100,0
	Total	2908	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.38 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	432	14,9	14,9	14,9
	1	2476	85,1	85,1	100,0
	Total	2908	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.39 DC in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	451	15,5	15,5	15,5
	1	2457	84,5	84,5	100,0
	Total	2908	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.40 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	446	15,3	15,3	15,3
	1	2462	84,7	84,7	100,0
	Total	2908	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.2.2.3 Centre zone (Z3)

Table A.41 Sticker in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	3045	77,5	77,5	77,5
	2	279	7,1	7,1	84,6
	3	603	15,4	15,4	100,0
	Total	3927	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.42 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	3047	77,6	77,6	77,6
	2	257	6,5	6,5	84,1
	3	623	15,9	15,9	100,0
	Total	3927	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.43 Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	3022	77,0	77,0	77,0
	2	265	6,7	6,7	83,7
	3	640	16,3	16,3	100,0
	Total	3927	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.44 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2933	74,7	74,7	74,7
	2	326	8,3	8,3	83,0
	3	668	17,0	17,0	100,0
	Total	3927	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.45 Gross Vehicle Weight (DW)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	3873	98,6	98,6	98,6
	1	54	1,4	1,4	100,0
	Total	3927	100,0	100,0	

*DW=0 between 2728kg and 3856kg; DW=1 more than 3856kg

Table A.46 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	595	15,2	15,2	15,2
	1	3332	84,8	84,8	100,0
	Total	3927	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.47 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	616	15,7	15,7	15,7
	1	3311	84,3	84,3	100,0
	Total	3927	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.48 DC in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	624	15,9	15,9	15,9
	1	3303	84,1	84,1	100,0
	Total	3927	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.49 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	628	16,0	16,0	16,0
	1	3299	84,0	84,0	100,0
	Total	3927	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.2.2.4 East zone (Z4)

Table A.50 Sticker in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1485	78,7	78,7	78,7
	2	131	6,9	6,9	85,6
	3	272	14,4	14,4	100,0
	Total	1888	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.51 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1482	78,5	78,5	78,5
	2	134	7,1	7,1	85,6
	3	272	14,4	14,4	100,0
	Total	1888	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.52 Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1469	77,8	77,8	77,8
	2	136	7,2	7,2	85,0
	3	283	15,0	15,0	100,0
	Total	1888	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.53 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1421	75,3	75,3	75,3
	2	180	9,5	9,5	84,8
	3	287	15,2	15,2	100,0
	Total	1888	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.54 Gross Vehicle Weight (DW)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	1848	97,9	97,9	97,9
	1	40	2,1	2,1	100,0
	Total	1888	100,0	100,0	

*DW=0 between 2728kg and 3856kg; DW=1 more than 3856kg

Table A.55 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	267	14,1	14,1	14,1
	1	1621	85,9	85,9	100,0
	Total	1888	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.56 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	274	14,5	14,5	14,5
	1	1614	85,5	85,5	100,0
	Total	1888	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.57 DC in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	277	14,7	14,7	14,7
	1	1611	85,3	85,3	100,0
	Total	1888	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.58 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	277	14,7	14,7	14,7
	1	1611	85,3	85,3	100,0
	Total	1888	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.2.2.5 West zone (Z5)

Table A.59 Sticker in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1364	76,9	76,9	76,9
	2	123	6,9	6,9	83,9
	3	286	16,1	16,1	100,0
	Total	1773	100,0	100,0	

1:”HZero”; 2:”HOne”; 3:”HTwo”

Table A.60 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1361	76,8	76,8	76,8
	2	124	7,0	7,0	83,8
	3	288	16,2	16,2	100,0
	Total	1773	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.61 Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1362	76,8	76,8	76,8
	2	109	6,1	6,1	83,0
	3	302	17,0	17,0	100,0
	Total	1773	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.62 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1316	74,2	74,2	74,2
	2	157	8,9	8,9	83,1
	3	300	16,9	16,9	100,0
	Total	1773	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.63 Gross Vehicle Weight (DW)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	1744	98,4	98,4	98,4
	1	29	1,6	1,6	100,0
	Total	1773	100,0	100,0	

*DW=0 between 2728kg and 3856kg; DW=1 more than 3856kg

Table A.64 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	276	15,6	15,6	15,6
	1	1497	84,4	84,4	100,0
	Total	1773	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.65 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	284	16,0	16,0	16,0
	1	1489	84,0	84,0	100,0
	Total	1773	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.66 DC in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	294	16,6	16,6	16,6
	1	1479	83,4	83,4	100,0
	Total	1773	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.67 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	290	16,4	16,4	16,4
	1	1483	83,6	83,6	100,0
	Total	1773	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.2.3 By Manufacturer

A.2.3.1 Chrysler and Dodge (M1)

Table A.68 Sticker in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1625	75,2	75,2	75,2
	2	181	8,4	8,4	83,6
	3	354	16,4	16,4	100,0
	Total	2160	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.69 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1620	75,0	75,0	75,0
	2	197	9,1	9,1	84,1
	3	343	15,9	15,9	100,0
	Total	2160	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.70 Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1625	75,2	75,2	75,2
	2	189	8,8	8,8	84,0
	3	346	16,0	16,0	100,0
	Total	2160	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.71 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1563	72,4	72,4	72,4
	2	249	11,5	11,5	83,9
	3	348	16,1	16,1	100,0
	Total	2160	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.72 Gross Vehicle Weight (DW)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	2102	97,3	97,3	97,3
	1	58	2,7	2,7	100,0
	Total	2160	100,0	100,0	

*DW=0 between 2728kg and 3856kg; DW=1 more than 3856kg

Table A.73 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	308	14,3	14,3	14,3
	1	1852	85,7	85,7	100,0
	Total	2160	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.74 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	310	14,4	14,4	14,4
	1	1850	85,6	85,6	100,0
	Total	2160	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.75 DC in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	314	14,5	14,5	14,5
	1	1846	85,5	85,5	100,0
	Total	2160	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.76 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	310	14,4	14,4	14,4
	1	1850	85,6	85,6	100,0
	Total	2160	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.2.3.2 Ford (M2)

Table A.77 Sticker in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1725	75,7	75,7	75,7
	2	264	11,6	11,6	87,3
	3	289	12,7	12,7	100,0
	Total	2278	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.78 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1728	75,9	75,9	75,9
	2	248	10,9	10,9	86,7
	3	302	13,3	13,3	100,0
	Total	2278	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.79 Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1720	75,5	75,5	75,5
	2	249	10,9	10,9	86,4
	3	309	13,6	13,6	100,0
	Total	2278	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.80 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1647	72,3	72,3	72,3
	2	320	14,0	14,0	86,3
	3	311	13,7	13,7	100,0
	Total	2278	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.81 Gross Vehicle Weight (DW)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	2227	97,8	97,8	97,8
	1	51	2,2	2,2	100,0
	Total	2278	100,0	100,0	

*DW=0 between 2728kg and 3856kg; DW=1 more than 3856kg

Table A.82 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	271	11,9	11,9	11,9
	1	2007	88,1	88,1	100,0
	Total	2278	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.83 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	272	11,9	11,9	11,9
	1	2006	88,1	88,1	100,0
	Total	2278	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.84 DC in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	271	11,9	11,9	11,9
	1	2007	88,1	88,1	100,0
	Total	2278	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.85 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	273	12,0	12,0	12,0
	1	2005	88,0	88,0	100,0
	Total	2278	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.2.3.3 Chevrolet (M3)

Table A.86 Sticker in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2458	87,2	87,2	87,2
	2	215	7,6	7,6	94,8
	3	147	5,2	5,2	100,0
	Total	2820	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.87 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2447	86,8	86,8	86,8
	2	226	8,0	8,0	94,8
	3	147	5,2	5,2	100,0
	Total	2820	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.88 Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2428	86,1	86,1	86,1
	2	231	8,2	8,2	94,3
	3	161	5,7	5,7	100,0
	Total	2820	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.89 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2383	84,5	84,5	84,5
	2	273	9,7	9,7	94,2
	3	164	5,8	5,8	100,0
	Total	2820	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.90 Gross Vehicle Weight (DW)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	2712	96,2	96,2	96,2
	1	108	3,8	3,8	100,0
	Total	2820	100,0	100,0	

*DW=0 between 2728kg and 3856kg; DW=1 more than 3856kg

Table A.91 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	174	6,2	6,2	6,2
	1	2646	93,8	93,8	100,0
	Total	2820	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.92 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	180	6,4	6,4	6,4
	1	2640	93,6	93,6	100,0
	Total	2820	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.93 DC in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	172	6,1	6,1	6,1
	1	2648	93,9	93,9	100,0
	Total	2820	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.94 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	174	6,2	6,2	6,2
	1	2646	93,8	93,8	100,0
	Total	2820	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.2.3.4 Nissan (M4)

Table A.95 Sticker in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1905	84,2	84,2	84,2
	2	69	3,0	3,0	87,2
	3	289	12,8	12,8	100,0
	Total	2263	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.96 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1900	84,0	84,0	84,0
	2	73	3,2	3,2	87,2
	3	290	12,8	12,8	100,0
	Total	2263	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.97 Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1890	83,5	83,5	83,5
	2	79	3,5	3,5	87,0
	3	294	13,0	13,0	100,0
	Total	2263	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.98 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1802	79,6	79,6	79,6
	2	156	6,9	6,9	86,5
	3	305	13,5	13,5	100,0
	Total	2263	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.99 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	322	14,2	14,2	14,2
	1	1941	85,8	85,8	100,0
	Total	2263	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.100 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	323	14,3	14,3	14,3
	1	1940	85,7	85,7	100,0
	Total	2263	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.101 DC in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	323	14,3	14,3	14,3
	1	1940	85,7	85,7	100,0
	Total	2263	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.102 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	328	14,5	14,5	14,5
	1	1935	85,5	85,5	100,0
	Total	2263	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.2.3.5 Volkswagen (M6)

Table A.103 Sticker in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1695	63,1	63,1	63,1
	2	148	5,5	5,5	68,6
	3	845	31,4	31,4	100,0
	Total	2688	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.104 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1703	63,4	63,4	63,4
	2	109	4,1	4,1	67,4
	3	876	32,6	32,6	100,0
	Total	2688	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.105 Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1683	62,6	62,6	62,6
	2	75	2,8	2,8	65,4
	3	930	34,6	34,6	100,0
	Total	2688	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.106 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1634	60,8	60,8	60,8
	2	116	4,3	4,3	65,1
	3	938	34,9	34,9	100,0
	Total	2688	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.107 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	800	29,8	29,8	29,8
	1	1888	70,2	70,2	100,0
	Total	2688	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.108 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	850	31,6	31,6	31,6
	1	1838	68,4	68,4	100,0
	Total	2688	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.109 DC in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	898	33,4	33,4	33,4
	1	1790	66,6	66,6	100,0
	Total	2688	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.110 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	900	33,5	33,5	33,5
	1	1788	66,5	66,5	100,0
	Total	2688	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.2.3.6 Honda (M8)

Table A.111 Sticker in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	497	99,6	99,6	99,6
	2	2	,4	,4	100,0
	Total	499	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.112 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	496	99,4	99,4	99,4
	2	3	,6	,6	100,0
	Total	499	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.113Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	499	100,0	100,0	100,0

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.114 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	499	100,0	100,0	100,0

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.115 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	499	100,0	100,0	100,0

*DC=1 with catalytic; DC=0 without

Table A.116 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	499	100,0	100,0	100,0

*DC=1 with catalytic; DC=0 without

Table A.117 DC in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	499	100,0	100,0	100,0

*DC=1 with catalytic; DC=0 without

Table A.118 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	1	,2	,2	,2
	1	498	99,8	99,8	100,0
	Total	499	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.2.3.7 Renault-Peugeot, Mercedes Benz-BMW-Audi, and Luxury cars (M579)

Table A.119 Sticker in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	252	87,2	87,2	87,2
	2	2	,7	,7	87,9
	3	35	12,1	12,1	100,0
	Total	289	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.120 Sticker in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	252	87,2	87,2	87,2
	2	1	,3	,3	87,5
	3	36	12,5	12,5	100,0
	Total	289	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.121 Sticker in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	248	85,8	85,8	85,8
	2	4	1,4	1,4	87,2
	3	37	12,8	12,8	100,0
	Total	289	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.122 Sticker in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	251	86,9	86,9	86,9
	2	1	,3	,3	87,2
	3	37	12,8	12,8	100,0
	Total	289	100,0	100,0	

1:"HZero"; 2:"HOne"; 3:"HTwo"

Table A.123 Catalytic Converter (DC) in S1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	35	12,1	12,1	12,1
	1	254	87,9	87,9	100,0
	Total	289	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.124 DC in S2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	35	12,1	12,1	12,1
	1	254	87,9	87,9	100,0
	Total	289	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.125 DC in S3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	36	12,5	12,5	12,5
	1	253	87,5	87,5	100,0
	Total	289	100,0	100,0	

*DC=1 with catalytic; DC=0 without

Table A.126 DC in S4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	35	12,1	12,1	12,1
	1	254	87,9	87,9	100,0
	Total	289	100,0	100,0	

*DC=1 with catalytic; DC=0 without

A.3 Descriptive statistics INE dataset

Table A.127 Descriptive Statistics for numerical explanatory variables

	N	Minimum	Maximum	Mean	Std. Deviation
price	533	5901	32960	13473,96	5435,057
Household age (HAGE)	533	15	79	39,62	11,219
Household size (HS)	533	1	9	3,20	1,505
income	533	200	13333	2106,84	1634,081
Valid N (listwise)	533				

A.4 Frequency Tables INE dataset

A.4.1 Dependant variables

Table A.128 Expected car use (ECU)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	134	25,1	25,1	25,1
	1	399	74,9	74,9	100,0
	Total	533	100,0	100,0	

*ECU=1 yes; ECU=0 no, i.e., public transport use

Table A.129 Frequency of transportation (FT)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	69	12,9	12,9	12,9
	1	464	87,1	87,1	100,0
	Total	533	100,0	100,0	

*FT=1 daily; FT=0 no-daily

Table A.130 Frequency of transportation per hour (FTH)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	136	25,5	25,5	25,5
	1	297	55,7	55,7	81,2
	2	100	18,8	18,8	100,0
	Total	533	100,0	100,0	

*FTH=0 less than 3hrs; FTH=1 between 3 and 6hrs; FTH=2 more than 6hrs

A.4.2 Explanatory variables

Table A.131 Manufacturer (manuf)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	94	17,6	17,6	17,6
	2	27	5,1	5,1	22,7
	3	123	23,1	23,1	45,8
	4	16	3,0	3,0	48,8
	5	51	9,6	9,6	58,3
	6	11	2,1	2,1	60,4
	7	22	4,1	4,1	64,5
	8	4	,8	,8	65,3
	9	185	34,7	34,7	100,0
	Total	533	100,0	100,0	

*1: General Motors; 2: Ford; 3: Honda; 4: Nissan; 5: Peugeot; 6: Renault; 7: Seat; 8: Toyota; 9: Volkswagen

Table A.132 Degree of importance for Price (DGI1)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	11	2,1	2,1	2,1
	2	89	16,7	16,7	18,8
	3	433	81,2	81,2	100,0
	Total	533	100,0	100,0	

*DGI=1 indifferent; DGI=2 more or less; DGI=3 very important

Table A.133 Degree of importance for Engine's power (DGI2)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	20	3,8	3,8	3,8
	2	176	33,0	33,0	36,8
	3	337	63,2	63,2	100,0
	Total	533	100,0	100,0	

*DGI=1 indifferent; DGI=2 more or less; DGI=3 very important

Table A.134 Degree of importance for Comfort (DGI3)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	11	2,1	2,1	2,1
	2	87	16,3	16,3	18,4
	3	435	81,6	81,6	100,0
	Total	533	100,0	100,0	

*DGI=1 indifferent; DGI=2 more or less; DGI=3 very important

Table A.135 Degree of importance for Security (DGI4)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	12	2,3	2,3	2,3
	2	54	10,1	10,1	12,4
	3	467	87,6	87,6	100,0
	Total	533	100,0	100,0	

*DGI=1 indifferent; DGI=2 more or less; DGI=3 very important

Table A.136 Degree of importance for Related expenses (DGI5)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	58	10,9	10,9	10,9
	2	146	27,4	27,4	38,3
	3	329	61,7	61,7	100,0
	Total	533	100,0	100,0	

*DGI=1 indifferent; DGI=2 more or less; DGI=3 very important

Table A.137 Degree of importance for Environmental performance (DGI6)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	55	10,3	10,3	10,3
	2	85	15,9	15,9	26,3
	3	393	73,7	73,7	100,0
	Total	533	100,0	100,0	

*DGI=1 indifferent; DGI=2 more or less; DGI=3 very important

Table A.138 Degree of importance for Fuel consumption (DGI7)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	28	5,3	5,3	5,3
	2	61	11,4	11,4	16,7
	3	444	83,3	83,3	100,0
	Total	533	100,0	100,0	

*DGI=1 indifferent; DGI=2 more or less; DGI=3 very important

Table A.139 Degree of importance for Status (DGI8)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	101	18,9	18,9	18,9
	2	160	30,0	30,0	49,0
	3	272	51,0	51,0	100,0
	Total	533	100,0	100,0	

*DGI=1 indifferent; DGI=2 more or less; DGI=3 very important

Table A.140 Payment form (DPF)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	152	28,5	28,5	28,5
	2	356	66,8	66,8	95,3
	3	25	4,7	4,7	100,0
	Total	533	100,0	100,0	

*DPF=1 single payment; DPF=2 financing; DPF=3 self-financing

Table A.141 Planned use of car (DU)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	289	54,2	54,2	54,2
	2	41	7,7	7,7	61,9
	3	137	25,7	25,7	87,6
	4	30	5,6	5,6	93,2
	5	36	6,8	6,8	100,0
	Total	533	100,0	100,0	

*DU=1 work; DU=2 school; DU=3 work and school; DU=4 home activities;
DU=5 holidays

Table A.142 Public transport use (DPTU)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	370	69,4	69,4	69,4
	1	163	30,6	30,6	100,0
	Total	533	100,0	100,0	

*DPTU=0 no use; DPTU=1 yes

Table A.143 Total number of cars (DTNC)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	273	51,2	51,2	51,2
	2	91	17,1	17,1	68,3
	3	169	31,7	31,7	100,0
	Total	533	100,0	100,0	

*DTNC=1 one car; DTNC=2 two cars; DTNC=3 more than two

Table A.144 Marital status (DMS)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	323	60,6	60,6	60,6
	1	210	39,4	39,4	100,0
	Total	533	100,0	100,0	

*DMS=0 with couple; DMS=1 single

Table A.145 Sex (DSX)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	345	64,7	64,7	64,7
	1	188	35,3	35,3	100,0
	Total	533	100,0	100,0	

*DSX=0 male; DSX=1 female

Table A.146 Source of income (DSI)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	362	67,9	67,9	67,9
	1	171	32,1	32,1	100,0
	Total	533	100,0	100,0	

*DSI=0 from others; DSI=1 self source

Table A.147 Years of education (DEDUC)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	21	3,9	3,9	3,9
	2	131	24,6	24,6	28,5
	3	381	71,5	71,5	100,0
	Total	533	100,0	100,0	

*DEDUC=1 less than high school; DEDUC=2 high school but less than university degree; DEDUC=3 university degree

Table A.148 Household with kids/teenagers (DHK)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	270	50,7	50,7	50,7
	1	263	49,3	49,3	100,0
	Total	533	100,0	100,0	

*DHK=0 no kids/teens; DHK=1 with kids/teens

APPENDIX B

GLOSSARY*

AIR POLLUTION. The presence of contaminant or pollutant substances in the air that do not disperse properly and interfere with human health or welfare or produce other harmful environmental effects.

CARBON DIOXIDE (CO_2). A colourless, odourless and non-poisonous gas that results from fossil fuel combustion and is normally part of ambient air. It is also produced in the respiration of living organisms (plants and animals). It is considered to be the main greenhouse gas contributing to climate change.

CARBON MONOXIDE (CO). A colourless, odourless gas resulting from the incomplete combustion of fossils fuels. CO interferes with the blood's ability to carry oxygen to the body's tissues and results in numerous adverse health effects. It is even more dangerous at higher elevations where the partial pressure of oxygen is lower and where many people may already suffer from inadequate oxygen supply. CO is a CRITERIA AIR POLLUTANT.

CATALYTIC CONVERTERS. Devices which reduce the emissions of automobiles (or other pollutants) from the exhaust by providing surfaces for chemical reactions, such as the reduction of NO_x to N_2 and O_2, and the oxidation of hydrocarbons to CO_2.

CRITERIA AIR POLLUTANTS. A group of six common air pollutants (carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter and sulphur dioxide) regulated by the government on the basis of information on health and/or environmental effects of each pollutant.

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* Source: Molina and Molina 2002 and Viegi and Enarson 1998.

EMISSION FACTOR. The emissions from a given source category per unit activity. Emissions factors are multiplied by measures of activity (such as population, mass of production by an industry, or vehicle kilometres travelled) to estimate the emissions from a source category. For example, in the case of mobile source emissions, estimated emissions are the product of an emission factor in mass of pollutant per unit distance (e.g., grams per kilometre) and an activity estimate in distance (e.g., average kilometres travelled).

EMISSIONS INVENTORY. An estimate of the amount of pollutants emitted into the atmosphere from major mobile, stationary, area-wide and natural sources over a specific period of time such as a day or a year.

ETHANOL. Ethyl-alcohol, a volatile alcohol containing two carbon atoms (CH_3CH_2OH). For fuel use, ethanol is produced by fermentation of corn or other plant products.

FINE PARTICULATE MATTER. Atmospheric particles with aerodynamic diameter smaller than 2.5 micrometers. (See $PM_{2.5}$)

GREENHOUSE GASES (GHGS). Gases that absorb infrared radiation, thereby altering the radiative balance of the Earth. The major GHGs responsible for anthropogenic climate change (global warming) are carbon dioxide (CO_2), methane (CH_4), nitrogen dioxide (N_2O) and the chlorofluorocarbons (CFCs).

HYDROCARBON (HC). Any of a large number of compounds containing various combinations of hydrogen and carbon atoms. They may be emitted into the air as a result of fossil fuel combustion, fuel volatilization and solvent use, and are a major contributor to smog. (See also VOC).

LEAD (PB). A very toxic metal; it inhibits haemoglobin synthesis in red blood cells, impairs liver and kidney function and causes neurological damage. Most atmospheric lead comes from antiknock compounds added to gasoline. The use of unleaded gasoline has practically eliminated problems of lead exposure from air pollution.

MOBILE SOURCES. Sources of air pollution such as cars, motorcycles, trucks, off-road vehicles, boats and airplanes. (Contrast with STATIONARY SOURCES.)

NITROGEN OXIDES (OXIDES OF NITROGEN, NO_x). A general term pertaining to the compounds nitric oxide (NO) and nitrogen dioxide (NO_2)—both commonly referred as NO_x. Nitric oxide is a colourless and odourless gas, while nitrogen dioxide is a reddish-brown gas with a pungent smell. It is corrosive to materials and toxic to humans. Nitrogen oxides are typically created during combustion processes and are major contributors to smog formation and acid deposition. NO_2 is a CRITERIA AIR POLLUTANT, and may result in numerous adverse health effects; it absorbs blue light, resulting in a brownish-red cast to the atmosphere and reduce visibility.

OZONE (O_3). A strong smelling, pale blue, reactive toxic gas (discovered by the Swiss chemist C.F. Schönbein in 1840) whose molecules consist of three oxygen atoms. Ozone exists, providing a protective layer shielding, in the upper atmosphere (stratospheric ozone) as well as in the lower atmosphere (tropospheric ozone) and at the Earth's surface, where is it a major component of smog (which seriously affects the human respiratory system). It may cause plant damage and adverse health effects and is a CRITERIA POLLUTANT.

OZONE PRECURSORS. Chemicals such as hydrocarbon and oxides of nitrogen, occurring either naturally or as a result of human activities, which contribute to the formation of ozone, a major component of smog.

PARTICULATE MATTER. A suspension of solid or liquid particles in a gas, such as smoke, mist or smog. The term represents a state of matter rather than a specific chemical, and is often characterized by its particle size. Typical categories include total suspended particles (TSP), particles less than 10 micrometers in aerodynamic diameter (PM_{10}), particles less than 2.5 micrometers in aerodynamic diameter ($PM_{2.5}$; fine particles), and particles between 2.5 and 10 micrometers in aerodynamic diameter ($PM_{10-2.5}$; coarse particles).

PHOTOCHEMICAL REACTION. A term referring to chemical reactions brought about directly or indirectly by solar radiation. The reactions of nitrogen oxides with hydrocarbon fragments in the presence of sunlight to form ozone are examples of photochemical reactions.

$PM_{2.5}$ (PARTICULATE MATTER LESS THAN 2.5 MICROMETERS). A subset of PARTICULATE MATTER that includes those particles with an aerodynamic diameter less than a nominal 2.5 micrometers. This fraction of particulate matter penetrates most deeply into the lungs, and causes the majority of visibility reduction. They are primary combustion particles or are formed as secondary pollutants from the condensation of gas phase species.

PM_{10} (PARTICULATE MATTER LESS THAN 10 MICROMETERS). A major air pollutant consisting of particles with an aerodynamic diameter less than a nominal 10 micrometers (about on tenth of the diameter of a human air). They are generated mainly by agriculture, mining and road traffic.

SMOG. Combination of smoke and fog in which products of combustion such as hydrocarbons, particulate matter, and oxides of sulphur and nitrogen occur in concentrations that are harmful to human beings and other organisms.

STATIONARY SOURCES. Non-mobile sources such as power plants, refineries, and manufacturing facilities which emit air pollutants. (Contrast with MOBILE SOURCES.)

SULPHUR DIOXIDE (SO_2). A strong smelling, colourless gas that is formed by the combustion of sulphur-containing fossil fuels. SO_2 is converted in the atmosphere to sulphuric acid, which contributes to the problem of acid deposition. Its health effects include irritation and restriction of air passages, accompanied by symptoms that may include wheezing, shortness of breath and chest tightness during exercise in persons with asma. SO_2 is a CRITERIA POLLUTANT.

SUSPENDED PARTICULATE MATTER. Finely divided solids or liquids that may be dispersed through the air from combustion processes, industrial activities or natural sources. Particulate matter was measured initially as total suspended particles (TSP), the weight of whatever collected on a filter as the air was pulled through it. From the standpoint of health, the most important particles are those with diameter of 10µm or less (PM_{10}). Fine particles (those with diameter of less than 2.5µm or $PM_{2.5}$) have an even larger impact on human health. (See PARTICULATE MATTER.)

THERMAL INVERSION. A case where cold air (at the surface) lies below warmer air. With this thermal structure, air tends not to mix vertically and pollutants emitted near the surface tend to accumulate near ground level.

VOLATILE ORGANIC COMPOUNDS (VOC). A volatile organic compound that exists as a gas under typical atmospheric conditions. An organic compound contains carbon combined with atoms of other elements, commonly hydrogen, oxygen and nitrogen. Simple carbon-containing compounds such as carbon monoxide and carbons dioxide are usually classified as inorganic compounds. VOCs contribute to the formation of smog and/or may themselves be toxic. VOCs often have an odour, and some examples include gasoline, alcohol and the solvents used in paints.

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