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Audit of Car Ownership Models

Gerard de Jong, James Fox, Marits Pieters,
Liese Vonk, Andrew Daly

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Preface

RAND Europe has carried out out a research project on car ownership modelling, called 'Audit of car ownership models', for the Transport Research Centre (AVV) of the Dutch Ministry of Transport, Public Works and Water Management.

In this report, a review was presented of existing models for car ownership. This review contains a description and comparison of existing Dutch car ownership models and a review and comparison of recently developed models in the international literature and models used in practice. The provision of this review was one of the objectives of this project. The other objective was to recommend on directions for potential development for improving the AVV car ownership models.

The car ownership model that AVV uses for most applications is the so-called FACTS model (Forecasting Air pollution through Car Traffic Simulation). FACTS also provides the future total number of cars that is used as an external total in the Dutch national Model System (LMS) for traffic and transport.

The background of this audit is the desire of AVV to obtain information on the basis of which a well-founded decision can be made on the development of an improved car ownership model, that can produce robust and sensible car ownership forecasts for all kinds of variants of variabilisation of the road tax (MRB) and car purchase tax (BPM).

As part of this project, a number of policy advisers was interviewed about what types of outputs are required from a car ownership model, what should be the forecasting horizon and what should be the policy variables to be simulated.

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Summary

We recommend to develop a new model system for predicting car ownership in The Netherlands. The preferred model system consists of:

- Duration models for the time between vehicle transactions (and the type of transaction: disposal, replacement, acquisition, also scrappage) to explain the total number of cars. An alternative option for this would be a Markov-type panel model.

- Vehicle type choice models for the choice of a brand-model-vintage alternative for all vehicle transactions that involve purchasing a(nother) car. These choice alternatives can be aggregated to get the composition of the fleet in terms of most of the required distinctions. Some less important distinctions need to be made by a post-processing procedure.

- Regression equations for the use of every car in the household, measured in terms of annual kilometrage, or through a logsum linkage with the national transport model system, LMS.

- A micro-simulator for 'birth' and 'death; of households and transitions between households types over time; a simpler but less consistent (in terms of dynamics) alternative would be to reweigh a given sample of households in each time period.

- Possibly a model for the number of business cars (company-owned and lease cars), depending on (sectoral) economic development , which need to be allocated to households. Private car ownership could be made conditional on the outcome of this.

- An allocation procedure to the 1308 LMS zones (also post processing).

Such models have been developed before, particularly as components of the Dutch Dynamic Vehicle Transactions Model (DVTM) and/or the model for the likely penetration of electric and hybrid cars for California.

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1. Introduction

1.1 Objective and background of the project

RAND Europe has carried out out a research project on car ownership modelling for the Transport Research Centre (AVV) of the Dutch Ministry of Transport, Public Works and Water Management. The objective of this project, called 'Audit of car ownership models' is:

To review car ownership models in the Dutch and international literature and policy-making and to recommend on directions for potential development for improving the AVV car ownership models.

The car ownership model that AVV uses for most applications is the so-called FACTS model (Forecasting Air pollution through Car Traffic Simulation). FACTS also provides the future total number of cars that is used as an external total in the Dutch national Model System (LMS) for traffic and transport.

The background of this audit is the desire of AVV to obtain information on the basis of which a well-founded decision can be made on the development of an improved car ownership model, that can produce robust and sensible car ownership forecasts for all kinds of variants of variabilisation of the road tax (MRB) and car purchase tax (BPM).

1.2 Deliverables

In this project, a number of memoranda and reports has been written:

- A memorandum (memo 1) on the interviews that have been carried out with policy advisers (Ministries, also car importers) on what is required from a car ownership model; A copy of this memo (in Dutch) is attached as Annex 1 to this report.

- A memorandum (memo 2) on the first round of the audit of car ownership models: description of existing models, weak and strong points of different car ownership modelling approaches, pre-selection of most promising approaches given the requirements; Is FACTS appropriate as a basis for future model development? This memo, slightly revised, is included in this report as chapters 2-4.

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- A report which includes the information of the two memoranda, but also contains:
  - The second round of the car ownership models: going into greater depth on the weak and strong points and the confrontation with the requirements for the most promising models;
  - Several scenarios for improving the AVV car ownership models
  - Recommended car ownership model type for the Netherlands.

This report 01192 of January 2002 is the third of the above-mentioned deliverables. In chapter 2 the FACTS model is described. Other car ownership models, available in the Netherlands are reviewed in chapter 3. Chapter 4 is the review of the international car ownership literature. In the international review we focussed on models developed recently (say since 1995) or models that are still in use, because the review should give the state-of-the-art and state-of-practice. For the Dutch models in chapter 3 we do include older models. A cross-comparison of the different model types, with advantages and disadvantages can be found in chapter 5. In chapter 6, the outcomes of the interviews with policy advisers, as agreed with the client steering group is reviewed. In chapter 7 we provide recommendations on what seem to be the most promising types of modelling car ownership and on the development of such models. Finally in chapter 8, a summary and recommendations are given.

2. Description of FACTS: Forecasting Air pollution by Car Traffic Simulation

In this chapter, we shall first describe the predecessors of the present FACTS3.0 model: the GEBAK-model and FACTS 2.0. After that, we shall describe the FACTS 3.0 model.
This review mainly describes the car ownership model in FACTS and the modules that are closely related to the car ownership model. Not very much attention is paid to the air pollution module of FACTS.

2.1 Brief history: from GEBAK to FACTS 2.0

About the GEBAK-model

The GEBAK-model predicts car ownership and car use. It can also compute the emissions of pollutants by car traffic through a set of emission factors. The starting point of model is a base year '(reference variant)'.

GEBAK computes car ownership for a number of car types and combinations of car types: 18 classes of passenger cars, divided into private car ownership and business car ownership. The 18 classes are:

fuel type:
- petrol
- diesel
- LPG,

weight (here we give the classification of FACTS 3.0):
- 950 kg or less
- 951-1149 kg
- 1150 kg or more

and age of the car:
- 5 years old or less
- more than 5 years old.

The GEBAK-model strictly distinguishes between the private and the business car. The costs of a business car are fully paid by the company who 'owns' the car. Market segmentation is used within the segments private car and business car. In GEBAK, a certain private car is considered to coincide with a certain way of living with a certain expenditure pattern and mobility pattern. This way of living is determined by income,

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age and household structure. A classification in homogenous groups as this influences car ownership and car use was developed. The level of expenditure and the mobility pattern of the business car is treated as depending on profession or function within the company.

The two basic assumptions of the model are:

- The budget share (of the income) spent on the ownership and use of the private car is assumed to be constant for homogenous groups of households. It is supposed that households allocate their budget, given their mobility needs, in a way that they get the maximum utility out of their car(s). This utility also depends on the comfort of the car. The latter is assumed to be a derivative of the price of the car and the weight of the car. The households are classified by age, household income and family composition. The cars are classified by fuel type, age and weight class. Different national and international research studies have shown that the budget share within homogenous household segments is approximately constant. However there is also evidence pointing in other directions (see discussion on fixed travel budgets later on).

- Households aim at retaining (car) mobility. The level of (car) mobility depends on the way of living of a household. The households are not only segmented by age and composition of the household but also by (net) household income. This hypothesis is used as valid for a period of time in which a household can adapt its car use to a change in the costs of car ownership and use. A possible way to do this is to buy a different car type. The supply of different car types is sufficiently heterogeneous to make it possible to substitute between fixed and variable costs in order to maintain the level of mobility. It is also assumed that the supply of infrastructure follows the demand for infrastructure. This implies that the average speed or travel time stays constant.

About FACTS 2.0

FACTS 2.0 predicts car ownership, car use and car emissions using alternative economic, demographic and emission scenarios as well as car cost policy measures of the government. The model does not compute the car fleet from year to year, although computations can be made for different future years. The number of trips made by car is not computed. The total traffic flow is not assigned to the network (this is being done in the LMS, using the car ownership predicted by FACTS).

The structure of the FACTS-model

The FACTS-model consists of various modules. FACTS 2.0 contains the following modules:

- Input module A, parameters which are independent of environmental and policy scenarios. This module contains input data like budget share per household type on car ownership and car use and the distribution of a car trip in different classes with a different average speed.
- Input module B, parameters which depend on environmental scenarios, but not on policy scenarios. This module contains data that depend on the chosen environmental scenario, like the average fuel use per car type.
- Input module C, parameters that depend on environmental and policy scenarios. This module gives the possibility to compute different kinds of policy measures, directed at influencing car costs.

- Simulation module, in which a household, depending on its class and mobility needs, will choose a car from a given number of car types. Every car type has its own cost specification.
- Output module car ownership, car use and emissions.
- Output module energy consumption.
- Output module revenues of the government.

The basic assumptions of FACTS 2.0

Time and money are important constraints for car ownership and car use. Key notions for the factor time are the average travel speed and available time. Controlling factors for the factor money are the costs of car ownership and car use as well as disposable household income. The only constraint implemented in FACTS 2.0 is about money (budget constraint), there is no time constraint. The basic hypotheses remained the same as in the GEBAK-model (see the above text).

Input and simulation

In FACTS 2.0 there is no sequential dependency: all modules together give the information to the simulation process within the model. But there are differences in the way and degree different environmental and/or policy scenarios affect the input data.

Growth of income: the economic growth is translated into disposable household income. A growth in this income will lead to a growth of the number of cars and a growth of the number of kilometers driven.

Model structure FACTS 2.0

FACTS is composed of a number of blocks:

Main blocks:
- The 'computed' base year: in this block the number of cars, kilometers driven and emissions are computed for the base year. This is the first test on the outcome of FACTS. The results of the simulation of the base year are compared with the results of the computed base year. The computed base year is not used anymore as a reference for the forecasts for future years.
- The Simulation Model Car Choice (SMAK): in this block the choice process of households is simulated using to the basic hypotheses. The output contains the following variables:
  - The future allocation of the number of car types per household class;
  - The share of Dutch households per household class who own a car in the year the forecast is made;
  - The average number of kilometers driven in a future year, split by household class and car type;
  - The share of household classes for the future number of households in the Netherlands.
  These variables are used in the next sub-block:
- The simulated base year and the forecast year are produced.

Other blocks:
- Business car fleet; the following variables are used as input in SMAK:
  - The total number of business cars, summed by car type and production sector;

- The share per car type in the total number of business cars;
- The average number of kilometers driven per year per business car type.
- Fixed and variable car costs;
- Fuel consumption and emission.

The main similarities and differences between GEBAK en FACTS 2.0
- The basic hypotheses in FACTS 2.0 remained the same as in the GEBAK-model.
- In GEBAK it was assumed that business cars were not sensitive to car costs. This assumption is not used anymore. The following solution was chosen:
  - Restriction of the category business cars. The cars in this category are only the cars registered on the companies name or lease cars.
  - In line with the first restriction, drivers who have a business car are not sensitive to costs, because the employer pays for ownership, use, repairs, fuel consumption etc.
- Because of this there was a reduction in the number of cars that can be marked as business cars compared to GEBAK. This led to an increase in the number of car kilometers that can be influenced by policy measures on car costs.
- FACTS takes the ownership of a second car into account: households who have sufficient budget and want to drive enough private kilometers can own two private cars. Households with a company car can't own two private cars.
- In FACTS the two blocks (private cars and business cars) are integrated. In GEBAK the blocks were handled separately. The total amount of business cars is still determined by sector-specific developments, but after this these cars are divided among the Dutch households, based on a probability distribution function. Business cars can be used for both private and business kilometers. A private car can also be used for business kilometers.
- FACTS 2.0 includes a mechanism which makes it possible for a household to own no car, even if it can afford a car.
- In FACTS links were established between prices of new and old cars. This link assures that prices of old cars develop in a same way as prices for new cars. This link was missing in the GEBAK-model.

An acknowledged shortcoming of FACTS 2.0 was that it is the missing an adequate car supply model.

2.2 FACTS 3.0

Introduction to FACTS 3.0
With FACTS 3.0 forecasts can be made of car ownership, car use and emissions under alternative economic and demographic scenarios, emission targets, developments in fuel efficiency as well as policy measures in the area of traffic and transport.

The structure of FACTS 3.0 shows the effects of car ownership and use due to (changes in) costs of ownership and use, as well as the total number of households and composition of these households and their incomes. Effects of car ownership and car use due to not explicitly modeled variables like travel time, spatial planning effects and public transport service levels are all included in a single factor.

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Model description

The heart of the model contains the simulation of the choice process on private car ownership of households. This behaviour is influenced by fixed and variable car costs per car type, whether a household has a company car, and a number of exogenous variables (like the level of household income and the share of that income that is available for the private car), along with the two basic hypotheses (as already mentioned).

When all households have made their choice from the 18 car types distinguished, the next step follows: the confrontation of demand and supply of different car types. After this confrontation the total number of cars per car type is known, and together with that the number of kilometers driven per car type. With the help of the fuel consumption- and emission module the total amount of fuel consumption and emissions can be computed.

SMAK (simulation car choice)

The starting point is the computation of the fixed and variable costs per car type. These costs depend on the chosen scenario. Also the total size and composition of the business car fleet are - depending on the chosen scenario - determined. These business cars, distinguished by type, are allocated to households based on a probability distribution function per household class. This probability depends on a household class specific probability and the share of this household class in the total number of households in The Netherlands. People who are 65 and older can not own a business car.

In the next step the available budget for private car ownership and private car use (for one or two cars) is determined. This net income might be altered by a travel cost reimbursement per household type. In the business car module the number of business cars per car type is determined.

The next step is the determination of the number of kilometers driven per household. This variable is determined by drawing from a specific probability distribution per household class. Based on this the number of driven kilometers can be adjusted to the variable 'mobility needs'. This variable takes care of the changes in mobility needs due to measures that can not be modeled explicitly within FACTS. After the determination of the mobility needs a first selection of households takes place to see whether they are considered to own a private car or not. At least they need to have:

- A mobility need at or above a exogenous minimum determined value, AND
- An available car budget sufficient to buy the car with the minimum total annual costs at the mobility threshold.

If one of the rules is not fulfilled, it is not possible for this household to own a private car. The household can still own a business car.

The next selection a household has to go through is a procedure that determines whether a household will have no private car at all, even if it can afford one. The remaining households go to the next procedure. In this procedure it is determined whether the household is a single-person household or not. This has certain consequences for the next steps. There are four possible routes from here:

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1. A single-person household - business car. It is assumed that it is not possible to own more than one car. When this kind of household owns a business car, this household can not own a private car.
2. A single-person household - no business car.
3. A more-than-one-person household - business car. If the private need is smaller than an exogenous minimum limit, a private car can not be owned. If the need is bigger than this minimum limit, the household will own a car. This household can also have a business car. The mobility need is diminished with the number of private kilometers that is driven with the business car.
4. A more-than-one-person household - no business car. In this situation it is possible that a household will have the disposal of two private cars (more than two cars is not possible). This does not include the group of people who are 65 and older. To own two cars the following requirements must be taken into account:
   - The private-mobility need must be above an exogenously determined minimum for the owning two cars.
   - If the remaining budget is smaller than the minimum needed to own a first car with a mobility need that is equal to a minimum limit, the second car is taken from the household.

First it is determined if it is possible to own a second car; otherwise the budget would all be spent on the first car.

Every household that is 'allowed' to own a first private car, may 'choose' a car type in the next step. A household can choose from a set of cars. These cars all fit within the available budget (or within some user-defined excess budget).

In somewhat more detail this means that the first step in this car type selection process is the comparison of the at random selected number of kilometers driven per year with the kilometer threshold in the choice between petrol and diesel or the threshold for a petrol versus LPG. When this random selected number of kilometers driven is smaller than both minimum levels a household can only 'choose' from petrol cars (6 types). When the random picked number of kilometers driven is bigger than both minimum levels a household can 'choose' from all 18 distinguished car types. In both other situations a household can 'choose' from 12 car types.

After restricting the households car choice to 6, 12 or 18 car types, the costs of the relevant car types are raised with the psychological car costs. This –multiplicative-factor is put in, because otherwise it leads to an overestimation of the share of certain car types, notably diesel and LPG. The idea behind this variable is that it should represent (perceived) disadvantages of LPG (reduced lugagge space, sometimes seen as dangerous) and diesel (noise, slow).

In the next step, after the restriction process, households choose from a set of (maximum) 4 cars. These cars cost nearly the same as the 'best' car (probability procedure, see below). These 4 cars get a probability based on the distances of the car cost (at the kilometrage selected) to the budget.

The probability procedure contains the following three steps:
1. Determine the budget deficit (variable plus fixed car cost bigger or smaller than car budget) for the car types that households can choose (6,12 or 18 car types);

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2. Determine the 1-4 car types for which a probability will be calculated. These are the cars closest to the budget, under the restriction that it is not allowed that the budget deficit of these selected car types is bigger than a user-defined excess budget (the budget can only be over-spent by some margin).
3. Compute the probabilities for each of the 1-4 car types. The probability differences depend on the distances between the budget deficits of each of the car types to the budget: the car type closest to the budget gets the highest probability .

FACTS assumes that every household chooses that car that fits best within the budget (all the budget will be used, and if an excess budget is allowed, possibly a bit more).

After the probabilities for the 1-4 car types have been determined, a random number generator is used to choose one car type from the set of up to four car types. FACTS does not work with sample enumeration (adding probabilities over the sample), but assigns a specific car type for every car owned.

When a household can own two cars but the budget deficit is bigger than allowed a household can loose the probability to the second car. When a household can not own two cars the budget deficit is checked a second time. When the budget shortage is bigger than approved, the randomly selected number of kilometers is adjusted. If the household still has a bigger budget than allowed, the household is not permitted to own a car.

SMAK defines the following output variables:
- The division of the number of car types per household class;
- The share of the Dutch households who own a car per household class;
- The average number of kilometers driven per household class and car type;
- The share of each household class within the total number of households in the Netherlands.

These variables are used in the next block: the simulated base and forecast year.

Simulated base and forecast year
In this module predictions are made for the total number of cars per type and household class. This number can be seen as the demand for the most preferable car type per household. This demand will be confronted with the number of cars supplied. The number of cars that is the result of the equilibrium process is the total number of cars per car type and per household class. In the next step, the VRAAGJ-procedure, the result is distributed by vintage (year of construction). By shifting this result over time (taking account of vehicle scrappage), the supply for next forecast year can be determined (see below).

Business car fleet
The size of the business car fleet is directly related to the production structure of the economy. The following output variables are used as input in the SMAK-procedure:
- The total number of business cars, summed by type and production sector;
- The share per car type in the total amount of business cars;
- The average number of kilometers driven per year per business car type.

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The supply side of the car market
In FACTS 3.0 some attention is paid to the supply side of the market. Now it is possible to let demand and supply interact. A distinction is made between old cars (>5 years) and young cars (≤ 5 years).

The supply of young cars is assumed to be equal to the demand of young cars. The supply of old cars is computed by FACTS. To determine the number of old cars supplied, information is needed about the 'administrative' car fleet (this is the fleet in use plus the car stock of the dealers) in the base year specified by fuel, weight and construction year of the car. FACTS determines the number of cars that will survive (the opposite of scrappage) on to the next forecast year (t+5), using a survival function. The size of the computed car fleet can be influenced by the number of imported and exported cars (>5 years). The result is used in the demand- supply confrontation procedure.

Demand - supply confrontation procedure (de RAS-procedure)
It is possible that an Excess Supply or an Excess Demand will develop. The price mechanism takes ensures that an equilibrium is found by changing the demand of young cars and the number of non car owners. Adding this result to the number of business cars and second cars determined earlier gives the 'active' fleet (not including the car stock of the dealers).

It might seem odd that the demand supply confrontation only takes into account the first private owned car, this is done because in the RAS-procedure the non-car-owners are taken into account. These non-car- owners can not be compared with the total number of cars demanded per household. That is why, before the demand supply confrontation procedure starts, the simulated demand of cars and the number of a second car and business cars are subtracted. This results in a total number of households with one private car.

VRAAGJ-procedure
In this procedure the active car fleet by type and household class, as determined after the demand supply confrontation, is divided over vintage categories, using the result of this, the number of cars supplied in the next forecast year can be computed.

The distribution by construction year for young cars is not known for the future years. The supply of these cars is simulated within FACTS. But FACTS does not distinguish cars by construction year, but by construction year class (≤ 5 year en >5 year). The distribution of young cars therefore is determined in the VRAAGJ-procedure. The annual growth of the car fleet between t and t+5 is determined through interpolation.

The last step to determine the administrative number of cars is the adjustment of the demand for young cars per year of construction to the maximum potential supply of young cars. The demand for young cars is raised by a factor to get the administrative car fleet.

Finally the administrative fleet of old cars is added to the number of young cars supplied. This results in a total maximum potential supply of cars per construction

year, fuel type and weight in the year t+5. This outcome is the starting point for the determination of the size of the car fleet in the year t+10.

The output variables are:
- The total number of cars supplied by fuel type, weight and year of construction for the year t+5.
- The total number of cars scrapped by fuel type, weight and construction year created in a 5-years period.

The main differences between FACTS 2.0 en FACTS 3.0
- By activating the variable 'mobility needs' the consequences of an increase in congestion or changes in driving behaviour can be simulated. The changes in the mobility needs can be differentiated by household class and simulation year. Altering this variable will result in a proportional change in private kilometers of the household. By changing the annual number of kilometers driven the probability of private car ownership of a household also changes. In FACTS 3.0 the variable 'mobility needs' has been simplified by dropping the differentiation between household classes. It is very difficult to measure the effect of a prolonged travel time per household class. Also, boundary values have been specified within which the mobility needs are allowed to vary. When there would be too much freedom to increase or decrease the mobility needs, this would undermine the 'normal' operation of the model and lead to incredible model results.
- 18 household classes are distinguished:
  - Disposable income. This category was changed in FACTS 3.0.
  - Age of the head of the household. This category was not changed compared to FACTS 2.0.
  - Household structure (one-person or multi-person household). This category was not changed compared to FACTS 2.0.
- The number of sectors of the business car module was reduced from 7 (FACTS 2.0) to 5 (FACTS 3.0).
- The basic hypotheses remained the same.
- FACTS 3.0 has a supply function to bring about the interaction between the demand and supply side of the car market. The previous models did not have this mechanism.

2.3 Advantages and disadvantages of FACTS

In this subsection we list the advantages and disadvantages of the FACTS model. FACTS has been reviewed before: some of the advantages and disadvantages listed below (or rather of GEBAK) have already been mentioned in De Jong (1989).

Advantages of FACTS:

- FACTS has an excellent track record; it has been used in many applications, and has also been regularly updated and extended to account for changed circumstances and to remedy things that were not modelled satisfactorily or were missing. On the other hand we have not seen a validation of FACTS forecasts against observed future year data. Comparisons for a base-year are available for all versions, and in 1989 FACTS was used in a backcasting exercise to predict

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1981 car ownership. The outcomes were compared with observations from the CBS car panel PAP. The main outcome was that total car ownership was predicted well, but the distribution over car types, especially fuel types deviated considerably from what was observed. The introduction of the 'psychological car cost' in later versions of FACTS might have reduced this problem. For the present FACTS 3.0 we have not seen such a backcasting exercise.

- FACTS is flexible, rather fast and easy in use.

- FACTS can produce outputs in many dimensions: number of cars owned, fixed and variable car cost, composition of car fleet in terms of 18 car types (fuel type, weight, vintage), impacts on households distinguished by income, age of head and household size, and car use; together with the emissions module it can also predict fuel consumption and emissions.

- FACTS contains a special treatment of business cars (leased cars, company-owned cars). This is related to production structure of the Dutch economy. The decisions of households on private car ownership are made conditional on the presence of a business car.

- FACTS contains a confrontation of car demand and supply (for cars older than 5 years).

Disadvantages of FACTS

- Policy advisers now ask for even more output dimensions, especially for car types (see chapter 6 of this report).

- The basic assumptions of a constant money budget for car ownership and use and that households will seek to maintain their mobility level are at odds with economic theory. The assumptions imply cost maximisation within some range: the households try to 'fill' the budget by choosing the most expensive affordable car. The empirical evidence on these assumptions is mixed. Some international evidence is discussed in sections 4.17 and 4.22; some Dutch work is report in the subsections below.

- Generally speaking a model is better if it uses fewer assumptions to get the same outputs. FACTS is a powerful instrument, but rests on far-reaching assumptions, which might be tested empirically using models that require less observations.

- FACTS is not really suitable for giving impacts of large changes in cost (because of these basis assumptions): in case of large cost changes (could be larger than observed before), it becomes more likely that households will change the car budget share and the number of kilometers. This cannot be tested with FACTS.

- FACTS is not really a causal model, but a system that consists of a number of pre-defined decision rules and some random procedures.

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- The psychological car cost variable is an artificial device to correct for wrong car type share predictions; the decision to let all influences on car type choice have impacts through cost variables only poses severe restrictions and can lead to implausible car type choice results. Changes in variable and/or fixed cost (including variabilisation) will in FACTS be translated into cost changes including the psychological cost, which can lead to implausible choices in terms of light versus heavy cars and in terms of old versus new cars.

- Car use is not explained in FACTS, but comes from drawing from a distribution, and is not directly affected by variable or fixed car cost. In an indirect way there is some effect: the kilometrage can be reduced to some degree if the car cost exceed the budget.

- Whether there will be second cars in the household in FACTS, mainly depends on the sum of the mobility needs (in terms of kilometers) of the household. One might argue that most households with two of more cars will rather own more than one car because they need two cars simultaneously than because they have to make many kilometres in total, since the fixed cost of a second car are substantial (synchronicity instead of additivity). Other households might have more than one car, because some car types are more suited for certain travel purposes (e.g. shopping, recreation) than others (specialisation of car types within a household).

Review of the discussion on monetary travel budgets in 'Time to Travel, A model for the allocation of time and money' by Kraan (1996)

The purpose of this Ph.D. thesis is to study how limited time and money budgets will lead to limited growth of mobility. A –selective- review is included in this memorandum because of its relevance for the basic assumptions of the FACTS model (constant money budget per household segment; maintaining mobility level). An overview of recent Dutch evidence on constant time budgets can be found in Van Wee, et al. (2001). This paper however does not deal with money budgets, as are used in FACTS.

The model used in the thesis, which will not be discussed here, is based on the flexible budget approach by Golob et al (1981) and Downes & Emerson (1985). It is not the intention to provide a summary, however we focus on the discussion throughout the thesis about the impact of the money budget restriction on a household's possibilities to travel.

In addition to following on the BREVER-law (well-known, but also often criticised) which states that the time spent on travel is constant, models such as FACTS and UMOT make the assumption that the percentage of the income spent on travel is fixed as well. A counterintuitive critique, for example, is that when car speed increases, a longer car distance can be covered within the same time, but this will cost more money (assuming the variable cost does not change). Keeping the budget of money constant, some expensive car kilometers should be compensated by cheaper kilometers, for instance public transport kilometers.

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The problem lies in the fact that there is no interaction between the money spent on travel and other activities. Even when a more flexible approach is taken and money can be spent otherwise, travel is still considered as an end itself, and not as derived demand. Other activities are grouped as one variable, where a distinction between various activities (or travel purposes) as reason for the trip should be taken in to account. Due to the lack of interrelationship a thorough activity-based study would be needed to really solve the problem/.

Activity-based approaches consider the total activity pattern. In contrast to the conventional four stage models, both frequencies, and time expenditures are endogenous, depending on total activity pattern. Money expenditure is also included in the total activity pattern. Every activity will cost an amount of money, which can be divided between fixed and variable costs. For travel, the fixed costs are purchase or maintenance of the car, the purchase of public transport season ticket, or the purchase of a bicycle. The trip length normally determines the variable costs. Individuals make various kinds of decisions subject to time and money constraints. Activities can be distinguished by their type (obligatory, maintenance and leisure) and the characteristics duration, location, frequency and costs. Out-of-home activities will generate travel, where obligatory trips are fixed in the short run.

Although the theory outlined above is well-defined, there is no data available in the Netherlands to test the model that allocates both time and money expenditures. The problem is that time and money expenditure data is given by different survey units, individuals versus households. In terms of time expenditures the model in the thesis considers individuals, but the money spent on activity patterns is mostly household based. In most of the cases one or two members of the household earn an income that is used for expenditures of the entire household. The model should be adjusted to a household model with individuals being modelled in a submodel.

Review of 'Large changes in prices. An empirical controlled budget approach'

The outcomes of this project, that was carried out by MuConsult for AVV, were reported at the CVS by Rosenberg, Meurs and Meijer (1997). The purpose of the study was to examine if large price changes have proportionally different (i.e. greater) effects on mobility and car ownership than small price changes. The review of this paper is included in this memorandum because we think this is relevant for evaluating the basic assumptions of FACTS.

When a price increase in a transport good occurs a household can compensate this by adjusting the budget reserved for transport (income effect) or decreasing their budgets for other goods, which can also be a reduction in the household savings (substitution effect). The assumption made throughout the article is that households will first adjust their transport budget, before changing other budgets like housing, food, clothing or recreation. This approach is consistent with the two-stage budgetting approach in Deaton and Muellbauer (1980).

The project included a budget game with 830 workers who all possessed a car. The reaction of the respondents to a large increase in price was monitored. Price increases were made on the fuel price, which were compensated or not-compensated by fixed car costs and public transport fares in combination with the first two options.

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In total, eleven combinations were evaluated and the overall conclusion is that consumers will compensate the price increases mainly by cutting down on their savings. But also other non-transport related budgets were affected, such as food and clothing, and recreation. If savings were made on car costs, this was mostly done by reducing the number of car kilometers.

Examining the price elasticities, the conclusion can be drawn that large price increases have relatively more effect than small ones. Four other remarks, focusing on car users, can be made:

- The elasticities are greater for low income households than for households with high incomes, which may indicate that economic growth reduces price elasticity.
- A reduction on car kilometers is mainly achieved by decreasing the private (not including commuting here) kilometers rather than kilometers driven for commuting. However, an abrupt large increase in the price is more likely to reduce the commuting kilometers than a small increase.
- 'Urban' households are more price sensitive than households that live in a more rural area. This is caused by the high share of low income classes in cities and the better quality of public transport.
- When car users are compensated for increasing fuel prices by a reduction on the fixed car costs the elasticities drop significantly.

In the long run, some additional options to adjust the household budget were provided to compensate for the price increase. The options that the households could choose included moving to a location nearer to work, changing jobs, working at home or relocating to less expensive housing. None of the options were chosen often, because transaction costs are perceived as high. Nevertheless, the households who were willing to change their budget by one of the options, estimated the probability, to actually perform the change, as high.

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3. Other car ownership models for the Netherlands

3.1 The 'Cramer' model for forecasts of the car fleet

This model is described in Cramer and Vos (1985). It is based on an earlier model developed in 1973 at the University of Amsterdam by Cramer and Van der Vlis. In 1985 this model was revised and applied for forecasting the car fleet until the year 2010.

The model
The model describes the number of cars at the end of year t. Four sub fleets are distinguished: distinction is made between old and new cars and between first and second or next car of a household. The groups can also be summed to a (sub)total.

The model consists of 2 blocks:
1. The first block describes the car fleet at the end of year t.
2. The second block of the model describes the market process and the block also produces the number of cars purchased Q and the secondhand car price P_o. Q and P_o are determined per year.

The dynamics of the model lay in the determination of the equilibrium between the number of purchased cars (defined by the number of people, the number of households, the average income and the distribution of incomes, and various prices) and the supply side of the market (defined by the number of scrapped cars, aging, new bought cars of the year before).

The two unknown endogenous variables in the model are Q_t: the number of purchased cars (the supply-function) and $P_{o, t}$: the price of a secondhand car (in the demand-function).

The dynamics of the car market is expressed by the adjustments in the demand for the existing number of old cars, via the price of secondhand cars, and through its effects on the demand for new cars. So if the price of a secondhand car decreases, the demand for new cars will also drop. The model describes the developments from year to year.

Block 1: the supply side of the car market
The first block contains equations for the size of the total car fleet at the end of year t. The total number of cars is computed by the number of cars sold (Q) in that year. For this, age-specific scrapping probabilities (s(a)) are used. Besides that, age-specific

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transition probabilities (r(a))are used. These define which fraction of new cars passes to the second owner. It is represented as a linear transition in the first 6 years. The import and export of used cars are also taken into account. This is done through an 'growth factor'. It is assumed that the import of used cars has the same distribution in age as the domestic car fleet.

Block 2: de demand for cars
The second block contains demand equations for the desired size of the four subfleets (old versus new cars and first versus second and beyond cars). The starting point for these equations is that for the first, the second and others cars, there is a point of saturation. This point is similar to the number of potential car owners. The function for this point of saturation ranges between 0 and 1. The explanatory variables are income, prices, etc.
The desired size of the car fleet' is a function of M (the number of potential car owners) and the saturation level F.

The number of potential car owners
The number of potential car owners with a first car is set equal to the number of households. This also includes the 1-person household or singles. This series is derived from an interpolation process on figures of the CBS. The total amount of potential car owners (as needed to define the number of car owners with a second or even third car) is fixed at the adult population between 20 - 70 years.

The function to compute the saturation level
The function to compute the saturation level F of a sub market is specified as a 'standard normal distribution function'. The saturation level is defined by the following exogenous variables:
- The income level (Y_t). Y_t is defined by the real disposable income (purchasing power) per head and the variance of this income distribution.
- The increase or decrease in the inequality in the distribution of incomes (S_t)
- The effect of all other variables ($\mu_{\ell i,t}$).

The parameter $\mu_{\ell i,t}$ is defined by the following exogenous variables:
- A 'constant' which fixes the level of the demand-function. This differs for each of the four demand-functions.
- The generation-effect. This is connected to the gradual disappearance of generations that were too old at the beginning of the mass-motorization in the early sixties to accept a car or to pass a drivers license test. This effect is represented as a declining trend.
- The utility-effect or the spatial planning-effect. This is a rest-factor composed of a complexity of factors. The size over time of this rest-factor is connected to the values of other coefficients, like the coefficients of price indices.
- The price indices of old and new cars and the ratio between these two. There is no distinction between the first and the second car, because both would eventually be used in the same way. The price indices are determined as a linear combination of other price indices, namely: the variable car costs (V), fixed car costs (F), the price of new cars (P_n) and the price of secondhand cars (P_o). All these price indices have a fixed weight. The utility-effect maintains, because limitation of the utility-effect leads to unacceptable high elasticities.

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- A dummy variable. This dummy variable takes into account because the effect of the first oil crisis and the effect of that oil crisis on the demand of cars.

The confrontation between the two blocks
Eventually the two blocks have to be confronted in order to find the equilibrium. The final result is reached if the two blocks will have the same result and the differences between the numbers of new and the numbers of old cars will be zero. To reach this result an iterative process of adjustments is started, which reduces the deviation between the two estimations to less than 0.1%.

Usually no more than 7 iterations are sufficient to reach the above result. The result is reached in the following way: the old price ($P_{0,\,t-1}$) and the number of sold cars ($P_{0,\,t-1}$) of the year before are used as starting values. With these new exogenous variables this leads to two different estimations for the two subfleets. The differences between the estimations are reduced. To do so the number of sold (Q) cars is corrected with complete difference in the new fleet $\Delta X_{nz'}$. Also the price of secondhand cars P_0 is adjusted. In practice this led to convergence quite quickly. To stop the iterative process a certain ratio value that indicates that the outcomes are sufficiently close to equilibrium was chosen.

3.2 The Van den Broecke car ownership model

A description of this model can be found in Van den Broecke (1987). This model was developed in 1986/1987 for the Projecbureau Integrale Verkeers- en Vervoersstudies (PbIVVS). The outcomes of the Van den Broecke car ownership model for 2010 (especially the prediction of 7.9 mln passenger cars in total for 2010) were used in applications of the Dutch National Model System for SVV-II and NMP in the second half of the eighties and early nineties. Later on this role has been taken over by FACTS.

The Van den Broecke car ownership model can be characterised as a combination of a cohort survival model and an econometric model. A cohort is defined here as a group of persons with the same birth year (and some other common characteristics, see below). The calculations in the model are done at a detailed level; population groups are distinguished by :

- Birth year
- Gender
- Education level
- Married/not married
- Employed/not employed.

The econometric component is used for producing the impact of changes in income on car ownership.

The Van den Broecke model start by relating car ownership to the number of owners of a driving licence in a population group ('cohort'). The saturation level of licence holding and the income growth per cohort are determining factors for the future

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growth of car ownership in the model. Predictions of future licence holding (these can come from cohort models for licence holding also developed by Van den Broecke) and the income elasticities used in the model are therefore crucial factors in the model for forecasting car ownership. Both in predicting licence holding and car ownership, Van den Broecke assumes that the preferences of persons with regards to owning licences and cars remain unchanged. Only the numbers in the cohorts and the incomes that can be spent will change in the model.

The model gives total car ownership per cohort, without distinguishing between private and business cars. It also does not produce the distinction between first and second cars in the household (it is a model at the person not the household level) or car types by vintage, engine size or weight. Car costs or other policy levers are not included. The model is most suited for predicting the impact on car ownership of changes in the size and composition of the population.

3.3 The disaggregate car ownership model within the LMS

Within the LMS there is a car ownership model, which operates at the household level. The LMS car ownership model reproduces the car ownership model developed in an earlier project, the 'Zuidvleugel Study'. The car ownership choices of the household are conditioned on household licence holding (which is also explained in the LMS by using disaggregate models):

- A household without licences will have zero cars
- A household with one licence can choose between two options: zero cars or one car.
- A household with two or more licences can choose between two options: one car or two more cars.

Figure 1. Structure of LMS: Household car ownership conditional on the number of driving licences in the household
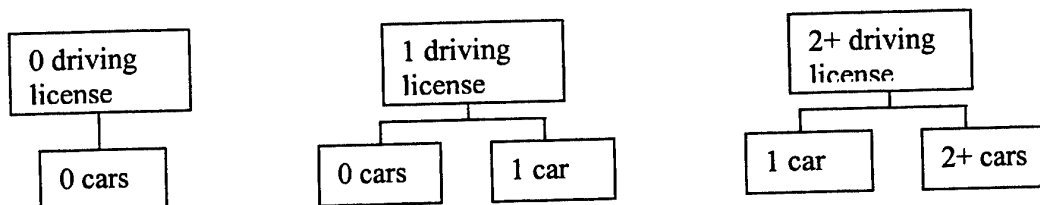
These choices are modelled as binary logit models, estimated on disaggregate data from the Dutch National Mobility Survey (OVG). These models are based on random utility theory and can be interpreted within this behavioural framework.

An important explanatory variable in both the 0 or 1 cars choice-model as the 1 or 2+ cars choice-model is the monthly income that a household can freely spend; the monthly expenditures on food, clothing and housing have already been subtracted. If the household would chose to own a car it incurs fixed car cost; if there would be two cars, the household would have to pay fixed car cost for two cars.

So if the monthly incomes in the Netherlands rise, the probability of car ownership will rise as well. If the fixed car costs rise the car ownership probability will decrease. Other explanatory variables are age, gender, household size, number of workers in the household and region-specific variables.

The total number of cars in a future year in the LMS is usually imported from an external model (initially the van den Broecke model, later FACTS). This has been done to be able to compare different policy variants (e.g. changes to the networks) on the same basis. The role of the disaggregate model then is to subdivide the national total supplied by an external model over zones and households.

LMS car ownership without external totals
In a project called 'Cost sensitivity of car ownership and car use in the LMS without adjustments to the control-total for future car ownership' that Hague Consulting Group carried out in 1990 for the Dienst Verkeerskunde (now AVV), the effects of not using the 7.9 mln cars in 2010 from the Van den Broecke model were investigated (Hague Consulting Group, 1990).

In the LMS changes in variable car costs (esp. fuel costs) influence the mode choice and the destination choice for a journey. At the time of this project, the disaggregate model for car ownership in the LMS was adjusted to the forecast of the national car ownership from the Van den Broecke model (later FACTS was used for this). Adjusting the car ownership will make it impossible to examine the effect on car ownership and use of changes made in the fixed car costs, since these cost only appear in the disaggregate car ownership model. If one would not use the adjustment procedure the LMS could compute the influence of changes in the fixed costs on car ownership and use. Changes in car ownership influence the mobility predictions of the LMS, e.g. the total amount of car kilometers driven.

Key questions of the research project were:
- What effect do changes in the fixed car costs have on car ownership, in the LMS, in a situation where future car ownership is not a fixed number?
- What effect do changes in the fixed car costs have on the mobility forecasts in the LMS, and especially on the number of car kilometers?

The only change to the LMS that was made in the 'Main variant' of this project, was the removal of the fixation of the national number of cars to the control-total of 7.9 mln cars (Main variant) in the year 2010. The remaining control-totals in the Main variant (car ownership in the base-year, licence holding) remained unchanged.

The 'Dienst Verkeerskunde' suggested an other variant: in this variant not only the control-total of future car ownership is dropped but also the control-total of car ownership in the base year is abandoned. This variant (Variant A) was computed subsequently.

In the research three 'exercises' were done: predictions of car ownership, deriving a fixed costs elasticity of car ownership and the effect of fixed costs via car ownership on mobility. The forecasts on car ownership and the fixed cost elasticity were computed for the Main variant as well as in the Variant A.

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Information about income is used while making the car ownership forecasts. In current practice the classification of the personal net income of the OVG (onderzoek verplaatsingsgedrag) is maintained. In the OVG there are 5 income classes and 3 classes for a no or unknown income. But it turned out that for the car ownership effects it was preferable to use more spread in household income. In this project, this was accomplished by Monte Carlo simulation (drawing incomes within the classes, similar to FACTS).

To get the information about incomes for a future year, the real growth of the net household income was used. Next, assumptions had to be made about the expenditure on a house, the daily expenditure and the fixed car costs in a future year.

The outcome was 7.6 mln cars in 2010 (the Van den Broecke control-total being 7.9 mln).

Fixed costs elasticity of car ownership
The effect of a change in fixed costs on car ownership was examined. It appeared that a rise of the fixed costs with different percentages mostly affected the choice of households with 2+ drivers license between 1 or 2 cars. The fixed cost elasticity of car ownership was –0.1.This was also published in Klooster and de Jong (1991).

Effect of cost changes working through car ownership on mobility
The probabilities on driving license ownership and car ownership, as computed for households, were transformed into probabilities per person. The latter form the input for the travel frequency models and the mode and destination models. The combination of both of these models produces several outputs. On the one hand the output contains origin- and destination tables for journeys per travel purpose. These tables are part of the input for the information that is used in the assignment module.

- On the other hand a combination of travel frequency tables and the mode and destination models provides a more aggregated mobility forecast: the number of kilometers (and journeys) in of persons in the Netherlands by mode and purpose. In this study attention was paid to the effect of fixed costs on national mobility predictions. This effect is working through car ownership probabilities. These form the input for travel frequency models and also affect the choice of mode and the choice for a destination. Two applications were done with the travel frequency models and mode choice and destination choice models.

The effect of a change in the fixed costs on the total amount of tours (also per purpose) is so small that it can be neglected. The effect of lower car ownership probabilities on mobility goes not via travel frequency, but via mode choice and destination choice.

In terms of kilometers, there is some substitution from the car (esp. car driver) to public transport and slow modes. The fixed cost elasticity of car kilometers on average was –0.1 (the variable cost elasticity of car kilometers was on average –0.4).

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3.4 The joint car ownership and use models of De Jong

In his Ph.D. thesis (supervisor: Professor Cramer of the University of Amsterdam, mentioned in section 3.1), De Jong developed two different disaggregate models (De Jong, 1989a) each of which simultaneously explains:

- Whether a household will own a private car or not
- Conditional on car ownership: the number of kilometers driven per year (private car use).

The basis idea for both models is that decisions of households on car ownership and car use are strongly interrelated and should be studied together. Both models are joint discrete-continuous models (variants of the Tobit model), and were estimated on data from the Dutch Budget Survey.

The first model can be used for demand predictions in a situation without major policy changes. It is not directly based on economic theory and was called the 'statistical model'. It assumes that a household has a structural desired annual kilometrage, which depends on attributes of the household. Only if this desired kilometrage exceeds a threshold, the household will own a car. The observed kilometrage can deviate from the desired kilometrage through a random disturbance term. Explanatory variables for car ownership and use in this model are household income, household size, age, gender and occupation of the head of the household.

The statistical model has not attracted much attention, unlike the second model, the 'indirect utility model', which can also be found in De Jong (1989b, 1991). This model is based on micro-economic theory, especially on the relationship this theory postulates between indirect utility functions and demand functions through Roy's Identity. As a result, the relationship between car ownership and car use is included in the model in a way that is consistent with economic theory. The basic idea is that households compare combinations of car ownership and car use with each other and choose the combination that gives then the highest utility. The model also contains fixed car cost and variable car cost as explanatory variables (besides the variables that are in the statistical model). The fixed car cost influence both car ownership and use, and so does variable car cost, and the model has been used for simulating these changes and variabilisation of car cost in the Netherlands.

In the course of developing a national model for Norway, the indirect utility model was extended to include the option of two cars per household (see De Jong, 1987). The model has also been estimated in data for Israel. Attempts at estimating the indirect utility model for the UK, for use in the NRTF forecasts, have not produced stable results.

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3.5 Car ownership models on the Dutch Longitudinal Mobility Survey (LVO) 1984-1989

In Kitamura (1987) a model is developed for the simultaneous determination of car ownership (0, 1, 2 or more) and the total (all modes together) number of trips in a week. The discrete choice is estimated using normal probabilities and the estimation of the continuous choice is done using Heckman's method. The data set is a panel and the model contains lagged effects. All equations are linear.

In the paper by Golob and van Wissen (1989) an ordered-response probit model for car ownership in the household (0, 1, 2+) is combined with a standard tobit model for the continuous variables, which are the distances travelled per week by four modes. The overall framework is that of structural equations, with direct synchronous, indirect synchronous and lagged effects. The structural equations system is estimated with the LISCOMP procedure on panel data. Within this the tobit-model is estimated with Maximum Likelihood.

The model in Golob (1989) is similar to the above model in formulation and estimation, but it explain car ownership and travel time per week for three modes.

The Ph.D. thesis of Meurs (1991) also contains car ownership models estimated on the panel data of the LVO. These models explicitly take account of the panel nature of the data. The car ownership models in the thesis include linear simultaneous equations models of car ownership and use, discrete choice car ownership models, estimated through mass point estimation, and joint car ownership and mobility models (also in Meurs, 1993). These models focus on the effect of income on car ownership; car cost variables are not included.

3.6 Car ownership in the ScenarioExplorer, version 1.2

This model was developed by TNO-Inro afdeling Vervoer for AVV (TNO, 1999). The ScenarioExplorer is an instrument that enables the analysis of long term developments in transport demand. The model combines scenario building, system dynamics and strategic transport modelling. Segmentation of transport demand is realised by means of an aggregated strategic transport demand model. Projections aim at the Dutch national level with a time horizon of 15 to 60 years in the future. The base year for all calculations still is 1990.

The core of the ScenarioExplorer is the transport demand model. Given the model input variables as constructed by means of the Scenario Construction Module, developments in transport demand, travel times and car ownership are calculated simultaneously. Starting with a base situation, changes in the number of trips are calculated for each year and for each travel purpose, transport mode and type of traveller, using an incremental multiplicative model. Equilibrium mechanisms are strong determinants for the long term growth potential. To account for this, several direct and lagged feed-backs are distinguished in the transport model. The

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Netherlands is divided into six functional zones, determined by the level of urbanisation.

The output of the model can be summarized in four groups: transport volume, car ownership, time and money expenditures on transport and accessibility. Below we describe the car ownership model.

Car ownership model
The development of the car ownership is endogenously determined within the ScenarioExplorer. The purpose of the car ownership model is to forecast the number of passenger cars in the Netherlands for three submarkets:
1. company cars
2. first cars in the household
3. second and further cars in the household.

The number of company cars largely depends on economic growth. After three years it is assumed that company cars will flow into the private market. The household income and the price of the car determine in great part the acquisition of the first household car (consumption), while the purchase of the second car (or more) depends on the user costs (production).

The number of cars per submarket in the observed year depends on the number of cars in the previous year multiplied by a growth factor. The calculation of the growth factor differs per submarket:
1. growth factor for company cars: based on the number of business trips and number of workplaces.
2. growth factor of first cars in the households: based on annual net personal income, the purchase price and the number of households
3. second and further cars in the household: based on annual net personal income, purchase price, variable costs per kilometer and the number of persons per household

The number of cars for the base year (1990) is exogenous.

Within the passenger car market, no distinction is made in age classes. Developments of the market due to demographic shifts or cohort effects can not be modelled in the ScenarioExplorer.

Two other models in the ScenarioExplorer produce feedback for the car ownership model:

1. Saturation levels (maximum number of persons that are able to posses one or more cars) per submarket. These levels have a negative feedback on the number of total cars.
2. (Lagged) feedback on the demand for cars. High car use will yield a high demand.

The input for the car ownership model is:
- population older than 18
- income and employment

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- number of households
- purchase prices per car type, fixed car costs, variable car costs
- composition of the car fleet by fuel type and emission/energy usage factors
- travel times for public transport

The output generated by the car ownership model is categorized per submarket by the future size of the car fleet and saturation level. The number of cars is distributed over different population categories: three age groups (12-18, 18-65, 65+), male/female, unemployed/parttime/fulltime, and low or high education.

3.7 The Dynamic vehicle transactions model

This is a model, developed and tested by Hague Consulting Group in the period 1993-1995 for AVV (HCG, 1993, 1995a,b, De Jong 1996). The data used in estimation originate from a project for Novem to measure the effectiveness of a government campaign to increase energy efficiency of passenger cars ('Koop zuinig/Rij zuinig'). The main objective of the modelling exercise was to extend the disaggregate modelling approach for the size and composition of the car market into the domain of dynamic models. Static disaggregate car ownership models ('holding models') can only give a time path for the car fleet if one is prepared to assume that in each period a household compares all vehicles (or vehicle combinations for multiple car ownership) and chooses the alternative with the highest utility. This static equilibrium assumption for every period considered will lead to an unrealistically high number of transactions, unless this is made unattractive by introducing dummies for not changing the household fleet. A more detailed critique on static holdings models can be found in De Jong and Kitamura (1992). In the Dynamic Vehicle Transactions Model (DVTM) each household will keep its vehicle holdings the same unless it explicitly decides to engage in a transaction.

The DVTM consists of the following submodels

- Hazard-based duration models for the time that will elapse between two household vehicle transactions. Initially there was only a model for the duration of ownership of a single vehicle until replacement; later on this was extended to transactions such as extending the household car fleet (e.g. from one to two cars) and disposal without replacement
- Vehicle type choice models, for households replacing or extending their fleet. Vehicle types are distinguished by brand and model (for instance Volkswagen Golf 1.6 diesel and Toyota Starlet 1.3) and by vintage. For each brand/model/vintage combination, the engine size, weight, average fuel efficiency, fuel type, type of catalytic converter (if any) and fixed and variable cost are known, which are used in this multinomial logit type choice model. The outputs can be aggregated over these categories. The most expensive car types were not included in the sample; company cars were not included either.
- A model for annual car use (similar to the indirect utility model)
- A model for style of driving determining a possible deviation from the average fuel efficiency.

The DVTM has been used to simulate the impact of changes in fixed and variable car cost and income on the size and composition of the Dutch car fleet for the short and medium run (1-5 years ahead). For application to the long run a car (type) supply component would have to be added. The outcomes of these simulation runs generally speaking were quite plausible.

3.8 A model for the effects of motivational factors on car use: a multidisciplinary modelling approach

This section is based on a paper by Linda Steg, Karst Geurs and Michiel Ras (2001). Although it is about a model of car use, not car ownership, it is included in this review because at the inception meeting of this audit project it was decided to consider car use as well.

Transport models are widely used for making long-term transport forecasts. Result of such models form an important input for policy making and planning. In general transport models forecast car use based on assumptions on socio-demographic, economic, price, technical, infrastructural / accessibility and spatial developments. Changes in motivation, e.g. attitudes and preferences related to transport mode choice and car use, are usually not taken into account at all, or at most, only through an implicit assumption being that motivations within homogenous population groups do not change over time and thus can be incorporated via constants.

For three reasons it would be preferable to include motivational factors in transport models:
- Psychological and sociological studies reveal that people's motivations form an important explanatory factor for car use.
- Several studies from outside the transport field show that motivations might change over time.
- Some policy measures are explicitly aimed at changing motivations of large-scale information campaigns.

The aim of the paper is to examine the effects of motivational factors on present and future car use. Via a multinomial regression model, using socio-demographic, socio-economic and motivational variables three things were examined:
- Whether car use can be better explained by taking motivational factors explicitly into account.
- Whether the level of car use forecast changes significantly if changes in people's motivations are assumed under different scenario conditions: Scenario 1: divided Europe, Scenario 2: European co-ordination, Scenario 3: global competition
- Clarification how motivational factors can be incorporated in existing transport models.

In current car-use models the level of car use depends on three determinant categories: (1) location of human activities, (2) needs and desires of people and (3) transport resistance. The three determinant categories are interdependent

Psychological models explain relationships between attitudes and other motivational factors on the one hand and mode choice and/or car use on the other hand. Factors from other determinant categories such as land-use, technology, travel time and prices are usually taken into account. Golob and Hensher (1998) found relationships between attitudes and actual commuters' mode choice. Steg found that the more people use their cars, the more positive their attitude is towards car use, the less serious they receive the problems of car use and the less favourable they evaluate policy measures aimed at reducing car use. A literature study revealed the following motivational factors to be related to car use and travel-mode choice: (1) attitudes towards different models of transport, (2) emotions evoked by car use, (3) social norms, personal norms, (4) awareness of problems caused by car use, and (5) perceived responsibility for and perceived control of problems caused by car use. Unfortunately, most studies don't give a definite conclusion on the causal relationship between attitudes and car- use behaviour, for attitudes and car use are mostly assessed at one point in time. Mode choice may also influence attitudes, through experience and psychological phenomena such as cognitive dissonance reduction.

In a study of Kitamura, et al. (1997), variables from all three determinant categories were used to explain travel behavior, i.e., the effect of socio-economic, land-use and attitudinal variables on travel behavior were assessed. The highest proportion of de variation in the data could be explained by attitudinal variables.

A model for car-use simulation in the Netherlands

The model for car-use simulation in the Netherlands (MOCASIN) forecasts car use on an individual level on the basis of socio-economic, socio-demographic and motivational characteristics. To reduce complexity, contextual developments like changes in land-use, transport prices, travel time or technology are not taken into account. The MOCASIN assesses future car use on the basis of development in population characteristics and based on the relationship between these characteristics and car use. The development of MOCASIN involved three steps. First, the relationship between car mileage and socio-economic, socio-demographic and motivational determinants were examined by means of a multinomial regression analysis. Second, scenarios were constructed which differ in future development in these determinants. Third, a Population Model was constructed for estimating the size and composition of the Dutch population for the years 1995, 2010, 2020 according to these scenarios.

In the 'basic' version, only the effects of changes in the composition of the population, classified according to age, level of educational attainment, gender, household composition, and household income were explicitly simulated.

Step 1: the relationship between car mileage and the three determinants
Assessment on the relation between various variables was done through regression analysis for nominal variables. Two regression analyses were performed. First, it was examined to what extent age, level of education, gender, household composition and household income contributed to the explanation of car use. Second, the relationship between car use and these personal background variables was studied, along with a motivational factor (viz., problem awareness) to examine whether the explanation of car use improved.

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The result shows that 21% of the variation in the weekly car mileage was explained by age, level of education, gender, household type and household income. The result also shows that car use could be better explained when problem awareness was included in the regression analyses (+5% explained variance).

Step 2: scenario assumption
Three scenarios (as mentioned above) ware used to study the effect on car use. The scenarios differ in the expected international economic and political developments, and in national demographic, socio-cultural, technological and economic developments.

Step 3: the Population Model
A Model Population is an expected classification of the population. It provides information on the size and the composition of the population for different points in time and different scenarios.

The results from MOCASIN indicate that current - more comprehensive - Dutch national transport models could possibly be improved by adding motivational factors, thus creating the possibility to simulate the effects of changes in motivations under different scenario conditions. This is especially relevant with regard to policy measures aimed at changing people's motivations.

3.9 A dynamic lifetime utility model of car purchase behaviour (Golounov, Dellaert and Timmermans, 2001)

In this paper submitted for presentation at the 2002 TRB annual meeting, the authors first develop a theoretical model for the purchases and consumption of cars, other durable goods and other day-to-day and long-term purchases. This is an explicit dynamic model, based on the concept of (remaining) lifetime utility from economic theory. They -correctly- state that most existing dynamic car ownership models (duration models, panel models, cohort models) do not have a strong theoretical underpinning (an exception is the work of Hensher et al. (1992), but here the link from theory to econometrics is not particularly strong). Golounov et al. then present a model for an individual (not a household as in most disaggregate car ownership models) is assumed to optimise the sum of discounted utilities for every period over the remaining lifetime. The utility in a period depends on the consumption in that period of four goods:

- Cars (internal to the model)
- Other optional durables (internal to the model)
- Long-term fixed purchases (external to the model)
- Fixed day-to-day purchases (external to the model).

Consumption in a period for the first three goods is defined as depreciation of the commodity. So car consumption (say in a year) is the decline in the value of the car (in the year). This definition of car consumption differs from that of De Jong (1989), where car consumption is defined in terms of car use (e.g. the annual number of kilometres). The model of Golounov et al. does not have a link to car use (except in

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the interpretation of some of the coefficients found), but it has the advantage of being dynamic.

Besides the direct utility function to be maximised, the theoretical model also contains a number of restrictions, including a budget restriction with income, savings/loans, and purchases of the four types of goods. Consumption of durable goods (including cars) and expenditure on purchasing these goods can take place in different periods.

On the basis of the economic model, an econometric model for the purchases and consumption of cars and other optional durables is specified, which is estimated on seven waves (1993-1999) of data from a revealed preference consumer panel. This panel (CentER savings Survey) focusses on financial assets and liabilities of the persons. Additional assumptions had to be used to make this dataset suitable for estimation of the model. Also depreciation functions were adopted from the Dutch Automobile Association (ANWB/BOVAG). In estimation, parameters for the discounting function, the utility from cars and from other optional durables are estimated, as well as variance-covariance parameters. The model only contains 8 significant coefficients (besides the constants). Although the model used different brand-model-vintage combinations, it does not yield vehicle type choice probabilities. The major contribution is that car purchase behaviour over time has been formulated is an explicit dynamic theoretical model, and that this has been translated into an estimable econometric model, The authors have plans to collect new stated preference data and use this to develop and test the model further.

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4. Review of the recent international literature

In this chapter the recent (since 1995) international literature on car ownership modelling is reviewed. Also some information is added on models, especially if these are still being used as regional or national car ownership models, that have not appeared in publicly available journals, but are only available known from conference papers or project reports.

4.1 Algers, S, A. Daly and S. Widlert (1989) The Stockholm Model System – Travel to Work

In this paper, the work model component of the Stockholm Integrated Model System (SIMS) is described. The paper describes the system as a whole, but the review focuses on the car ownership and car allocation components of the model.

In formulating the work model structure, the authors note that different travel purposes are often modelled separately. In practise, there are important cross-influences between different travel purposes, and in principle the total travel pattern should be considered simultaneously. In a similar manner, travel for each individual member of a household is often modelled separately, while in fact interactions exist between the travel patterns of individual household members. Thus if possible, the total travel pattern of the whole household should be modelled.

In model systems such as the LMS, car availability utility terms are used to account for the availability of cars to household members. This is perhaps the most important household interaction in modelling travel to work. In the Stockholm context, it was decided to explicitly model car allocation amongst workers as part of the work model structure. A high level of female workforce participation was a factor in this decision.

The overall structure of the work model adopted was complex, and incorporated a high degree of household interaction, as shown by Figure 2. All submodels are disaggregate tree logit models.

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Figure 2. SIMS Work Model Structure
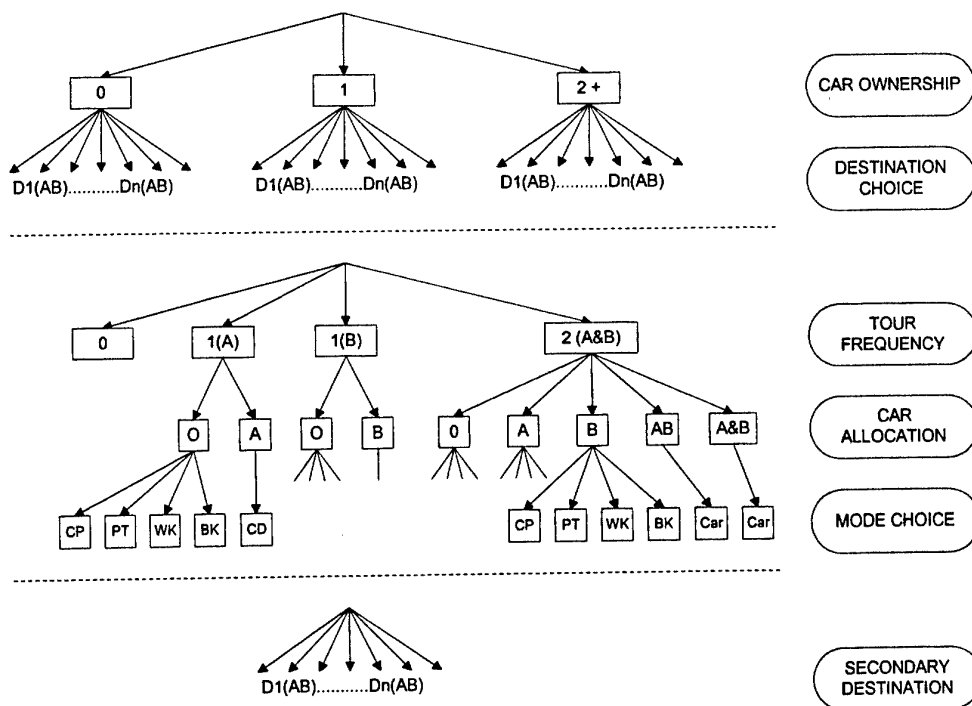
The models of tour frequency and car allocation are below each destination alternative. The destination alternative in this case is the workplace, which represents a long-term choice decision.

In the model of mode choice for households the modes refer to the modes available to person A in the household. Therefore:

- when no car is allocated, A can use any mode except car-driver (this option is not illustrated in Figure 2 for households with 2 cars);
- when only A is allocated a car, then A is car-driver by default (this option is not illustrated in Figure 2 for households with 2 cars);
- when only B is allocated a car, then A cannot be a car driver, so the modes available to A exclude car-passenger;
- when A and B share a car (AB) then A is car-driver by default;
- when A and B are both allocated a car (A&B), then A is car-driver by default.

Logsum accessibility measures feed back up the structure, providing a linkage between the model components.

When estimating a tree model structure, it is preferable to have the choice decisions with which more error is associated towards the top of the tree, because error is passed up the tree. The car ownership decision represents a long-term decision, and the car purchase decision may have occurred years before the date of the travel survey. Furthermore, the conditions which influenced the car purchase decision in the household may be quite different to those at the time of the travel survey. Therefore

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the household car ownership decision was modelled at the top of the tree, with the alternatives 0, 1 and 2+ cars.

Below the car ownership decision is the choice is workplace for the head of the household (A) and their partner (B) *conditional* on the outcome of the car ownership model. So households with no cars will be predicted to choose workplaces more accessible to public transport. The choice of workplace is also a long-term decision, which cross-sectional travel diary data collected on a single day may find hard to explain.

The models of tour frequency model the combinations of household members travelling to work. Next is an explicit car allocation model. The alternatives in this model are that no household member uses the car, A uses the car, B uses the car, A and B share the same car (AB) or A and B both use separate cars (A&B). Note that the availability of these alternatives is dependent of the number of cars in the household. In the car allocation models gender variables demonstrated that, all other things equal, men had a higher probability of getting access to the car. However, women under 40 and women with a higher education had higher probabilities of 'negotiating' for the car than other women.

At the bottom of the model structure is a model of detours to secondary destinations during the work tour. Car and PT modes were modelled separately. The model of car detours found detours to CBD and inner city destinations were less likely, which may reflect in part difficulties in parking in these areas.

4.2 HCG and TØI (1990) A Model System to Predict Fuel Use and Emissions from Private Travel in Norway from 1985 to 2025 (also in De Jong, 1997)

The Norwegian model system was developed in 1990 in response to increasing international concern about the Greenhouse Effect. It has been updated several times since and is used now the as national model system STM-4.The main objective of the project was to create a forecasting system capable of assessing the success of carbon-dioxide control measures in Norway. A secondary objective was that the forecasts of transport demand should be fully compatible with the macroeconomic forecasts produced by the Norwegian Central Bureau of Statistics (SSB). This review focuses on the car ownership and usage model components.

Due to the importance of predicting vehicle usage accurately in order to determine vehicle emissions, disaggregate models of joint car ownership *and* use were estimated. The joint model estimated is based on the micro-economic theory of consumer behaviour, which depicts the household decision problem as maximising utility under a given budget constraint. It is an extension of models developed for The Netherlands (De Jong, 1989), which only considered households with zero or one car. Considering the 0/1/2 car ownership decision, the approach considers two goods: automobile use in kilometres per year A, and X the volume of all other goods and services per year. The cost of usage is decomposed into fixed costs C and variable (marginal) costs v. The problem can then be formulated as:

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Maximise{ $U = U(A, X)$ }

subject to the budget restriction:

$Y \geq X$	if no car
$Y \geq v_1 A_1 + C_1 + X$	if one car
$Y \geq v_1 A_1 + C_1 + v_2 A_2 + C_2 + X$	if two cars

where Y represents net household income.

If a household does not own a car then it can spend all income on other goods. If the household decides upon car ownership, then to overcome the disutility associated with the fixed costs it must drive a positive number of kilometrages. Exogenous Norwegian data was used to determine the fixed and variable costs of owning a car. Comparing the costs of the first and second cars, the fixed costs were similar, whereas the variable costs (per km) of the second car tended to be lower, a reflection perhaps of smaller engine sizes.

Conditional indirect utility functions were defined for each positive car ownership outcome; for the zero cars outcome a direct utility function could be defined. The functional form for the demand function for kilometres was based upon statistical analysis of car ownership and use in the Netherlands and on research in the US. The linkage between the indirect utility functions and the demand functions was provided by Roy's identity. It was not computationally feasible to find out which of the three conditional direct/indirect utility functions was highest for a given household. Therefore households with one licence were allowed the choice zero/one car, and households with two or more licences were allowed the choice one/two cars.

The model estimation was performed using the GAUSS package. For both cars, significant terms were estimated for the log of *remaining* household income, the variable cost of driving, the log of household size and percentage urbanisation. For the first car only, significant terms were identified for a female head of household. For the second car only, significant terms were estimated for age of head of household over 45 plus, and age of head of household over 65.

To validate the models estimated, simulations were undertaken in order to compare car ownership and kilometrage elasticities to 1985 Dutch values. These comparisons revealed the Norwegian predictions to be reasonable, although somewhat lower than the Dutch values.

4.3 Jong, G.C. de (1993) Car Ownership Forecasts for France

This memo provides an overview of how car ownership forecasts for France have been determined, based on a number of original – French – reports, mainly by INRETS. Furthermore it describes how national car ownership forecasts had been updated and translated into regional forecasts. Car use is also predicted in the form of regional fuel consumption. The car fleet is predicted using a demographic model, whereas fuel consumption is predicted using an econometric model.

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The demographic car fleet model treats cars as essentially household or person attributes. The car fleet is predicted using a demographic method, looking at ownership by age cohort. Three stages were identified in the development of car ownership in France, by plotting age against cars per adult for 10-year cohorts:

1. Diffusion to all generations until the mid-sixties;
2. Movement to cruising speed until the mid-eighties;
3. A move towards saturation, shown by a shorter distance between trajectories of ownership of successive cohorts.

The model extrapolates the observed trends. The memo notes that the gaps in car ownership between cohorts will become smaller and smaller as saturation is approached. A possible problem with the approach is that is at odds with the possible demotorisation of the elderly; however the elderly in France tend to retain their cars but drive them less. Two hypotheses are used in the demographic car fleet model: firstly that the trends in car ownership by cohort show parallelism, and secondly that car ownership by cohort approaches a saturation level.

The regional data source could not give the trajectories by cohort; instead an average ownership per cohort per region for each of the eight ZEAT regions in France was available. The lower car ownership levels for Ile de France (including Paris), particularly for younger persons, are noted. This data source was used to produce the regional car fleet forecasts, obtained by multiplying the forecast number of adults by the number of cars per adult from the cohort trend extrapolation.

In a similar fashion, car usage (kilometrage) is predicted using the same cohort trend extrapolation methods. Due to ageing of the population, the total kilometrage ('circulation') is forecast to grow less than the car fleet. The kilometrage is predicted by region of *residence*, which does not necessarily coincide with traffic by region.

The econometric fuel consumption model models fuel sales. The log of fuel samples was used as the dependent variable in a model with a constant, the log of the fleet, the log of real income per capita and the log of real fuel price as regressors. By using a double-log form, the coefficients are elasticities. The income variable was insignificant and so was dropped from the model. Regional variations in elasticities were observed. The fleet elasticity took values between 0.7 and 1.1, whereas the price elasticity was around –0.2.

4.4 Golob, T., D. Bunch and D. Brownstone (1996) Forecasting Future Vehicle Usage Using a Jointly Estimated Revelealed- and Stated-Preference Model

This paper focuses on the development of a model of household vehicle usage behaviour by type of vehicle. Vehicle usage forecasts were needed to forecast future vehicle emissions, specifically including the potential gains from alternative fuel vehicles. The forecasts needed to be made by fuel type, body style and size, and vintage of the vehicle.

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The data used household based mail-back surveys collected in California. Two SP vehicle type choice experiments were collected for each household. Vehicle usage SP questions followed the vehicle choice experiments. The usage questions asked the household to assign principal drivers to each vehicle in the new vehicle fleet, *including* the chosen SP vehicle, and indicate how many miles per year the vehicle would be driven. Note that the chosen SP vehicle may be an alternative fuel vehicle. The survey was designed in such a way that respondents first reported principal drivers and usage patterns for their current vehicles before performing the SP task. Thus both RP and SP measures of annual vehicle miles travelled were collected.

The usage model variables are divided into three groups: *behavioural* vehicle usage characteristics, *physical* vehicle characteristics and *household* structural characteristics. Because the models were to be used in a forecasting system, the household variables were limited to those which could be produced by the available demographic forecasting model. Separate models were developed for single-vehicle households and multi-vehicle households.

A key feature of the models is the endogenous treatment of driver allocation behaviour. However as no forecasts of principal driver characteristics are available, driver allocation behaviour is specified as a function of *exogenous* variables, for which forecasts are available.

The two-vehicle usage model covers the usage of the *newest* two vehicles in multi-vehicle households. Casual relationships between the endogenous variables were specified by two types of direct effects: within-vehicle effects and between-vehicles effects. The results demonstrated *driver* age has a significant effect on vehicle usage that is uniform for the two vehicles: if either driver is younger, both the first and second vehicles are likely to be used more. Contrastingly, gender and employment status effects are consistent and reciprocal across the two vehicles: if the principal driver is female, that vehicle is driven less but the other vehicle is driven more; similarly if the principal driver is employed, that vehicle is driven more but the other vehicle is driven less.

The effects of vehicle age are stronger for the second vehicle, although consistent for both: the older the vehicle is the less it is used. Furthermore, the older the first vehicle, the less the other vehicle is used as well. The implication is reduced usage over time if no vehicle transactions occur.

The effects of operating cost were not precisely estimated, but had intuitive signs. A higher operating cost for the second vehicle implies a shift in usage from the second vehicle to the first.

Considering the impact of the SP data regarding new electric vehicle (EV) usage, the model results suggested that the EV will be driven less, *ceteris paribus*. Furthermore, if the EV is the newest vehicle in the fleet then the second vehicle (probably petrol) will be driven more than otherwise expected. Therefore the model captures a shift in usage from EV to conventional fuel vehicles, which has important implications for emissions reduction targets. Note that a range effect term also captures a reduced usage effect from alternative fuels vehicles.

The number of household members aged between 16 and 20 years old has a positive effect on usage of both the first and second vehicle. However, the number of drivers in the household has a *negative* effect on VMT of both vehicles, perhaps indicating a shift towards third and fourth vehicles in the household. High (three plus) vehicle ownership was accounted for via a negative dummy on usage for the first and second vehicles.

The forecasting model was applied using a dynamic microsimulation, incorporating a sociodemographic transition model and a vehicle transactions model. The usage model is used to predict before and after situations, which are applied using a pivot-point approach. This method has the advantage of preserving heterogeneity across households not captured in the usage model.

4.5 Nobile, A., C. Bhat and E. Pas (1996) A Random Effects Multinomial Probit Model of Car Ownership Choice

In this paper, Nobile et al. estimate a random effects multinomial probit model of car ownership level, using longitudinal (panel) data collected in the Netherlands.

The authors note that analysis of panel data enables the incorporation of both intertemporal dimensions present in car ownership choice, such as resistance to change in ownership levels due to search costs and uncertainty of financial position in the future, and intratemporal dimensions such as acquired taste for a certain lifestyle. The unobserved factors are likely to make some car ownership alternatives closer substitutes than others, which questions the validity of the IIA assumption often maintained in discrete choice models. The authors thus seek to model car ownership choice to account for both unobserved determinants using a multinomial probit (MNP) model.

The data source for the modelling was data drawn from Dutch National Mobility Panel. Ten waves were collected between March 1984 and March 1989. Data from waves 3, 5, 7, and 9 of the period was analysed, collected between 1985 and 1988. Data from wave 1 was omitted due to considerable sample attrition between waves 1 and 3. In total, the four waves comprise 2,731 households for a total of 6,882 observed choices. As less than 1 % of choices corresponded to three or more cars, the car ownership alternatives modelled were 0, 1, 2+.

The approach used for model estimation was Bayesian: a prior distribution of the parameters of the longitudinal MNP model is specified and the 'posterior' is examined using Markov chain Monte Carlo methods. The papers details the mathematical formulae involved.

A total of 50,000 draws were used for the Markov chain, with an initial burn-in of 5,000 draws excluded to ensure that the Markov chain had stabilised. No reference is made to computation time, which may be considerable given the high number of draws.

The model results for the wave dummies were all negative (measured relative to wave 3), suggesting generic temporal effects. The authors noted the pattern of the terms was in some agreement with the Dutch business cycle during 1985-88.

Considering the cross-sectional terms, standard disaggregate household model terms were estimated for the 1 and 2+ car alternatives, with no cars as the base. Namely terms for level of urbanisation, number of licences in the household, number of full and part time workers, number of adults, number of kids and household income.

The authors do not make forecasts with their model. Implementing such a model would necessitate a high number (thousands) of draws to be made per record, and so run times could be expected to be considerable.

The authors conclude that most of the variability in the observed choices can be attributed to between-household differences rather than to within-household random disturbances.

4.6 Bhat, C. and V. Pulugurta (1998) A Comparison of Two Alternative Behavioural Choice Mechanisms for Household Auto Ownership Decisions

In this paper the authors consider two methods of modelling car (auto) ownership choice within a behavioural econometric framework. They consider ordered response choice mechanisms, and unordered response choice mechanisms. In both cases, disaggregate household based models are employed.

Ordered-response choice mechanisms are not consistent with global utility-maximisation. They are based upon the hypothesis that a single continuous variable represents the latent car owning propensity of the household. The decision process can be viewed as a series of binary choice decisions. A given household assigns utility values for each car ownership outcome, and then makes an independent utility maximisation decision for each range. Based upon the decision outcome for each range, the actual choice is determined by the range in which the household falls. Only one set of M household parameters need to be estimated in this approach, but this is also a disadvantage in that (for example) variation in sensitivity to income cannot be specified to vary between alternatives. The ordered-response mechanism employed by the authors was Ordered Response Logit (ORL).

Unordered-response mechanisms are consistent with the theory of global utility-maximisation. The choice process can be viewed as a simultaneous choice between each alternative, with the choice determined by the alternative with the highest utility. The method allows greater flexibility on the parameter effect, however substantially more parameters need to be estimated: $(K - 1) * M$ as one base alternative is defined. This allows for variation in sensitivity to household income to vary with car ownership alternative if necessary. The unordered-response mechanism employed by the authors was Multinomial Logit (MNL).

To investigate the two approaches, four data sources were used: three regional data sets from the US and one Dutch national dataset. The US regional data sets are

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obtained from the 1991 Boston Region Household Travel Survey, the 1990 Bay Area Household Travel Survey and the 1991 wave of the Puget Sound Household Travel Panel Survey. The Dutch national dataset was based on the 1987 wave of the Dutch Mobility Panel Survey. For each survey, the sample was split into an estimation sample (typically 1500 households), and a smaller validation sample (typically 500 households). Descriptive statistics of car ownership levels on the estimation sample demonstrated much higher car ownership levels in the US (up to 2.09 cars per hh, compared to 0.81 in the Dutch data). Consequently, the car ownership outcomes modelled were 0, 1, 2, 3, 4+ cars for the US data, and 0, 1, 2+ cars for the Dutch data.

For each data set, ORL and MNL models were estimated. A number of socio-economic variables were included, but only three were consistently significant across the data sets. These variables were number of working adults, number of non-working adults and household income. It should be noted that the selection of variables (no number of children terms, for example) may be significantly conditioned by the US context of three of the four data sets.

The measures of fit from the estimation sample showed a better adjusted likelihood ratio index for the MNL specification for each data set. Comparison of the aggregate elasticities demonstrated significant differences. In particular, the ORL model is constrained to have rigid and monotonic trends in elasticities, whereas MNL is more flexible in picking up the effects of variables upon specific alternatives.

The authors then applied the model results to the validation samples. Using an aggregate measure of model performance - a comparison of actual and predicted percentage shares by alternative – the MNL was superior for each of the four data sets according to the rooted mean square error measure. Using a disaggregate measure of model performance – the average probability of correct prediction – the results again demonstrated the MNL specification to be superior for each of the four data sets.
The conclusion of the paper is that their comparison of the ordered (ORL) and unordered (MNL) choice mechanisms clearly indicates that the appropriate choice mechanism for modelling car ownership is the unordered-response structure, such as MNL or multinomial probit models.

4.7 Dargay, J.M. and P. Vythoulkas (1999) Estimation of a Dynamic Car Ownership Model; A pseudo panel approach

The pseudo-panel approach is a relatively new econometric approach to estimate dynamic (transport) demand models that circumvents the need for panel data and their associated problems (e.g. attrition). The purpose of the paper is to evaluate the method of pseudo-panels rather than to set up a detailed car ownership model.

A pseudo-panel is an artificial panel based on (cohort) averages of repeated cross-sections. Extra restrictions are imposed on pseudo-panel data before one can treat it as actual panel data. The most important is that the cohorts should be based on time-invariant characteristics of the households, which in this case is the age of the head of the household. By defining the cohorts one should pursue homogeneity within the cohorts and heterogeneity between the cohorts.

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One important feature of pseudo-panel data is that averaging over cohorts transforms disaggregate (discrete) values of variables into cohort means, thereby losing information about the individuals

The pseudo-panel data set is constructed from repeated cross-section data contained in the UK Family Expenditure Survey. There are on average 7,200 households per year in the survey since the 1960's. The data is based on the years 1983-1993 resulting in a total of 165 observations.

Having defined the cohorts, a conclusion is drawn that heads of households born earlier tend to have a lower average car ownership rate over their lifetime than the ones born later.

The model in the article is a fixed effects model, but for a pseudo-panel this results in an error-in-variables estimator following Deaton (1985). A generation effect is added to the model proposed by Deaton and a lagged dependent variable is included to estimate the dynamics of the model. Three other models are estimated to compare with the fixed effect model: OLS, random effect specification and random effect with a first order auto-regressive scheme.

The dependent variable is the number of cars per household. The variable now indicates the average number of cars for that particular cohort.

The explanatory variables are socio-economic characteristics of the household: income, the number of adults, the number of children, metropolitan and rural areas and a generation effect for the head of the household. Price indices for car purchase costs, car running costs and public transport fares are added to the set of explanatory variables.

The four models are estimated and the lagged dependent variable is significant in all, indicating that the number of cars of an average household depends on the number of cars in the previous year. Almost all other variables are significant in the four models and have the expected sign. Only the number of children and the public transport fares are insignificant at a 95% confidence level.

The random effects model with a first order autoregressive scheme is the favoured model. The long term elasticities in this model are almost 3 times as large as the short term elasticities, which indicates a lot of dynamics in car ownership.

4.8 Dargay, J. and D. Gately (1999) Income's Effect on Car and Vehicle Ownership, Worldwide: 1960-2015

In this paper, the authors estimate an econometric model to the relationship between per-capita income and car ownership, defined throughout as total cars divided by total population. The model is estimated on annual national data from 26 countries over the period 1960-1992, using both high and low income country data. The authors then go on to make projections of car ownership up to 2015.

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The authors first consider patterns in the growth of car ownership at the national level, relative to growth in per-capita income, during the period 1970-1992. Relative to growth in per-capita income, the increase in car ownership has been greatest in the fastest growing economies, South Korea and Japan. Vector plots of per-capita GDP against car ownership for a range of countries show a clear positive relationship between the two variables.

The ratio of the average annual percentage growth in ownership to the average annual growth in per-capita income is a rough measure of the income elasticity of car ownership. Historical plots show that for low-income countries, car ownership has grown at least twice as first as income, i.e. the income elasticity has been much higher than 2.0. A further pattern apparent is that the higher a countries per capita income the lower its ratio of ownership growth to income growth. From the plots produced, a saturation level of ownership would be reached at income levels of around $30,000 (all figures quoted are 1985 US $).

To fit a model to the relationship between vehicle ownership and per capita income, the authors considered a range of functional forms to describe the S-shaped curve observed. The functional form selected was the Gompertz function, which is more flexible than the logistic model, as it allows the specification of different curvatures at the low and high income levels of the ownership curve. Their ownership model took the following specification:

$$V_{it} = \gamma \, \theta \, e^{\alpha exp(\beta iGDPit)} + (1 - \theta) \, V_{t-1}$$

where: i denotes country, t denotes time (at yearly intervals)
   α, β are low and high income shape parameters respectively
   γ is saturation level
   θ is a speed of adjustment affect ($0 \leq \theta \leq 1$)

The authors choose to estimate a single value for parameters α, γ and θ but country-specific values for β. Thus they estimate a family of long-run Gompertz functions from pooled time-series cross-sectional data, allowing the high-income shape parameter to vary between countries, but assuming changes with income at the bottom of the curve, and final saturation levels, are constant between countries. It is noted that in order to estimate the curve properly, data from both low and high income countries is required.

In estimation, each country's data was weighted by its total population. The estimated model gave a global saturation level of 0.62 cars per-capita. The value for θ was 0.09, suggesting only 9 % of the total response to income changes occurs within one year, a slow response.

The Gompertz form allows plots of income elasticity against per-capita GDP to be determined. These plots show an asymmetric curve, with rapid rise to a peak income elasticity around 2.4 for per-capita GDP around $4,000, dropping down again fairly rapidly, and then trailing off to around zero income elasticity for per-capita GDP of $30,000.

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Projections of car and vehicle ownership up to 2015 are made using population and GDP predictions; these predictions are more relevant to lower income countries were the predicted increases in ownership are more significant.

In conclusion, the authors believe that for most OECD counties car ownership levels will converge to levels close to saturation in the two few decades. The most rapid increases on car ownership within the OECD will occur in countries with relatively low incomes but high rates of income growth, such as Portugal. The fundamental point of the paper is the strong historical relationship between the growth of per-capita income and the growth of car ownership.

4.9 Hanly, M and J. Dargay (2000) Car Ownership in Great Britain – A Panel Data Analysis

A car ownership model is set up to examine whether owning in car in the previous year(s) has a significant effect on the current state. The main purpose is to test the dynamics within the model by applying advanced econometric estimation methods.

A panel analysis is carried out using data from the British Household Panel Survey. Data of four years (1993-1996) are used to estimate the model.

The dependent variable is the number of cars owned by the households in each of the four years. This is a discrete variable, which can take the values 0, 1, 2, and 3 or more. The dependence on past experience is incorporated by introducing lagged endogenous variables. The model specification is an ordered probit model. With four choices this results in a quaternary, ordered choice latent regression model.

Three types of models are estimated: a model without a lagged dependent variable, a model with a lagged dependent variable and a model with dummies for the number of cars in the last year (0,1,2,3 or more cars). For each of the three models an additional model is estimated with a household specific, time invariant error-component to compensate for household heterogeneity.

The explanatory variables are household income and household socio-demographic variables, such as number of adults of driving age, number of children, number of adults in employment and a dummy variable indicating whether the head of the household is of pension age. Five location dummies are included reflecting urbanisation and the population density.

The results of the model focus on the issue of state dependence, meaning the state of car ownership a household was in last year compared with the state it is in this year. The results support the hypothesis that last years car ownership influences the current car ownership significantly at a 95% confidence level.

Almost all the estimated coefficients for the exogenous variables are significant at a 95% confidence level, like the number of adults of driving age and in employment. The head of the household who has a pension status negatively influences the car

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ownership. More rural areas will generate higher car ownership, because there are less alternatives.

4.10 Standard & Poor's DRI and K.U. Leuven (1999) Tremove version 1.1 Auto - Oil II Cost-effectiveness Study; description of the analytical tools

Introduction

TREMOVE is a behavioural model designed to analyse cost and emission effects of a wide range of technical and non-technical measures to reduce emission from road transport. The model was developed to support the policy assessment process within the framework of AOII, the second European Auto-Oil Programme.

TREMOVE can be seen as consisting of three key, interlinked, blocks. The first describes transport flows and the users' decision making process when it comes to choosing which mode they will use. The second is the stock module: it describes how changes in demand for transport across modes or changes in price structure influence the number of vehicles of each type in the stock. The third block calculates emissions, based on the number of kilometres driven by each type of vehicle. *See figure 3 and 4.*

TREMOVE is a simulation model, not a forecasting model. It's more a scenario explorer; the equations in TREMOVE are specifically designed to analyse changes in behaviour as a result of changes in economic conditions.

What does TREMOVE compute?

TREMOVE computes the effects of various types of policy measures on the key drivers of transport emissions, such as the size and composition of the vehicle stock and vehicle usage. Is simulates consumer behaviour with regard to the choice of transport mode and vehicle type, assesses how these choices are affected by introduction of policy measures, and what effect this has on emission.
The model takes into account a large number of transport modes, and determines the demand for each mode and emissions from road transport by taking into account the many interactions between the various transport modes.

TREMOVE computes the difference in costs between alternative transport scenarios, and can decompose these by category of costs (cost of transport, cost to government and cost to transport producers).

What's the output of TREMOVE?

The output of TREMOVE includes annual forecasts of transport flows (vehicle usage), vehicle stock size and composition, costs to society from transportation, and emissions from transport both in the base case and in any variant thereof.

The model describes for example transport flows, vehicle stocks and vehicle usage across three modelling domains per country: a target city, other urban areas, and non-urban areas. In these three domains a distinction is made between daily peak and off-

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peak periods. In the urban modules, a further distinction is made between commuters and inhabitants. There is no distinction between different purposes of trips, and the model does not provide information on seasonal variations in traffic or emission.

Modelling vehicle stock and usage

The module on the vehicle stock calculates the size and structure of the vehicle stock. It gives a full description of the vehicle stock every year, by vehicle type and by age of the vehicle. The age structure of the vehicle stock is an essential variable to assess the impact of emission reduction policies. The key input variables of this module are road transport demand by mode, vehicle costs, fuel prices and policy measures that affect vehicle choice. This module also calculates the usage for each category of vehicles from which the usage cost can be derived. *See figure 5.*

The vehicle stock consists of annual vintages that are handed over from period to period. The vehicle stock size in a given year t is a function of:
- The vehicle stock in the previous year (given value)
- New vehicle sales (endogenous variable)
- Retirements, or scrapping of vehicles (endogenous and exogenous variable)

Stock i (t) = Stock $_i$ (t-1) - Scrap $_i$ (t) + Sale $_i$ (t)
i= vehicle type

The module takes into account traffic demand by mode that leads to desired stock. New sales is the outcome of the difference between the desired stock and the surviving stock (the surviving stock is the stock that remains when the scrapping stock is subtracted).

Scrapping of vehicles is both an endogenous and an exogenous variable. The endogenous scrapping is based on the idea that there is an age dependant probability of breakdown. Following breakdown, repair expenditures are needed to restore vehicles to operation conditions. Exogenous scrapping representing the cars that can no longer be repaired.

Figure 3. TREMOVE structure

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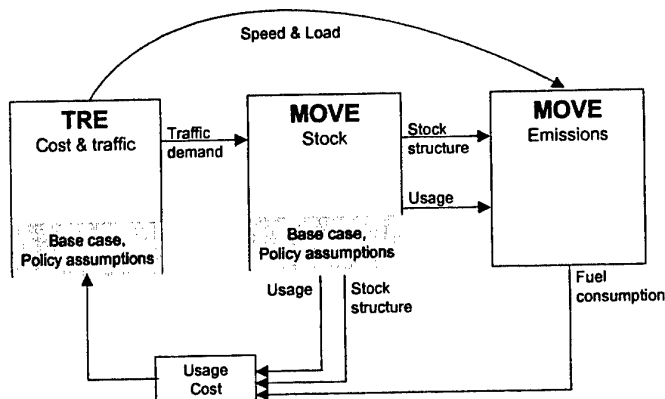
Figure 4. Overview of TREMOVE

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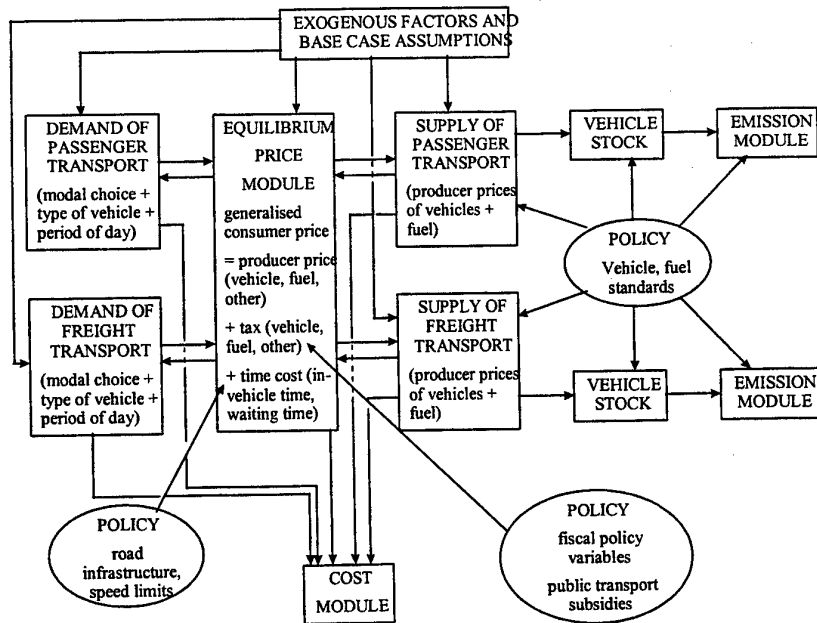
Figure 5. Flow chart of vehicle stock and usage module
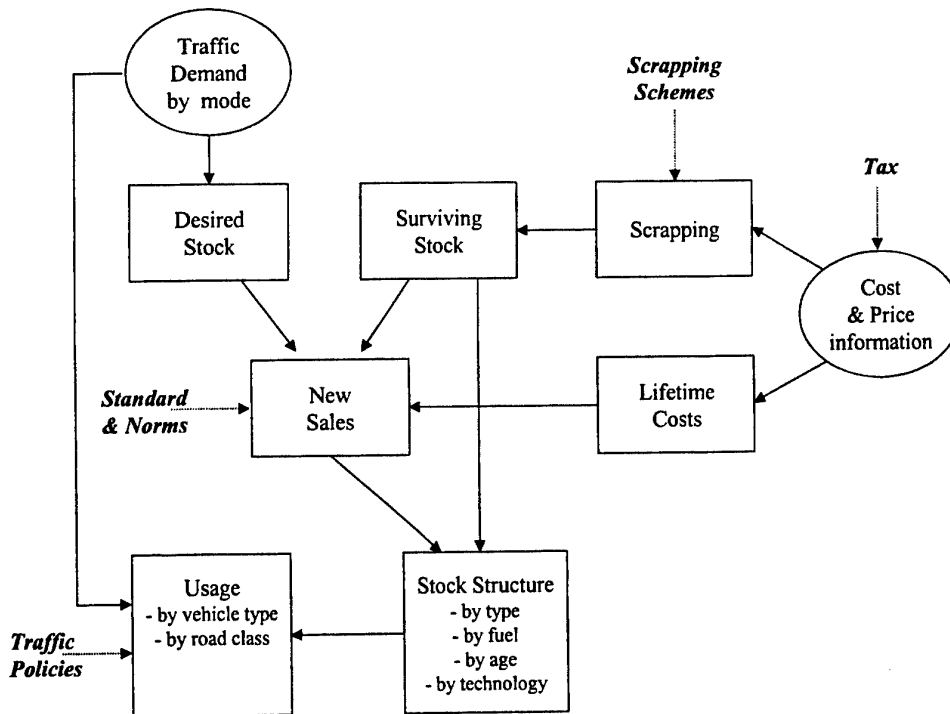
4.11 Kveiborg, O. (1999) Forecasting Developments of the Car Fleet in the Altrans Model

This paper describes the submodel developed to model the car fleet in the ALTRANS (ALternative TRANSport systems) model complex. ALTRANS is a model developed for analysing the environmental impact of different policy proposals on car and PT usage in Denmark. The model of the car fleet submodel described in the paper gives as outputs energy consumption and emissions stemming from car use.

The car fleet is modelled as being composed of three parts – the existing fleet, the purchase of new cars and the scrappage of old cars. Different exogenous variables have been used to model new car purchase (acquisition) and scrappage. The acquisition model was developed by the Danish consultancy firm Cowi, and is not described in detail in the paper.

The paper describes the historical developments of the Danish car fleet, demonstrating the impact of changes in economic conditions, the effect of high new car purchase taxes and the impact of a scrappage policy.

Focussing on the car-fleet model, the model system is basically an accounting type model. Acquisitions are forecast using Cowi's model, which takes as inputs prices, incomes etc. The historical stock of cars in different categories is used to determine the existing fleet. The scrappage model is calibrated to historical scrappage rates in different categories. Once the car fleet model has been run, the total car emissions for the forecast year can be determined through application of the emissions model.

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The scrappage model predicts the number of cars scrapped by two fuel type, three weight of vehicle, and 20 age of vehicle categories. The model was estimated of detailed vehicle registration data from 1991 to 1997, augmented by more aggregate data from between 1977 and 1990. The final scrappage model contained terms for stock, income and fuel costs. The stock term was necessary because the model was estimated on *levels* of scrappage, as opposed to scrappage rates.

In the emissions calculations component of the model, a degradation factor is determined dependent the kilometrage driven. The kilometrage is determined from a formulae from the Road Directorate, dependent upon age of the vehicle. The emissions per vehicle are then determined using a formulae based upon the kilometrage of the vehicle. Cars fitted with a catalytic converter have higher emissions levels when cold. This has been accounted for in the emissions model by defining a cold engine component for the first 4 km of a trip (applied to catalytic cars only).

4.12 Brownstone, D., D. Bunch and K. Train (2000) Joint Mixed Logit Models of Stated and Revealed Preferences for Alternative-Fuel Vehicles

In this paper, Brownstone et al. compare multinomial logit (MNL) and mixed logit models for data on Californian households' revealed and stated preferences for automobiles. In the vehicle choice modelling context, they found RP data was critical for obtaining realistic body-type choices and scaling information, and SP data was critical for obtaining information about attributes not available in the marketplace, but pure SP models gave implausible forecasts, hence the use of joint models.

The SP and RP choice data were collected as part of a multi-wave panel survey carried out in California, commencing in June 1993. In Wave 1, 4,747 households completed a mail-back SP survey after recruitment via a telephone interview. The SP models in the paper were estimated from this Wave 1 data. Approximately 15 months after the Wave 1 survey, a geographically stratified sample of the households telephoned in Wave 1 was used for a second wave (Wave 2) of interviewing. In this survey 874 out of 2,857 households surveyed reported at least one vehicle purchased. An RP data set was constructed using these new purchases.

To deal with the large number of make-model-year combinations in the market, for each year model year usually beginning in 1974, the authors categorised vehicles into 13 body type/size categories, in turn sub-divided into a high and low purchase price group, and a domestic and import group. This gave 689 possible RP vehicle categories. Attribute data (current used prices, fuel economy, top speed etc.) was determined for each of these categories.

Before estimating joint SP/RP models, separate SP and RP models were estimated. However, a particular feature of the problem is that some preferences are only identified in the SP, and some preferences are only identified in the RP.

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The SP models were estimated using both MNL and mixed logit model forms. To identify the normally distributed random coefficients in the mixed logit form, the Lagrange multiplier test from McFadden and Train (1997) was used. Five random coefficients were identified. Four were applied to the different vehicle fuel types modelled, demonstrating large heterogeneity in taste for alternative fuel vehicles. The authors also note unpublished work with the SP data which found significant nesting for the different fuel types. Hence the variance components of the mixed logit models may model substitution patterns similar to those from nested logit models. The fifth random coefficient was for fuel cost, with a large variance indicating a wide range of cost sensitivity. An issue in estimating mixed logit models is the higher computation time required, resulting from the need to draw repeated numbers from in this case a normal distribution to estimate the random coefficients. In this work, it was found 1,000 draws were needed per observation to obtain numerically reliable estimates.

The RP models were also estimated separately. No significant random coefficients could be estimated in these models. A key issue with the RP models was the large number of vehicle type alternatives available. Initially random sampling was used, but the problem was that new vehicles only comprised 52 of the 689 alternatives, and so a random sample of 30 would only contain one or two new vehicles. The solution was to use importance sampling, where a stratified sampling according to vehicle vintage, including seven new vehicles, and modelling 28 choices in total. In terms of model results, only terms for price and operating cost could be determined with any accuracy due to high co-linearity between range, speed and acceleration.

Joint SP/RP models were then estimated. A scale factor was used to scale the SP data relative to the RP data. For the MNL model, this factor was less than one, indicating the stochastic error term is the SP data has a larger variance than the RP data set. Interestingly, in the mixed logit model specification (using the same random error terms as the SP model), where preference heterogeneity is captured by fuel-type error components, the scale factor *greater* than one. Note that both the MNL and mixed logit models assumed that unobserved error terms are independent across RP and SP choices made by the same households.

The authors proceeded to make new vehicle forecasts for California, using both the pure SP models, and the joint RP/SP models. An interesting result was that the SP models predicted unrealistically high sports car markets shares compared to the RP/SP model, demonstration of the benefits of combining RP and SP data. The mixed logit models tended to result in higher marker shares for the alternative fuel vehicles. A key point here is that the IIA properties of MNL means a proportionate share of each new vehicle's market share must come from all other vehicles, whereas the mixed logit specification results in the more plausible result that the market share for electric fuel vehicles comes disproportionately from other mini and subcompact vehicles.

The authors conclude that mixed logit models are a general and feasible class of models for joint RP/SP choice data. However, modelling RP vehicle choices with a discrete choice model presents difficulties due to the large number of alternatives in the marketplace, and procedures that rely on sampled choice sets for non-IIA models require more investigation. The alternative fuel models highlight the advantage of using joint RP/SP data in the vehicle choice context. Although plagued by

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multicollinearity, RP data appears critical for obtaining realistic body-type choice information, and for scaling information. SP data is critical for obtaining information about attributes not readily identifiable from the marketplace.

4.13 HCG (2000) Report 9009-3B, Chapter 3: Sydney Car Ownership Models

In this report HCG describe the car ownership models estimated as part of their recent work to extensively update the Sydney Strategic Transport Model (STM). Disaggregate models of company and total car ownership at the household level were estimated.

The disaggregate models were estimated from two data-sources, one collected during 1991/92, and one collected during 1997/98. However, prior to model estimation longer term trends in car ownership between 1971 and 1997/98 were investigated. These investigations revealed that a large part of the long-term trends could be explained by income changes and changes in licence holding. However, it could not be concluded that these effects accounted for *all* of the changes, and consequently the models included trend terms.

Model tests were undertaken to determine the most appropriate way of modelling company and total car ownership. Three approaches were tested:

1. Modelling private and company car ownership behaviour independently;
2. Modelling private car ownership conditional on company car ownership;
3. Modelling company car ownership conditional on private car ownership.

The model tests revealed the second approach gave the best structure, i.e. households choose the number of private cars dependent on company car ownership. The model structure adopted is shown in Figure 6.

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Figure 6. STM Car Ownership Model Structure
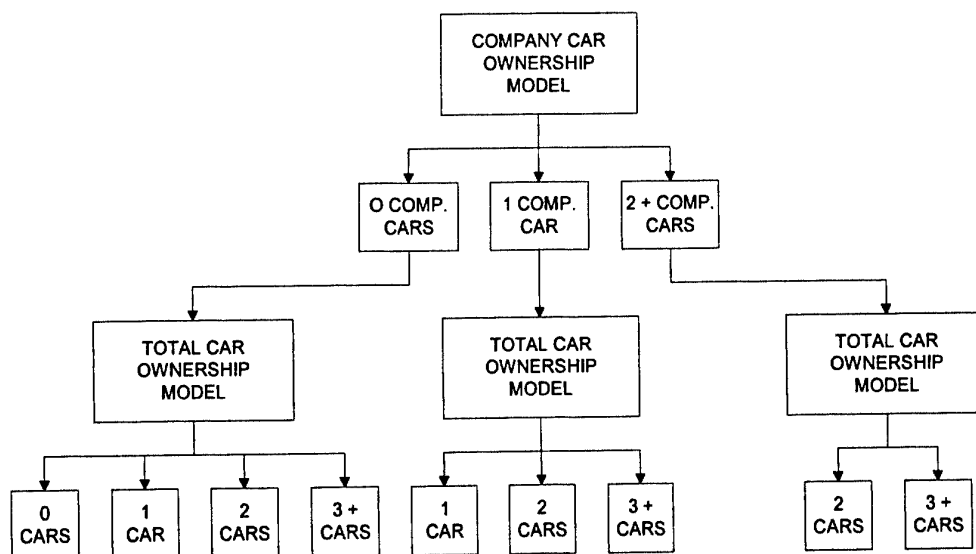
A logsum variable was tested to try to determine a significant linkage between the models. A significant logsum term could not be estimated however, this may be due to the similarity between the specification of the explanatory variables in the two models. As a result of the similar model specifications, the inter-household variation in utility is similar (accounting for scale differences) between the two models. This pattern makes identifying a significant logsum term difficult.

Both models predict car ownership dependent on the *logarithm* of net household income. The total car model accounted for impact on net household income of car ownership costs, with the effect dependent on the number of cars owned.

The number of licence holders in the household was an important term in both models. In both models, significant negative parking cost terms were estimated, accounting for lower car ownership in zones where parking is more expensive.

Both models identify the head of the household is identified as the individual with the highest income, and terms are estimated to reflect car ownership differences according to the age and gender of the head of the household.

The total car ownership model included an accessibility term from the home-work mode-destination model. This term accounts for higher car ownership in zones which are accessible to work places. No such term could be estimated in the company car model, consistent with the belief that company car ownership is dependent on job position and type, not accessibility to the workplace

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4.14 Hensher, D.A. and W. Greene (2000)   Choosing Between Conventional, Electric and LPG/CNG Vehicles in Single-Vehicle Households

In this paper Hensher and Greene estimate both multinomial logit (MNL) and mixed logit models to a combined SP/RP data, modelling vehicle choice in single vehicle households.

The data source for the analysis was a stated preference survey undertaken in late 1994 in six capital cities in Australia (Sydney, Melbourne, Brisbane, Adelaide, Perth, Canberra). The SP survey had two aims: the determination of respondents' preferences with regard to conventional vehicles for a given range of price and running cost attributes, and to assess whether respondents are willing to consider alternative fuel or electric vehicles as substitutes for conventional vehicles given a price, running cost and some physical differences.

In the SP survey vehicles were categorised according to the following attributes: three size categories based upon engine size (within a given engine size, respondents were asked to indicate a preferred body type), price of vehicle, registration fee (e.g. on conventional vehicles), fuel cost to travel 500km (variable described as approximate cost of filling a tank so respondents understood levels), fully fuelled range (only for non-conventional vehicles, as envisaged conventional vehicle ranges will remain stable, and expressed as percentage of conventional vehicle range), acceleration (frequently lower for non-conventional vehicles) and boot size.

The SP experiment was a two stage process. The first stage of the SP required a household member to consider three conventionally fuelled vehicles (one from each size class) and choose one. In the second stage, three electric vehicles and three alternative fuel vehicles were added to the choice set, and the household member asked to choose one vehicle from the nine. This experiment was repeated three times.

A total of 36 alternatives are possible in the SP vehicle type choice model (three size classes, three fuels, four vehicle ages). Tests of a reduced choice set demonstrated a choice set of 12 alternatives would give statistically indistinguishable parameter estimates. To select the choice set, four alternatives were selected from each fuel class. The age profile was randomised within each size class.

The RP model is defined by a 10-alternative choice set, using a random sampling procedure within each size class to assign vehicles of each vintage to the 10 alternatives given their size class. The advantage of using a ranked model was that it is possible to introduce class-specific constants and apply choice-based weights to the RP choice set to reproduce the base market shares for the 10 size classes.

To estimate the joint SP/RP models, one nested logit and three mixed logit specifications were estimated. In addition to the choice-based weights in the RP data set, exogenous weights were used for each observation to correct for differences in sample and population income distribution. For attributes common to both the SP and RP, separate parameter estimates were considered, but it was found that generic parameters were statistically preferable.

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In the mixed-logit models, random parameters were estimated for the electric and alternative fuel vehicle constants (normally distributed), and for the vehicle price (log-normally distributed to ensure parameter is always negative). The heterogeneity in consumer preference for non-conventional fuel vehicles is consistent with the findings in California, reported in the review of Brownstone et al (2000).

The three mixed logit formulations considered were:
1. No correlation assumed;
2. Correlated attributes;
3. Correlated attributes and SP choice sets.

The results for the three mixed-logit model were compared to those obtained from the comparable nested MNL model by examining variations in the willingness to pay (WTP) for a marginal improvement in vehicle range for non-conventional fuel vehicles. The WTP figures were similar for nested logit and the first two mixed logit models. However, when correlation between the two SP choice sets was allowed for, the impact on the WTP figures was large, with the WTP values almost halving in magnitude.

Switching propensities were also compared for the nested MNL and the third mixed logit formulation. This comparison demonstrated consistent patterns of over and under-prediction under a range of scenario options. The tendency was for MNL to over allocate to new fuels and hence under-estimate shares on conventionally fuelled classes, relative to mixed-logit.

4.15 Page, M., G. Whelan and A. Daly (2000) Modelling the Factors which Influence New Car Purchasing

In this paper, Page et al. describe the development of a model of new car sales for incorporation within the Vehicle Market Model (VMM) of the then UK Department of the Environment, Transport and the Regions (DETR). The objectives of the project were to improve knowledge of the factors which influence people's decisions when they buy new cars, and to develop a computer model to forecast the future distribution of new car sales.

The data collected for this study comprised four elements:

1. Existing revealed preference (RP) data – National Travel Survey (NTS) data from 1985-97 was used;
2. Focus groups – to discover what factors are important to potential and actual buyers;
3. Interview data – a survey of 500 respondents who answered a stated preference (SP) questionnaire;
4. Fleet managers' survey – the buying decisions of fleet mangers were probed, and this included an SP survey to assess the behaviour of this important section of the market.

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An important requirement of the model was the ability to discriminate between private (retail) and company (fleet) purchases, and therefore the relevant decision maker in each case had to be identified and approached.

The outcome of the focus groups provided input into the final SP surveys. The focus groups revealed that aspects of performance, engine size and image are more important to company car buyers than to private buyers. Purchase price and to an extent running costs were important factors as they provided a constraint on the range of vehicles considered.

The RP data used UK NTS a household survey data. For each vehicle less than one year old, information was extracted on population density and area type where the household was located, the socio-economic characteristics of the household and the attributes of the household's vehicle fleet. The sample generated gave 3,090 observations, 1,070 company owned, 2,020 privately owned.

The SP interview data collected information from households who were either planning to acquire a new car, or had just acquired a new car. The questionnaire was administered on laptop computers, and thus allowed customisation of the levels of the attributes. Background information was collected on the respondents' socio-economic characteristics, details of the household's existing fleet, company policy on company cars (where applicable), details of the preferred specification of the new vehicle and details governing future purchase decisions. The information provided a check on the representativeness of the sample, and was used to set the SP levels to ensure meaningful choices were presented.

The household SP experiments presented the following vehicle attributes to respondents: additional income tax (comp), monthly supplement due to loss of salary arising from company car ownership (comp), fuel costs, purchase prices, running costs, standing charges (road tax and insurance, private only), resale value, engine size, vehicle emissions, safety measures, fuel type (petrol, diesel or hybrid petrol-LPG) and fuel economy. Two SP questionnaires were presented to assess the likelihood of respondents opting in or out of the company car market, the aim being to elicit a 'value' associated with company car ownership.

The background questions in the SP revealed that after cost, the greatest concern for private buyers was reliability, whereas for company car users it was comfort, perhaps a reflection of greater mileages.

The fleet managers survey revealed that after necessity for work, the key reason for providing a company car was 'to aid staff retention/recruitment'. Clearly company car ownership is seen as an important benefit. Cost, both in terms of purchase and running costs, dominated the decision making process for fleet buyers. Fleet buyers were willing to consider alternative fuel vehicles, but only of they were cost effective and practical drawbacks could be overcome. SP models derived from fleet mangers were generally very good; given the knowledge the respondents have of the market this was expected. However, the fleet managers model was not incorporated in the final structure.

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The SP and RP data-sources were combined to form two nested *household* based models. The first model predicts the binary choice between a private and company car (ownership status model). The final model variables were the number of children in the household (seen as a proxy for stage in life cycle), male head of household dummy, age of head of household, the log of vehicle tax, the log of ownership cost and an alternative specific constant.

The second model predicted a multinomial choice between different vehicle types. Separate models were used for company and private cars. In the private car model terms were estimated for population density, log of annual household income, log of purchase price, number of children, running costs, variations in emissions, safety features, resale value, fuel economy, standing charges, hybrid engine type and diesel engine type. In the company car ownership model, the terms were population density, log of annual household income, log of monthly cost, number of children, fuel cost, engine size, variations in emissions, safety features, hybrid engine type. In both models, a scale factor was used to scale the SP data relative to the RP data. Some of the factors of importance in the choice of private vehicle were similar to those for company vehicles – an interesting feature of both models is that in areas with high population densities, where parking is likely to be more difficult, there is a higher probability of acquiring a smaller vehicle.

The model system was implemented using a pivot point or incremental logit model. The implementation was undertaken in Visual Basic 5. The model system predicts the proportions of different types of new cars over the period 2000-2031 inclusive. The new car sales are disaggregated by:

- Engine size (9 bands for petrol, 7 bands for diesel);
- Fuel type (petrol / diesel);
- Ownership type (private / company).

Note that individual make – model combinations, such as Ford Escort 1.6 L, are not disaggregated. The model can assess the impact of a range of policy measures through their effects on the impacts of the model which include:

- Engine size;
- Purchase price of the new vehicle;
- Standing charge (tax plus insurance);
- Running costs – pence per mile;
- Fuel economy;
- Fuel cost;
- Tax – tax liability for company car ownership;
- Ownership costs – for private car ownership.

4.16 Schafer, A (2000) Regularities in Travel Demand: An International Perspective

This paper is not about car ownership, but was included because it included an international review of the constant budget assumption that is crucial for FACTS.

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In this paper, Schafer compared major mobility variables from around 30 travel surveys in more than 10 different countries. He analysed both longitudinal and cross-sectional data, and his research broadly confirmed the theory that time and money travel budgets are stable at an aggregate level. He found that the two travel budgets showed strong regularities across space and time for all countries examined.

The papers begins by reviewing other literature in this area, and highlights previous findings that while travel budgets tend to be stable at high aggregation levels, such as national levels, variability exists at more disaggregate levels. Some research has emphasised the aggregate stability, other work seeks to explain the disaggregate variability. Zahavi, using cross-section data from cities inside and outside the US, suggests a time budget of 1.1 hours per day, and an income budget of 10-15 %, for individuals in car owning households.

The travel survey data sources were collected between 1975 and 1995, and as a first step in his analysis Schafer considers their comparability. He emphasises that more recent travel survey diary methods are more successful at recording all travel, and when compared to earlier surveys may imply growth in travel which is in fact due to better reporting. Another comparability problem is the inherent sample bias in any survey, which will vary between surveys, and problems of nonresponse. Non-respondents may have atypical travel patterns which bias the results. Other possible inconsistencies result from different survey designs, objectives, and definitions. For example some surveys were carried out on a single day, others represent a working day average. Schafer notes these problems should be borne in mind when analysing the results of his inter-survey comparisons.

Schafer used 26 travel surveys at different time periods (cross-sectional data) to calculate a mean travel budget of 1.22 hours per capita per day (h/cap/d) with a standard deviation 16 % of the mean. At the same time, the mean daily distance travelled showed considerable variation between surveys, from under 5 km in African villages to over 60 km in a 1995 US survey. Using the same data sources Schafer calculated a mean travel money budget of 10.73 % of disposable income with a standard deviation 31 % of the mean. Therefore the money budget showed more variation than the time budget. While both travel budgets demonstrated a horizontal response when plotted against daily distance travelled, plotting mean trip rates and trip distances against daily distance travelled demonstrated both increased with increasing daily distance travelled. The pattern in the data suggested as incomes increase, people make more trips (more personal business and leisure), and are able to afford to travel using faster modes, and so make longer trips. The next step of his project is to try to combine the data-sources in a more formal statistical manner, correcting for major inconsistencies in the surveys.

Considering the travel time budgets for the US in more detail, Schafer notes that the travel time spent by individuals has a skewed distribution and consequently the mean and median differ strongly, so that while the average per capita travel time is 1.18 h/cap/d, the typical resident travels only 50 minutes. Similarly the mean transportation expenditure represents 19.3 % of total expenditure, but the typical (median) household dedicates only 13 % of expenditures to travel.

Examining trends in the time budgets between journey purposes, Schafer looks first at commuting, which he notes tends to be well reported in travel surveys. For commuting, it seems travel time budgets have been increasing slightly at a country level, suggesting commuters have been unable to compensate longer distances with higher mean speeds. A similar pattern was observed for work related business. However, these patterns varied between countries, with no such increase being detected in Norway for example. Personal business and leisure do not show this pattern, i.e. follow a time budget pattern with increasing trip distances. Overall however, Schafer concludes that the per person travel time budget can still be considered roughly constant at high aggregation levels.

Considering travel money budgets, Schafer looked at six Western countries: France, Italy, the Netherlands, UK, US and (former) West Germany between 1970 and 1995. He observed that in general travel budgets have remained stable above motorisation rates of 0.30 cars per capita, where on average nearly all households own a vehicle. Only in West Germany have travel budgets risen (slowly) after this point in time.

Schafer goes on to examine the implications on travel patterns of travel budget stability. In terms of mode-choice, increasing incomes imply rising travel demand from the money budget, and the constant travel time budget requires travel at higher speeds and hence shifts towards faster modes. In terms of land use, as people travel further population tends to disperse, and mean distances to work are increasing, even in high density countries with good public transportation such as the Netherlands. In the US the distances to work are much higher than the European context, with a mean trip distance to work of c 60 km in a 1995 survey.

In conclusion, Schafer states that aggregate travel behaviour is determined largely by the two travel budgets. However, he believes neither budget is unique or completely stable. He believes that while most of the variation between travel budgets can be attributed to inconsistent survey methods, part of the variation may represent behavioural change. Given that the two budgets vary across different countries, Schafer suggests it may be most suitable to consider them as approximately constant on only very high aggregation levels (world-regional, global). Despite the very rough nature of the budgets, Schafer believes them to offer an elegant framework for explaining aggregate travel behaviour characteristics, and notes that so far no large alterations in either travel budget have been observed.

4.17 Tam, M. and W. Lam (2000) Maximum Car Ownership under Constraints of Road Capacity and Parking Space

Tam and Lam describe an aggregate zonal model for determining the maximum number of cars by zone in view of the capacity of the road network and the number of parking spaces available. Their model seeks to examine whether the existing road network is capable of accommodating future zonal car ownership growth. In their model, vehicle trip production and attraction are dependent on car ownership, available parking spaces and the accessibility measures of traffic zones.

The authors use a bi-level programming problem. The lower level problem is an equilibrium trip distribution/assignment problem, whereas the upper-level problem is

to maximise zonal car ownership by considering travellers route and destination choice behaviour while satisfying network capacity and parking space constraints.

A number of assumptions are made in the model developed. Parking is modelled as a fixed supply of public and private spaces by zone, and illegal parking is ignored. It is assumed that each car must occupy one parking space at its destination zone during the study period. Trip attraction is modelled as parking demand, and zonal trip production is assumed to be a function of the number of cars owned by the residents in the households in a zone, which reflects the number of households in the zone. The relationship between trip production and the number of cars is established by an elastic trip production rate. The accessibility measure for trip production is affected by the number of trips attracted and the generalised travel time between origin and destination.

Therefore while the authors have sought to account for the impacts of congestion and parking constraints on car ownership, they have modelled car ownership within a short-term aggregate network based framework. Car ownership is not modelled within a behavioural framework.

The authors proceed to present the formulae involved in their optimisation problem.

In conclusion, the authors propose their model can be used to determine the maximum number of cars by zone subject to network capacity and parking constraints. The output from the model in terms of number of cars by zone indicates to what extent zonal car ownership growth could be accommodated by the existing transportation facilities. At this stage, however, zonal car ownership growth projections would be best provided from an external model.

4.18 Whelan, G., M. Wardman and A. Daly (2000) Is There a Limit to Car Ownership Growth? An Exploration of Household Saturation Levels Using Two Novel Approaches

In this paper Whelan et. al. describe two approaches which have been used to estimate car ownership saturation levels explicitly, one disaggregate and one aggregate.

The paper begins by noting that a common theme of many car ownership models is the S-shape growth curve. The economic rationale behind the use of the S-curve is provided by product life cycle and diffusion theories, whereby the take-up rate for new products is initially slow, then increases as the product becomes more established, and finally diminishes as the market comes closer to saturation.

Examining trends in per capita and per household car ownership in the UK over the last 50 years, no S-shaped plot is apparent, suggesting overall saturation levels have yet to be reached. However, looking at variations in ownership across different household income groups, more clear S-shaped patterns are apparent, with higher income groups approaching saturation. If car ownership models were specified with an S-shaped functional form and a saturation level (either implicit or explicit), then forecasts of vehicle ownership will be curtailed as saturation is approached.. This is a highly significant feature in mature markets such as Great Britain or the Netherlands.

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Describing the background to the disaggregate model approach, the authors note the 1997 NRTF forecasts use information on household income, household type (number of persons and age structure), car-type and area type. Two separate models were estimated, a model predicting the probability that the household owns at least one car (P_{1+}), and a model predicting the conditional probability that the household owns two or more vehicles $P_{(2+|1+)}$. The saturation level S formed an *input* to the model, determined by plotting cars per household against income within each household category, and examining levels of car ownership amongst the highest income households. The disaggregate approach developed by the authors aimed to explicitly estimate these saturation levels.

Describing the background to the disaggregate model approach, the development of long-term extrapolation techniques by Tanner and others is noted. The initial preference for logistical time-series extrapolation is noted. This approach avoided the need for forecasting the future levels of explanatory variables, and Tanner believed the rate of growth in ownership in the forecast time period was closely related to the rate of growth in proceeding periods. Tanner believed a saturation point exists for car ownership, and that a logistic curve was compatible with this theory of car ownership. To estimate the saturation point S, Tanner fitted linear regressions from the US and the UK based on the relationship between the rate of growth in car ownership levels and the actual levels of car ownership. There was debate at the time as to whether the saturation point should be determined from time-series of cross-sectional data, with a general conclusion that time-series data was best.

To estimate saturation levels using disaggregate models, a partially constrained binary choice model was estimated, using the tree-logit structure. In this context the constrained group are the fraction $1 - S$ who are constrained not to own a car. Within the alternative 'no-car', a nest structure was set up to represent the constrained choice. Exploiting the binary choice situation, one of the attractiveness functions V_{nocar} was set to zero, and so V_{car} contained all the utility terms.

The model results are not described in the paper, but the review of Whelan (2001) outlines some of the findings. The outcome was that plausible saturation levels could be estimated from the data, with different saturation levels estimated for different household type and region combinations.

To estimate aggregate saturation levels, the authors used Tanner's power growth model. They calibrated the model to the proportions of P_{1+} and $P_{2+|1+}$ households using data from Transport Statistics Great Britain for the 47 years between 1951 and 1997. Other official publications provided figures on GDP indices of car purchase cost and car running cost. The estimation procedure used was non-linear least squares to estimate a model which is non-linear in parameters. The estimation was undertaken using the SAS statistical package. The separate estimation of P_{1+} and $P_{2+|1+}$ cases represents a development of previous approaches considering overall saturation levels only.

The aggregate models estimated also allowed for explicit estimation of saturation levels, for which significant estimates were obtained. The two models (P_{1+} and $P_{2+|1+}$) contained significant terms for trend effects, household income, purchase cost,

saturation level S and the power optimal power term. Operating cost was not found to be significant. For owning at least one car, a value for S of 0.85 was estimated with a confidence interval of ± 14%. For owning two plus cars, the saturation level is much lower at 0.49 ± 63%. Both figures were lower than were expected and were at odds with the disaggregate findings, and on this basis the authors concluded that there were problems with the aggregate approach.

In conclusion, the authors note that with a few exceptions car-ownership models incorporate the notion of saturation, and so direct estimation of saturation within the car-ownership model framework represents an advance on the use of externally derived saturation levels. This can be achieved through the use of a disaggregate model framework.

Comparing the results of the disaggregate and aggregate approaches, they believe the former to be more credible. The authors believe the problem with the aggregate approach is related to the use of time-series data, which has resulted in the estimation of time trend effects and both income and purchase price elasticities. To overcome these deficiencies the authors recommend the use of cross-sectional data, such as that used by Dargay and Gately (1999).

4.19 Birkeland, M.E. and J.Jordal-Jørgensen (2001) Energy Efficiency of Passenger Cars

Birkeland and Jørgensen developed a car type choice model for car buyers' choice of new cars, and then used this model to analyse which policy measures could be used to obtain a more efficient car fleet. The main focus therefore was on studying consumer behaviour in order to achieve a tool to analyse the possibilities of improving fuel efficiency for new passenger cars through changes in the tax structure. It is noted that energy efficiency changes are only modelled by modelling the purchase of new cars – changes in taxation structures impacting upon older vehicles and or vehicle scrappage are not considered.

The new car choice model was based upon three data sets. The first dataset describes the *supply* of new cars, and contained detailed information on approximately 1,500 different types of car available on the Danish market in 1997. The cars were described by a wide range in characteristics including price, performance, size and fuel consumption. The second data set described the *demand* for new cars, and described the 150,000 individuals and companies who purchased a new car in Denmark in 1997. Private and company car purchases were then modelled separately. For confidentiality reasons, the consultant never received the detailed database, instead they received data detailing the numbers of cars sold for each combination of car type and two background variables. The third dataset was a *stated preference* survey of 200 car buyers. This survey posed hypothetical questions such as changing fuel prices and the owner tax, and aimed to clarify buyers' preferences for different types of taxes.

The private car choice model was estimated as a household choice decision using standard utility maximisation theory. To deal with the large choice set available (1,500 vehicles), 49 vehicles were randomly selected, so that including the chosen

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vehicle each household had 50 alternatives available to them. Note that detailed make and mark combinations, such as Ford Escort 1.6 L, were considered in the model. Separate models were estimated for eight household types, described by the type of family (single/couple), the gender of the car owner, and the presence of children.

A total of 60 parameters were estimated in the private car choice model. The parameters represent car expenses for prices and fuel consumption, size of the car by cabin space, luggage space and exterior dimensions, engine capacity and acceleration. Variation in price sensitivity with household incomes was accounted for in the model specification.

The key estimation results are outlined in the paper. As expected, lower income households were more price sensitive than higher income households. Significant fuel cost parameters were estimated. A positive effect for petrol engine size was discovered, and regional variations in the utility of a large engine were also determined. No such effect could be determined for diesel engines, which tend to have a smaller range of engine sizes. Acceleration was also an important effect, and the model found it was most important to young buyers, and least important to old buyers.

The private car choice model has been used to forecast 1997 car sales in Denmark, and compared to actual sales figures. Overall, the model matches actual car sales well. A revised version of the model is being used at present to analyse the impact of tax changes on the energy efficiency of new cars, and to validate the model a series of tests have been made to assess its use in EU member states, comparing actual and forecast measures. The validation process considered three key outputs: CO_2 emission levels, new car registrations and estimates of parameter elasticities.

The model forecasts of CO_2 emission levels of new cars (CO_2/km) for Germany and Denmark revealed a good match to observed data, with private emissions lower than the overall observed mean, and company car emissions higher than the overall observed mean, for both countries. In Germany, company cars represent 41 % of new car purchases, which is substantially higher than in Denmark. Consequently observed CO_2 emissions are closer to the predicted company car emissions in Germany.

The models forecasts of new petrol car registrations for Germany showed a good correlation with the observed data, with the small discrepancies attributed to country specific preferences that the model (calibrated to Danish data) cannot capture. The model forecasts was validated for number of registrations by CO_2 emissions, number by engine size and number by nine engine size classes.

The model was compared to parameter estimates from a similar model based on data from 11 European countries, and against observed data from these countries. These tests confirmed the overall accuracy of the model. There were some discrepancies which result from the application of a Danish model to different countries.

The conclusion of model runs made suggests controlling choice of car through taxation may lead to a reduction in average fuel consumption of the *new* car fleet, hence reducing CO_2 emissions. However, differentiations in registration tax alone cannot achieve the aims of substantial reductions in CO_2 emissions.

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4.20 Jong, G.C. de, C. Vellay and J. Fox (2001) Vehicle Scrappage: Literature and a New Stated Preference Survey

De Jong et al describe the results of work to improve the scrappage forecasting component of the UK Vehicle Market Model (VMM). This work recognises that the emission of pollutants and energy use is strongly affected by the age composition of the fleet, since catalytic converter technology and fuel efficiency have been developing rapidly. Consequently in order to forecast emissions and fuel consumption accurately, forecasting vehicle scrappage is important. Prior to this work, the VMM contained a scrappage model which was calibrated to observed data, but was not formulated within a behavioural framework. In particular, the effect of policy measures such as differential taxation levels by engine size could not be assessed. The work also aimed to determine the relative importance of the different reasons for scrappage.

The first phase of the work was a literature review of scrappage literature over the last 25 years. More detail on the papers reviewed can be found in the paper. The key paper in the area is identified as Parks (1977), who considers vehicle scrappage as an economic decision. Parks considered the decisions 'keep' and 'scrap', and suggested that each year individuals considered the repair costs associated with the vehicle. If the repair costs for the vehicle exceeded its market value minus its scrap value, then the individual would scrap the vehicle. To explain the logit of the scrapping rate, Parks used make-specific age dummies, make-vintage dummies which capture durability effects, make-specific used prices expressed relative to the price of repair, and make-specific scrapping prices relative to the price of repair. Parks was worried about a strong correlation between used car price and durability, so he used new car price index as an instrument for used car price.

Much of the subsequent scrappage literature built upon Parks' economic treatment of scrappage. Research in the US into the use of scrappage bounties to encourage scrappage of older polluting vehicles has suggested that the policy can work in selected urban areas, where pollution problems tend to be most acute. However the policy is best viewed as a transitional strategy, as once the dirtiest vehicles are scrappage the gains are significantly reduced.

The literature review provided a framework for the design of the stated preference (SP) survey. The aim of the stated preference survey was to elicit preferences from owners who are about to scrap, or have recently scrapped, a vehicle. Both car and HGV owners were considered. Owners were defined as 'in scope' according to the following conditions:

- Owners of vehicles aged seven years or older: analysis of the Vehicle Information Database (VID) had suggested this is the age when vehicles may be scrapped due to final deterioration;
- Owners who had scrapped a vehicle in the last two years.

Respondents were recruited by telephone. No cash incentive was offered for questionnaire completion, but the potential environmental benefits of the research

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were emphasised. The choice decisions presented to vehicle owners were either 'keep vs scrap' or 'keep vs sell' their existing car.

The SP model for car owners had the following findings:
- The older the existing vehicle, the more likely it is to be scrapped;
- The older the suggested replacement vehicle, the more likely it is that the existing one is kept;
- The greater the value of the new vehicle, the more likely the existing one is kept;
- The greater the running costs of the existing vehicle, the more likely it is to be scrapped;
- The greater the running costs of the new vehicle, the more likely the existing one is kept;
- The lower the tax on the existing vehicle, or the higher the tax on the newer vehicle, the more likely the existing vehicle is kept;
- The higher the scrap value of the car and/or the associated scrappage bounty, the more likely it is to be scrapped;
- Larger engined cars are more durable and so less likely to be scrapped for a given age.

The model results suggested different disutilities associated with different types of cost. For example, road tax was perceived as having a higher disutility than weekly running costs.

The SP scrappage models have been combined with RP data of the UK Vehicle Information Database (VID) which provides observed revealed preference data (RP) on scrappage rates to form a forecasting model. This forecasting model has been developed using Visual Basic within an Excel spreadsheet package, and predicts scrappage rates by age of vehicle, engine size and fuel type, for each year up to 2031. The model uses the results of the SP survey to allow the assessment of the impact of the following policy measures: replacement price (new and second hand prices), scrappage schemes, tax incentives (road tax rates) and fuel prices. The model assumes vehicles up to seven years of age are only scrapped due to accident damage, which in turn is influenced by policy on speed restrictions.

4.21 Mokhtarian, P.L., I. Salomon and L.S. Redmond (2001) Understanding the Demand for Travel: It's Not Purely Derived

As the Schafer paper, this paper is not about car ownership models, but we included it because it is related to the basic assumptions of FACTS.

In this paper, Mokhtarian et al question the assumption that travel is a derived demand, instead suggesting travel has an intrinsic positive utility. They suggest that demand for travel arises from a fundamental human need for mobility and other subjective characteristics, as well as from the external causes typically measured.

The paper begins by reviewing literature, both academic and popular, covering the concept of a positive utility of travel. The common themes of the work quoted are that travel has both positive and negative features, and that travel may be performed

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as a desired activity in itself, and not just as a means of accessing activities. Rather than considering the dichotomy between undirected (e.g. leisure) and directed travel (e.g. mandatory and maintenance), the authors suggest all travel falls somewhere along a continuum, with totally undirected travel at one extreme (travel is primary, destination auxiliary) and totally directed travel at the other (e.g. a trip to the dentist).

The authors suggest three components in the utility for travel can be identified:
1. The utility of arriving at the destination;
2. The utility of activities that can be conducted while travelling;
3. The utility of travel itself.

The utility of activities of activities while travelling, e.g. working an a laptop or listening to music, contribute positive utility, and the authors suggest at a maximum make the utility for the whole trip positive. The theory that these activities may represent a way of minimising the negative utility *conditional* on the trip being made is not discussed by the authors.

Considering the travel time budget debate, a modified version of the travel time budget is suggested, which is that individuals have a *desired* travel time that is a function of their personality, lifestyle and attitudes (particularly attitudes towards travel itself and activities which can be conducted whilst travelling). Individuals whose utility of travel contains more of the second and third components are likely to have a larger travel time budget, all other things equal, are will be more resistant to policies intended to promote travel reduction.

To improve the understanding of the positive utility of travel, a 14 page questionnaire was designed and administered for 8,000 residents in San Francisco. A randomly selected adult in each household was asked to complete the survey. A total of 1,900 fully completed questionnaire were returned for analysis. Some sample bias towards persons with higher incomes and higher levels of education, and two-person households, was reported.

The questionnaire measured variables grouped into 11 categories: objective mobility, perceived mobility, relative desired mobility, travel liking, attitudes, personality, lifestyle, excess travel, mobility constraints, travel modifiers and demographics. Objective mobility questions recorded information about trip distance and frequency of travel, by mode and purpose. Trip frequency was recorded on a five point semantic scale. Total mileage per week was also recorded. It is emphasised that *typical* travel was recorded, as opposed to cross-sectional travel diary data. Perceived mobility was also measured on a five point semantic scale. The other variables were generally measured using five point semantic scales.

Examining descriptive statistics of some key indicators, nearly half of respondents disagreed that travel time is wasted time, and more than a third saw their commute trip as a useful transition and used that time productively. For 'travel liking', the results suggested a majority (55 %) of respondents were neutral about short-distance travel, and an even larger majority (63 %) were positive about long-distance travel (> 100 miles).

Considering ideal commute time, the authors report an average ideal one-way commute time of just over 16 minutes, suggesting this implies a non-zero optimum commute time. The reviewer suggests this may a context effect, reflecting people with higher commute times reporting a commute time they would consider short on the basis of their experience, but not necessarily implying they prefer 16 minutes to 10.

The paper concludes by suggesting that the same positive characteristics of travel which encourage people to engage in transport as a recreational activity are likely to motivate people to engage in apparently excess travel in the context of their mandatory and maintenance activities as well. The positive affinity for travel is believed to be universal to some extent, but distributed unevenly across the population dependent on personality, lifestyle, travel related attitudes, mobility constraints, demographic characteristics, and the mode and purpose of a given trip.

It is suggested that travel is not modelled as a disutility, but as a literal good having both positive and negative characteristics, and that some of the subjective factors giving rise to positive utility should be incorporated in modelling. To achieve this, the authors suggest the population should be segmented according to how they rate the three components of utility identified, and different travel models should be developed by segment on the premise that people who weight the different components of utility differently are likely to also weight typical explanatory variables differently.

4.22 Rich, J.H and O.N. Nielsen (2001) A Microeconomic Model for Car Ownership, Residence and Work Location

In this paper Rich and Nielsen present the results of a long-term travel demand model for households with up to two active workers. This model is formulated within a microeconomic framework. Car ownership is explicitly treated within their model structure, but does not form the main focus of the paper.

The paper notes that there is not much literature on modelling the behaviour of two worker households, and in particular co-operation between workers in the household is often not considered in model structures. Co-operation between workers in the household was investigated in Rich and Nielsen's research.

The model was specified as a nested logit model comprising two main components: a work model (W-model) modelling the choice of work location and car ownership, and a residential location model (R-model) modelling the zone and type (house/apartment) of residence. The work model was at the bottom of the structure, i.e. they assume that individuals choose their work location dependent on where they live. The paper does not discuss investigation of a different structure, for example workers choosing residence location dependent on work location.

The W-model considers A as the main worker (highest income), and B as the second worker. The W-model is itself is nested, with choice of work location for A at the top of the tree, followed by work location for B, and finally car ownership at the bottom of the structure. Hence car ownership is modelled as a decision made after both

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residential and work location choice. The car ownership alternatives considered in the model are 0, 1, 2 cars. No explicit treatment of company cars is mentioned.

To model choice of work location, Rich and Nielsen defined an interesting measure of co-operation between the workers which they termed ω:

$$\omega = [1 - \min(GTC_A, GTC_B) + GTC_{AB}] / \max(GTC_A, GTC_B)$$

where: GTC_A is the generalised cost of travel from home to A
GTC_B is the generalised cost of travel from home to B
GTC_{AB} is the generalised cost of travel from A to B

Thus ω measures the detour involved by the worker most distant from home picking up the worker closer to home on the way home from work. As $\omega \rightarrow 0$, the location bundle approaches optimal workplace choice, as no detour is required. Strictly speaking from a car-pooling perspective the term is most applicable to one car households of two workers, as here the need to pool if both workers travel by car is absolute. However, it remains a general measure of workplace choice process for other household types, for whom having workplaces located 'cleverly' remains advantageous.

The observed values of ω demonstrated households in more rural areas tended to locate more cleverly, as might be expected. However, it should be noted that if there is a single large centre of employment distant from a rural areas, we would expect a lower value of ω than for a household located in the middle of a centre of employment. The observed data also showed variation in ω with household type.

The best estimated models of work-location were segmented by commute accessibility (four segments), and this segmentation proved significant, i.e. choice of work location varies according to commuting accessibility. The best models used a Box-Cox form for time and cost, as opposed to linear forms, and this finding was a key conclusion of the paper. The Box-Cox cost form was net travel costs (travel cost – allowance) divided by average net wage in the household. The inclusion of the ω term improved the models significantly. The model results also demonstrated workers from less accessible residence zones were more likely to locate cleverly. Higher values of time for the main worker were implied by the model results.

The R-model of residential choice uses housing supply, commute accessibility and consider surplus as variables. The consumer surplus varies between houses and apartments. A highly significant accessibility term from the W-model was estimated, which pleased the authors. They suggest this term reflects the successful description of work-location and car ownership lower down in the model.

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4.23 Whelan, G (2001) Methodological Advances in Modelling and Forecasting Car Ownership in the UK

In this paper Whelan describes the result of recent work to update the car ownership forecasting methodology employed by the UK Department of Transport, Local Government and the Regions. The work forms part of a process of incremental improvement to the UK National Transport Model. Furthermore, the resulting model is intended to become the new standard for the UK (at least, after the new car purchase and vehicle scrappage components, described in other papers reviewed in this memorandum, will have their full effect).

The 1997 National Road Traffic Forecasts (NTRF) represented the previous major change in forecasting methodology. These models were calibrated on pool cross-sectional Family Expenditure Survey (FES) data from 1971 and 1997. The model used household income, household-type (eight types, defined by number and age structure of residents), and area type (five types: Greater London, Metropolitan Districts, and three other area types defined by population density) to define probabilities of household car ownership. Two binary models were calibrated for each household type – a P_{1+} model to predict the probability of the household owning at least one car, and a $P_{2+|1+}$ model, defining the conditional probability of the household owning two or more cars, given that that they own at least one car. The ownership models used a saturation level (S) of maximum car ownership, and a linear predictor (LP) which comprised a linear combination of explanatory variables. The model variables were licences-per-adult (LPA), household income and area type.

In 1999 the Department decided to improve the scope of the NTRF forecasts to include the economic, environmental and social impacts of traffic growth so that the forecasts could be used as a tool for policy analysis. Consequently Whelan undertook an audit of the 1997 NTRF models, and identified a number of possible improvements that could be made to the models:

- To account for the increase in multi-vehicle households;
- To assess the impact of company cars on ownership levels;
- To re-examine ownership saturation levels;
- To seek to explain why London has experienced minimal growth in ownership since 1991;
- To assess the impact of employment levels on car ownership;
- To introduce sensitivity to ownership and use costs within the model.

The new ownership model, provisionally named NTRF-2001, is similar to the 1997 NTRF but incorporates the improvements listed above. To account for the increasing numbers of multi-car households, an additional sub-model was introduced, modelling the conditional probability of a household owning three or more vehicles ($P_{3+|2+|1+}$). Unlike the 1997 NTRF, multiple car ownership by single person households was allowed. Multiple car ownership by a single household would not be expected to impact upon traffic forecasts, as only one person can drive the car. However to enable accurate forecasts of total vehicle stock, modelling such households is necessary.

To account for the impact of company car ownership on total household car ownership, company car dummies were introduced into the ownership models. In the $P_{2+|1+}$ model, a new term was estimated to account for the higher probability of owning at least two cars if the first vehicle is a company car. Similarly, in the $P_{3+|2+}$ model, a term was introduced if *both* of the first two vehicles are company cars. Thus total household car ownership is predicted as a function of company car ownership. This is consistent with the findings of HCG's work in Sydney, described above.

Saturation levels have an important impact upon the results of ownership models. The 1997 NTRF models had allowed variation by household type, but not area type. In the 2001 NTRF, variation in saturation levels by both household type and area type was allowed. Saturation levels were estimated from Family Expenditure Survey (FES) data (see Whelan, Wardman and Daly, 2000). A general pattern of higher saturation levels in more sparsely populated areas was observed for each model type (P_{1+}, $P_{2+|1+}$, $P_{3+|2+}$). Furthermore, a distinct 'London' effect was found, whereby saturation levels in the Greater London area were lower than in other area types, including Metropolitan districts. This pattern is likely to reflect restrictions upon parking (particularly in Central London), high levels of congestion, and the high density of PT provision relative to other areas.

The Department has raised concerns of a correlation between employment and income in the base data for the 1997 NTRF. The improved model dealt with this issue by explicitly including an employment term within the household utility function.

When attempting to model sensitivity to ownership and use costs, it was found that there has been little variation in real costs over the period (1971-1996), and the variation that did exist was strongly correlated with time. To overcome this problem, car ownership and cost indices did enter the household utility function, but the coefficients were constrained to use cost elasticities determined from external sources. Ownership cost elasticities were determined from an aggregate power growth model, giving an elasticity value of -0.34 for 1991. A use cost elasticity of -0.1 was supplied directly from the Department.

The models are applied using a prototypical sample enumeration procedure, whereby an artificial sample is generated and the models applied to this sample. The sample combines the detailed information between model variables in the base year, together with aggregate characteristics of the forecast area. In this application, weights are defined for 24 different household categories, as opposed to each individual household. A problem found in application was poor predictive performance in zones with low or high average incomes. This problem was overcome by adjusting income levels in the base sample by a common factor so that they on average they match the true income levels in each zone.

4.24 Other models used in practice

The recently completed Swedish national model for passenger transport (SAMPERS) uses car ownership totals from an external model, which is aggregate, cohort-based.

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The Italian national transport model contains a disaggregate model for the number of cars on the household, similar to the LMS car ownership model. The Danish national model system also uses a discrete choice model for household car ownership.

The Antonin-model for passenger transport in the Paris region, is quite similar to the LMS, also with regards to car ownership: it uses control totals on licence holding from a cohort-based approach and discrete choice models for the number of cars in the household. This model includes parking cost variables.

There are many older publications on static and (pseudo)-dynamic vehicle ownership models, most of which only deal with the demand side of the car market (number of cars per household and/or vehicle type choice), such as : Berkovec (1985), Chandrasekharan et al (1991), Gilbert (1992), Gunn et al. (1978/1979), Hensher et al. (1992), Hocherman et al. (1983), Mannering and Winston (1985), Manski and Sherman (1980), Manski (1983) Kitamura and Bunch (1990), Smith et al. (1989) and Train (1986). Especially the studies by Hensher et al., Manski and Sherman and Train have been very influential; all three include disaggregate vehicle type choice models with detailed vehicle types. The models of Hensher et al. and Train also include the number of vehicles in the household and car use.

5.Typology of car ownership models including advantages and disadvantages

5.1 Comparison of existing Dutch models

First we compare the car ownership models developed for the Netherlands with each other (see Table 1).

In this table, 'car type' is used as a general term to denote all possible classifications within the car fleet (e.g. by vehicle weight, fuel type, etc.). The cells for the row 'car type' indicate which (if any) classifications of cars are being produced in the model.

FACTS is a model that can provide car ownership (number of cars and 18 car types) and car use, with short run times. In a backcasting exercise, the total number of cars was backcasted adequately, but the composition of the fleet, especially in terms of fuel types, was predicted rather badly. The forecasts for future years for the total number of cars were also in line with those from other models. The 'psychological car cost' which was included in FACTS after this exercise, might have solved the car fleet composition problem to some degree, but causes other problems in predicting the composition of the car fleet by household type. The number of car types that can be distinguished in a model and selected on the basis of variable and fixed cost only is limited. It might well be that FACTS has already passed the threshold for the number of car types that can credibly be handled in this way. Furthermore FACTS uses assumptions that might turn out to be over-restrictive for simulating more radical policy measures. A number of variables are not at all or scarcely policy-sensitive: car use for a given car, business car ownership, scrappage. Making these variables policy-sensitive would make the model more interesting for policy makers and increase its range of possible applications. In summary: FACTS seems to have worked well enough for the total number of cars owned (whether this is sufficient for future runs with large cost changes remains questionable), but improvement is needed for the composition of the fleet, business car ownership and car use.

The models of Cramer and Van den Broecke are interesting for the treatment of demand-supply interaction and demographic effects respectively, but cannot be used to yield predictions for many car types and for simulating many changes in car cost.

The LMS car ownership model is most suitable for predicting car ownership in the long run (e.g. 20 years ahead). For short run forecasts (e.g. 1-5 years), the static nature of the model is a major problem. It is not possible to include many car types in such a

model (this can be done in a car type choice model conditional on the number of cars owned per household, but not in the model for the number of cars per household itself). The model is also appropriate for allocating car ownership to household types, given a national total number of cars.

The indirect utility model of De Jong provides a consistent way of including car use (defined by total kilometrage for each car only), has policy-sensitive ownership and use, but it cannot be used to handle many car types.

The LVO models also did not include car types. Nevertheless for predicting the total number of cars, also in the short run, a panel model might be an interesting option.

The car ownership model in the Scenario Explorer can be used for a many policy simulations and gives the number of cars as well as the distribution over a number of car types. Nevertheless we think that the empirical basis of this model is not strong enough to consider it as a potential successor of FACTS.

The Dynamic vehicle transaction model (DVTM) can give the number of cars owned, many car types and car use. It can be used for the same policy simulations as FACTS. But the data set used on car types is not up-to-date and incomplete. Moreover the model does not contain mechanisms for long-term predictions (procedures for refreshing the population and introducing new supply of car types are missing); it can be applied for situations 1-5 years ahead.

The work of Golounov et al. is very interesting from an academic point of view, it has potential for extension, but as it stands does not give car type outputs and policy effects.

Conclusion

On FACTS:
If policy-advisers require outputs for more car types (as they do, see next chapter) and radical cost changes need to be possible within the model, then the present FACTS model will not be adequate. Its car type choice mechanisms cannot be further extended and therefore a new model for car type choice is needed. Also car use and business car ownership need to be treated differently. It might be possible to continue to use FACTS mechanisms for the total number of cars.

On the other Dutch models:
None of the other Dutch models is capable of replacing FACTS or the weaker parts in FACTS, although aspects of the methodology of these models could be used in the development of a new model or new modules.

5.2 Classification and comparison of model types

In this section we classify the car ownership models from the national and international literature into a number of model types and give the relative advantages and disadvantages of these types of models. An overview is given in Table 2.

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Table 1. Comparison of existing car ownership models for the Netherlands

Aspect	FACTS	Cramer	Van den Broecke	LMS	De Jong	LVO models	Scenario explorer	DVTM	Golounov et al.
Demand-supply	Demand for all cars; Supply of cars >5 years; Equilibrium mechanism	Demand and supply; Equilibrium mechanism	Demand	Demand	Demand	Demand	Demand	Demand	Demand
Level of Aggregation	Disaggregate	Aggregate	Aggregate	Disaggregate	Disaggregate	Disaggregate	Aggregate	Disaggregate	Disaggregate
Dynamic or static model	Static, but shift from new to old cars over time	Dynamic	Dynamic	Static	Static	Static (except Meurs' panel model)	Dynamic	Dynamic	Dynamic
Long or short run forecasts	Medium & long	Short, medium & long	Medium and long	Medium & Long	Long	Long (except Meurs' panel model: short, medium and long	Long	Short & medium	Short & medium
Theory	Strong basic assumptions, can be at odds with theory	Economic market equilibrium theory	No strong links	Can be based on random utility theory	Strong links	Some links with random utility theory	No strong links	Some links with random utility theory	Strong links
All cars	All	All	All	All	Private cars	All	All	Private cars, no rare, expensive brands	All
Car use	Included as kilometrage, but insensitive	Not included	Not included	In other submodels	Included, kilometrage only	Included, in most models kilometrage only	In other submodels	Included, kilometrage only	Not included
Data requirements	Moderate	Light	Light	Heavy	Heavy	Very heavy	Light	Very heavy	Very heavy
Recent estimates	Updated 1999	No recent update	No recent update	No recent update (car ownership)	No recent update	No recent update	Updated 1999	Data of 1993/4	New model on recent data
Special treatment of business cars	Yes	No	No	No	No	No	Yes	No	No
Car types	Weight, fuel type, vintage, private/business, 1st/2nd car	Old/new, 1st/2nd car	No car types	1st/2nd car	1st/2nd car (Norway model)	No car types	Fuel type, energy use, private/company 1st/2nd car	Brand-model; many distinctions Defined	No type outputs; brand-model inputs
Impact of income	Yes	Yes, average and distribution	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Impact of car cost	Fixed and variable	Fixed and variable (but no policy runs reported)	None	Fixed cost (variable cost in other submodels)	Fixed and variable (also on car use)	None	Fixed and variable	Fixed and variable (also in car use)	Fixed (no policy runs have been reported)

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Aspect	FACTS	Cramer	Van den Broecke	LMS	De Jong	LVO models	Scenario explorer	DVTM	Golounov et al.
Car quality impacts	Need to work through car cost	No	No	No	No	No	No	Yes	Through price and depreciation
Impact of licence holding	No	No	Yes	Yes	Yes	No	No	No	No
Socio-demographic impacts	Age, household size	Generation effect	Age, gender, education, marital status, employed	Age, gender, household size, workers in household	Age, gender, household size, occupation	Included	Age, household size, education, employed	Included	Limited number of variables
Impact of public transport quality	No	No	No	No	No.	In some models	Yes	No	No
Impact of style of driving on fuel efficiency	No	No	No	No	No	No	No	Yes	No
Spatial component	No	No	No	Link to 1308 LMS zones	No	No	Link to large zones	No	No
Experience in policy simulation	Applied very many times	Applied long ago for a base-case	Applied long ago for different scenarios	Only one independent application, long ago	Several policy runs, long ago	Some not applied, others long ago, no policy runs	Applied regularly	Several policy runs, 7 years ago	No applications reported
Scrappage included	Yes, insensitive	Yes, insensitive	No	No	No	No	No	Yes, sensitive	Yes, insensitive

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Table 2. Comparison of types of car ownership models

Aspect	Aggregate time series model	Cohort models	Aggregate market models	Heuristic simulation models	Indirect utility models	Static disaggregate choice models	Panel models	Pseudo panel models	Dynamic transaction models
Demand-supply	Usually only demand	Demand	Demand and supply of 2nd hand cars; Equilibrium mechanism	Demand and supply of 2nd hand cars; Equilibrium mechanism	Demand	Demand	Demand	Demand	Demand
Level of aggregation	Aggregate	Aggregate	Aggregate	Disaggregate	Disaggregate	Disaggregate	Disaggregate	Aggregate	Disaggregate
Dynamic or static model	Dynamic	Dynamic	Dynamic	Static, but shift from new to old cars over time	Static	Static	Dynamic	Dynamic	Dynamic
Long or short run forecasts	Short, medium and long (saturation)	Medium and long	Short, medium and long	Medium and long	Long	Long	Short and long	Short and long	Short & medium
Theory	No strong links	No strong links	Economic market equilibrium theory	Strong basic assumptions, can be at odds with theory	Strong links	Can be based on random utility theory	Can be based on random utility or lifetime utility theory	Weak links with random utility theory	Parts can be based on random utility
Car use	Not included	Not included	Not included	Can be included, but insensitive (can be amended)	Included	Included in some models (logsum)	Sometimes included, but in ad hoc way	Not included, but can be	Sometimes included, but in ad hoc way
Data requirements	Light	Light	Light	Moderate	Heavy	Heavy, but car ownership data usually available	Very heavy	Moderate	Very heavy
Special treatment of business cars	Usually not, but possible	Usually not, but possible	Usually not, but possible	Usually	Usually not, but possible	Usually not, but possible	Usually not, but possible	Usually not, but possible	Usually not, but possible
Car types	No car types	No car types	Limited number of car types	Limited number of car types	Very limited number of car types possible	Very limited number in holdings model, but can be very many in car type choice model	Very limited number of car types possible, but could be combined with a type choice model	Very limited number of car types possible	Very limited number in duration model, but very many in car type choice model
Impact of income	Yes	Yes	Yes (average and distribution)	Yes	Yes	Yes	Yes	Yes	Yes
Impact of car cost	Fixed and or variable cost sometimes included	None	Fixed and variable	Fixed and variable	Fixed and variable (also on car use)	Fixed cost in holdings model; variable cost can be in type choice; logsum includes variable cost	No policy runs reported, but might be possible	Fixed and variable	Fixed and variable

Aspect	Aggregate time series model	Cohort models	Aggregate market models	Heuristic simulation models	Indirect utility models	Static disaggregate choice models	Panel models	Pseudo panel models	Dynamic transaction models
Car quality impacts	No	No	No	Can be included, might have to work through cost	No	Yes in type choice	No, unless type choice added	No	Yes in type choice
Impact of licence holding	No	Yes	Yes	No	Possible	Possible in holdings model	No, but possible	No, but possible	No, but possible
Socio-demographic impacts	Limited	Many possible	Limited	Many possible	Many possible	Many possible	Many possible	Limited	Many possible
Attitudinal variables	Hard to include	Cohort-specific attitudes can be included	Hard to include	Hard to include	Hard to include	Can be included if specific questions in dataset	Can be included if specific questions in dataset	Can be included if specific questions in dataset	Can be included if specific questions in dataset
Scrappage included	No	No	Can be included	Can be included	No	No	Can be included	No	Can be included

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I. Aggregate time series models

These models usually contain a sigmoid-shape function for the development of car ownership over time (as a function of income or GDP) and a saturation level. Examples are the work done in the seventies and early eighties in the UK by Tanner (e.g. Tanner, 1981). There are hardly any of these models in the references in this report (exceptions are the aggregate model in the NRTF forecasts in the UK and Dargay and Gately (1999) for worldwide application). The main reason for this is that these models do no longer appear in the academic literature.

(Dis)advantages:
+ limited data requirements
+ dynamic
- no or limited vehicle type distinctions
- no or limited number of policy variables and demographic distinctions
- no car use.

II. Aggregate cohort models

Examples are the models of Van den Broecke for the Netherlands and cohort-based car ownership models in France and Sweden.

(Dis)advantages:
+ limited data requirements
+ demographic developments represented well
+ dynamic
- no vehicle types
- no policy variables
- no car use.

III. Aggregate car market models

An example of such a model is the Cramer car ownership model. The main structure of the TREMOVE model and of the ALTRANS model is also that of an aggregate model (with the possibility of some disaggregate submodels).

(Dis)advantages:
+ limited data requirements
+ both supply and demand side represented
- static
- limited vehicle type distinctions
- limited number of policy variables
- no car use.

IV. Heuristic simulation methods

The FACTS model belongs to this category, but another example would be the UMOT model of Zahavi (1979). The advantages of FACTS have been discussed in more detail in chapter 2.

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(Dis)advantages:
+/- intermediate data requirements and vehicle type distinctions.
+/- car use included, but can not be directly affected in FACTS
+   many policy variables on car cost.
-   depends on strong assumptions
-   static
-   car type choice only influenced by car cost (including 'psychological car cost').

V. Indirect utility joint discrete car ownership and use models

The models of Train and of De Jong for The Netherlands belongs to this category, as does the extension of this model for the original Norwegian national model.

(Dis)advantages:
+   stays very close to economic theory
+   car use included
+   fixed and variable car cost affect both car ownership and use.
-   heavy data requirements
-   hardly or no vehicle types (might be extended)
-   static.

VI. Static disaggregate car ownership and type choice models

The car ownership models in the LMS and Page et al. (2000) for new vehicle purchasing and in Birkeland and Jordal-Jørgensen (2001) fall into this category, but there were many models developed in the eighties and early nineties that used a similar approach (see the overview in section 4.24). Several of these models, including at least one for The Netherlands (e.g. Zuidvleugel, Stockholm, Sydney, Rich's model for Denmark) link car ownership via a logsum variable to a range of other travel choices, allowing impacts on car ownership of variable car costs, public transport cost and quality etc. to be represented.

(Dis)advantages:
+   behavioural foundation
+   international body of experience
+   many car types possible
+   many policy variables possible (cost and quality separated)
-   large data requirements, but data on the number of cars per household is often available (e.g. OVG), unlike data on the brand-model combination of the car.
-   no car use (but can be included)
-   static or pseudo-dynamic; problems with equilibrium assumption if applied for shorter time periods (say less than 5-10 years); could potentially be linked to supply model.

VII. (Pseudo)-panel methods

The model of Dargay and Vythoulkas (1999) is a pseudo-panel (i.e. repeated cross-section for the same population groups) model; Meurs (1993) estimated discrete choice panel models for car ownership. Golounov et al. (2001) is also a panel model of car purchasing behaviour.

The LMS car ownership model falls into this category as well as into the discrete choice model category, as it was originally estimated on a repeated cross-section (OVG 1979 and 1983) with explicit time dependence (trend terms). This is described in the memo 'Extensions and improvements to models of driving licence holding', which contains an annex on car ownership and can be found in HCG, 1989.

(Dis)advantages:
+   dynamic (the models give separate short and long run effects)
+   car use included in some of Meurs' models (not in Dargay and Vythoulkas or Golounov et al.)
+   theoretical foundation (Golounov et al.)
-/+ very heavy data requirements (panel) or modest data requirements (pseudo-panel);
-   no vehicle types (but could be combined with a car type choice model)
-   no policy variables (in models reviewed, not impossible in panel models).

VIII. Dynamic car ownership models with vehicle type conditional on transaction

Examples of this category are Brownstone et al. (2000) and the Dutch DVTM. In these models, duration models determine whether a household will do a vehicle transaction. If a transaction involves purchasing a car, the vehicle type choice model is used.

(Dis)advantages:
+   dynamic, can give time path
+   many vehicle types possible
+   many policy variables possible (cost and quality separated)
+   car use can be included
-   heavy data requirements (panel or retrospective data and/or SP data).

Conclusions

Aggregate time series, cohort models and aggregate car market models do not appear very promising for the development of a full-fledged car fleet model, since they lack vehicle types and policy variables. They could only be used to predict a total number of cars in a future year (especially medium to long run), which would then be used as a starting point in other more detailed models. But even for this other types of models offer more possibilities of making the predictions policy sensitive (which is important for simulating large car cost changes). Cohort models remain useful for predicting licence holding, itself a potentially important determinant of car ownership.

Heuristic simulation models of car ownership do not offer extensive possibilities for including many car types either. On the other hand they can fruitfully be used for predicting the total number of cars with some policy sensitivities.

The static car ownership models can include discrete car type choice models with many car types. But for short-run and medium-run predictions they are less suitable, due to the assumptions of an optimal household fleet in every period. For such time horizons it is much better to predict only the *changes* in the car fleet, instead of

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predicting the size and composition of the entire car fleet in each period. For a long term prediction of the number of cars and the distribution over households and car types these models are more suited, though cohort effects on total car ownership might not be well represented.

Discrete car type choice models can be added to panel models for modelling the transitions between car ownership states of households. Panel models could then be used to give the evolution of the fleet, starting from the present fleet. For medium and long term forecasts, this can only be carried out if there also is a mechanism for predicting changes in the size and composition of the population (e.g. dynamic micro-simulation, or sample enumeration at different points in time).

Pseudo-panels offer an attractive way to get short and long run policy sensitive forecasts of the total number of cars (including the cohort effects), but can not take over the role of a choice-based model for the number of cars and car type.

Dynamic transaction models include duration models for the changes in the car ownership states of the households, and in this respect are a continuous time alternative of the discrete time panel models. They have been combined with detailed policy-sensitive type choice models. For short to medium term forecasts this combination seems a highly attractive option. For longer term forecasts (10-20 years ahead), as for panel models, a population refreshment procedure needs to be included. Long term changes in the supply of car types can be simulated through scenarios (this also goes for panel models combined with type choice).

6. Outcomes of the interviews on requirements for a car ownership model

The outcomes of the interviews with policy advisers are described in memorandum 1 (in Dutch), which is attached to this report as Annex 1. This memo was discussed with the client steering group. After this, the client made an updated list of the requirements for a new policy-sensitive car ownership model, mainly based on these interviews. The requirements are:

- A model for vans, for lorries and for buses was also requested in the interviews. It was agreed with the client steering group that this study would continue to deal only with passenger car models. If however possibilities would be found to include vans in the new model to be developed, this would be appreciated, given the growing importance of vans in private passenger transport.
- The model should include the number of cars per household (highest priority, prio 1).
- The model should include very many vehicle types (detailed distinctions), many more than are in FACTS now:
    - Highest priority (prio 1):
        - fuel type
        - weight
        - vintage or age of the car
        - private versus business car
        - first, second or third car in household (third car only if this can be done without serious complications to the model)
        - new or second-hand car
    - Lower priority (prio 2):
        - type code of industry (e.g. small, medium, large, sports car, etc.)
        - year that car type was officially approved
        - average energy consumption label, safety label (EURO NCAP)
        - accessories without purchase tax (BPM), safety equipment, equipment that affects energy use (especially air conditioning)
- Forecast horizon should range from 1 to 10+ years[1]; a dynamic model is preferred. For the short run forecasts the focus is on fiscal measures and financial effects; for the long run the emissions impacts are also very important. Prio 1.

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[1]   For providing LMS forecasts, horizons up to 20-30 years are needed. For these long-term forecasts, a dynamic model which represents the entire time path between the base and forecast years is scarcely credible. A dynamic model with bigger time steps (e.g. 5 years) might be possible here.

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- Including car use is required (also by fuel type and weight and by first, second or third car in the household). Prio 1, but if this poses extra complications, prio 2.
- More household types are required (now in FACTS 3 income classes, 3 age categories and 2 household size classes, giving 18 household categories in total); the household categorisation of the LMS prototypical sample and of the NSES model within the LMS were suggested by the steering group. Prio 1.
- Financial outputs are required as well:
  - income effect for population groups, effect for firms. Prio 1
  - government revenue. Prio 1.
- The likely penetration of future car types (e.g. hybrids) is requested. Prio 1.
- The new model should be compatible with an emissions module (similar to the one in FACTS now, preferably with a feedback of fuel consumption to car cost) and LMS. Prio 1.
- The model should have a spatial component (e.g. inclusion of degree of urbanisation); In terms of zones of residence of the households it should be compatible with the LMS: implementation should be possible for all (345) LMS zones. Prio 1.
- Policy measures that the model should be able to simulate are (all prio 1):
  - variabilisation of car cost
  - subsidies, e.g. on low emission vehicles
  - fuel tax policies
  - lease market policies, e.g. fiscal measures
  - accelerated scrappage subsidies.

This list of requirements is summarised and sorted by priority in Table 3.

Table 3. Requirements for new car ownership model, by priority

Highest priority requirements	Secondary requirements
Number of cars per household	Distinction by industry type code
Distinction by fuel type	Distinction by year of official approval of the car type
Distinction by weight	Average energy consumption label by car type
Distinction by vintage or age of the car	Safety label by car type
Distinction by private/business car	Accessories without purchase tax
Distinction by first/second/(third) car in the household	Safety equipment
Distinction by new/second-hand	Equipment affecting energy use
Forecast horizon 1-10+ years	Dynamic model
Car use	
Distinction by household type	
Income effect for population groups; effect on firms	
Effect on government revenue	
Likely penetration of future car types	
Compatible with emissions module and LMS	
Spatial component	
Can simulate variabilisation	
Can simulate subsidies, e.g. on low emission vehicles	
Can simulate fuel tax policies	
Can simulate lease market policies	
Can simulate accelerated scrappage subsidies	

7. Scenarios for developing a new car ownership model

7.1 Preferred model

A model that can handle all the above questions does not exist and is not likely to be developed in the very near future. We compared the model types with the requirements and our opinion is that the model type that can fulfill most requirements is the dynamic car ownership model (either a dynamic vehicle transactions model or a dynamic Markov-type panel model) with type choice conditional on vehicle transactions. This we regard as the preferred model, both because it represents the state-of-the-art in car ownership modeling and because it scores best when compared to the requirements described in chapter 6. This is worked out below.

Passenger car model

The proposed model is a passenger car model. Maybe vans can be included; we shall return to this issue below.

Number of cars per household

In a dynamic vehicle transaction model, such as the DVTM or the model for California of Brownstone et al., the number of cars per household is predicted on the basis of current car ownership of the household. A duration model predicts the time (e.g. in months) until the next vehicle transaction and the type of transaction (e.g. replacement, disposal, adding a car). In application the model is used in discrete time steps, for instance a year. For every household that does not transact in this year, the vehicle ownership situation of year t+1 will be equal to what it was in year t. For other households there will be a transaction and, if this involves replacing a car or adding a car, the conditional type choice model will be used to get new type choice probabilities. In this way the duration model can be used step by step, each time predicting transactions on the basis of the car ownership situation of the previous year. Vehicle scrappage transactions could also be integrated in such a model: with the passage of time, vehicles age and scrappage (other than accident-related scrappage) becomes more likely.

Alternatively, a panel model might be used to predict the car transactions from year to year. A panel model of household transitions between the different car ownership situations (Markov model) can serve the same purpose as a duration model. The alternatives in such a discrete choice model are the transitions that are possible from

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year t to year t+1, such as from one car to two cars, or from one specific car to another car (replacement), or scrappage.

Both for a duration model and a panel model of vehicle transactions, short run predictions (up to five years ahead) might be done without updating the population in the sample used. For medium and long run forecasts, the population needs to be updated.

The most sophisticated method for this is dynamic micro-simulation of 'birth' and 'death' of households and changes within households. This can be done by using duration models for the time that a household spends in a certain state (household lifecycle stages). Such duration models for household demographic and socio-economic changes can be combined in a consistent way with duration models for vehicle holdings, as has been done in the Californian car ownership project. Because duration models predict changes in continuous time, they can give all intermediate time steps. If one uses Markov models for car ownership changes, then the time steps need to be determined by the researcher (e.g. years, five-year periods). As soon as the time interval has been chosen, the Markov model cannot predict for shorter time intervals. The micro-simulation of household change needs inputs from the medium and long term CPB scenarios (e.g. on income and population over time), but also additional restrictions to remain consistent with the CPB scenarios.

A simpler method is to use the model for a specific sample recursively and afterwards reweigh the sample to reflect the changes in the household distribution between the present and the situation 10, 15 or 20 years ahead (based on information from the CPB scenarios). The latter method avoids the spurious accuracy and complication of modelling the generation and termination of households, but loses the dynamic aspect of aging of the households themselves.

This model will produce one of the vehicle type distinctions mentioned in the previous chapter: first and second car in the household. Including third cars would complicate the model substantially, since the number of transaction types would increase considerably.

Vehicle types

Conditional on specific vehicle transactions, the discrete vehicle type choice model will be applied. We recommend using as smallest observable unit (choice alternative) the brand-model-vintage combination, e.g. Opel Astra, 1.8 diesel of 1999. A similar distinction was used in the DVTM, which had about 1000 alternatives. Most of the vehicle type choice models in the literature also use brand-model-(vintage) alternatives instead of more aggegated vehicle categories. This distinction is not proposed here because we want to predict by brand (interesting for General Motors, not so much for government), but because:

- This specification is clear, for the researchers but especially for the consumers: this is the kind of vehicle alternative that we can can refer to when interviewing a respondent. Moreover, this is the kind of choice alternative that many consumers will have in mind when deciding on the type of vehicle.

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- This specification can be aggregated in many different ways to yield most of the required outcomes:

  - Fuel type (diesel versus petrol, for LPG, which is built in after producing the car, an extra distinction needs to be added, which can be done in a new sample survey)
  - Weight
  - Vintage
  - New or second hand
  - Type code of industry
  - Year that car type was officially approved
  - Energy consumption label, safety label.

Also average emission rates and fuel consumption for the brand-model-vintage combination can be used to give outcomes on these variables.

Specific BPM-exempt accessories, safety equipment and equipment affecting energy consumption usually vary even within brand-model-vintage combinations. To get the distribution in for these attributes, a post-processing of the outcomes of the car type model will probably be necessary using exogenous fractions, which depend on scenario assumptions.

Vans can be included as a number of special brand-model–vintage combinations, if data on the household possession of these would be available.

Business cars

The separate identification of business cars is specified by the client as being of the highest priority. Moreover, the factors influencing the ownership of business cars, as well as the types of cars used for this purpose, are different from those affecting cars privately owned, so that accurate and policy-sensitive forecasting of numbers and types of cars can be improved by making this distinction. In the Sydney discrete choice system, as in FACTS, business car ownership is predicted first and independently of private car ownership, which is then predicted conditional on the business car holdings of the household. However, in the UK New Cars model of Page et al., the total number of cars is predicted first and the manner of car holding (business or private) is predicted conditional on this. The choice between the two approaches depends on the results obtained from empirical models of the current situation in The Netherlands.

Either way, business cars can be treated in the same way as private cars with respect to the choice of type, dependence on socio-economic factors etc.. This could also include vans owned by companies, but being used by households for a mixture of private and business purposes.

As in the case of the Sydney and the UK model for business cars, the data to be used can be a household survey of (changes in) car ownership. It is possible to develop a model for company cars based on the production structure of the economy, as happened in FACTS, but operating, policy-sensitive models can also be constructed

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on the same data as for private cars. In the Sydney model for example, the variables influencing company car ownership are: household income, age and gender of the head of the household, cost of parking and composition of the household. Occupation and sector were tested, but not significant.

Forecasting horizon

This model, can be applied both for the short and long term, but because it starts from the present situation, it is more suited for short run forecasts, and the further one gets away from the present the more synthetic and less reliable the outcomes will get. Given the complexity of refreshing the population sample for long run forecasts, a simpler approach for the total car ownership in the long run (e.g. on the basis of a cohort model or a pseudo-panel model) might be considered. This could then provide the control total for the LMS. However, it is not desirable to have different car ownership forecasts that are not consistent with each other over time. Therefore we prefer to generate all forecasts from the same dynamic transactions (or panel transitions) model.

It may be possible to find ways of eliminating some of the intermediate steps without losing consistency with the short-term forecasting model. For example, it may be possible to work with longer steps. Alternatively, it may be possible to 'jump' several years and then allow the model to find a new stable situation in a short period (e.g. 5 years) before the forecast horizon. Elimination of intermediate steps is not primarily desirable to reduce the run time of the model, more it is to avoid dependence of the results on possibly minor features that might multiply over a long series of applications of the model.

Car use

A car use regression equation, for a limited number of car types can be added to the above model, as has been done in the DVTM and the Californian model (with fixed and variable car cost). These equations can be estimated by instrumental variables.

Alternatively, depending on the accuracy required, the LMS can be used. The advantage of using the LMS is that far more detail of the nature of car use is obtained (length of journeys, location of emissions (including noise), purpose of journeys and hence potential for reimbursement etc.). The disadvantage is that it is more time-consuming. However, the main time consumption in the LMS is in the calculation of capacity restraint on the road network. While this is burdensome, it also makes the forecasts more accurate and a car use model that omitted this equilibration would be likely to be inaccurate for large changes in car cost. When capacity 'feed-back' can be ignored, the LMS can be run quite quickly.

Household types

In models on disaggregate data such as the above models, many household types can be distinguished. It seems probable that the distinctions that are required will be contained within the quite rich data specification of the OVG sample and therefore that the new models can be connected to the LMS prototypical sampling.

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For input into the LMS travel choice models, a subset of these distinctions is required and problems of compatibility do not arise.

Financial outputs

Different income groups and the way these are affected can be distinguished in such models. The impacts on the government revenues can also be calculated by summing over all households and vehicle types.

New car types

If in the future new car types become available (and older cars disappear), the attribute values of the new types need to be described in an exogenous car type file, which will be the choice set for application of the car type model in a future year (can be done for various scenarios). The existing car type model coefficients will give the way people trade-off these attributes. Hybrid and electric cars can be included in the forecasts, but only if attributes that are especially relevant for such cars have been included in the model (range, re-charging options). This is only possible if the model is (partly) based on stated preference data, with such alternatives and attributes. SP data were used in the model of Brownstone et al. and in Hensher and Greene (2000).

Demand-supply equilibration

Neither the Dutch DVTM or the dynamic car ownership model for California contains a demand-supply equilibrium mechanism. For new cars in The Netherlands, such a mechanism is clearly not needed, since the new car market is an international market in which the Dutch demand fluctuations will not have an important effect. However, on the second-hand market, the assumption that supply follows demand for The Netherlands might be too strong (although within the EU it has become rather easy to import and export used cars). Supply of second-hand cars can be derived from the car fleet by vintage of previous years in combination with scrappage equations. This can be confronted with second-hand car demand, as happens in the FACTS RAS-procedure, with a feedback to demand in case of disequilibrium. We recommend that the new model will have a RAS-like demand-supply equilibrium mechanism.

Spatial component

It might be possible to find significant location-specific variables, such as degree of urbanisation when estimating the above models. However an allocation of cars to 1308 zones, as happens in the LMS, would be too much for a dynamic car ownership model that should also work with more than 1000 vehicle types. This could make the model untraceable, slow and less stable. We recommend that the allocation to zones will take place after applying the car ownership model, e.g. using procedures as are in the LMS now.

An important theoretical issue is how accessibility impact on car ownership. When this impact has been investigated, it has been found to be significant (e.g. in Zuidvleugel, Stockholm, Sydney and Rich's Denmark model), but it is not included in many large-scale model systems, such as the LMS. The inclusion of such an effect is useful in allowing a wide range of variables, including variable car costs, to be

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included in the car ownership model in a way that is internally consistent and satisfies economic theory. A potential problem is that it is not certain the accessibility influences car ownership: it may be the case that car owning households choose to live in areas where car travel is relatively superior, while non-car-owning households choose to live in areas well served by public transport. Rich's model may give some insight into this issue. There is also considerable complexity in this approach, but the alternative is to give substantial weight to location, e.g. described by urbanisation level, which gives no 'handle' for policy or insight into behaviour.

Policy measures

The impacts of variabilisation, subsidies and fuel tax policies could be tested with the preferred model as described. In a model structure such as the DVTM, changes in the variable car cost will have an influence on:

- The timing of the vehicle transactions (e.g. postponing an acquisition or accelerating a replacement)
- The vehicle type choice (e.g. a higher probability of choosing a fuel-efficient car in case of higher variable car cost)
- Vehicle use (e.g. a reduction in annual kilometrage in case of higher variable car cost).

A change in the fixed car cost will have an impact on the same choices. In order to get reliable results for large changes in variable and/or fixed car cost –larger than have been observed in the RP data– SP questions about reactions to large cost changes need to be asked. A paper reporting on such SP experiments is Rosenberg et al., 1997.

Changes in the taxation rules can have an impact on the choice between company/lease cars and privately owned cars. The representation of lease cars is required as a first priority for the new model. It appears to be of little interest to predict how businesses finance their cars (should a firm purchase the cars or lease the cars?), the lease car issue that is of interest to the –government– users of a car ownership model relates to private car ownership: ownership, type choice and use of lease cars by households may react differently to policy measures than that of privately owned cars.

The choice of leasing or outright ownership can be represented in the model in an appropriate structure with the choice of the type of car itself (possibly including vans). The advantage of leasing in terms of fiscal benefit will depend on annual kilometrage, percentage of business use and income, all of which are variables that are required in any case. A difficulty may arise in obtaining sufficient detail about other tax deductions available to the individual, which may well influence his or her benefit from leasing.

To include the impact of accelerated scrappage subsidies in the model it is necessary to base the scrappage transactions decisions on SP data (as in de Jong et al, 2001).

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7.2 Fall-back option 1

Developing the above model would certainly require a major effort and could take several years. A fall-back option, which would involve considerably less effort, and could also be considered for a model to be used while the above-mentioned system would be under construction, is a further extension and adaptation of FACTS.

It may be possible to add a policy-sensitive car use equation (also with a random component) to FACTS, to replace the random procedure in FACTS 3.0. This would make car use more sensitive to policy changes. The possibility of linking to the LMS, with the advantages and disadvantages discussed above, remains.

Also, it might be considered to replace the FACTS car type choice component by a disaggregate type choice model, and let the existing FACTS structure explain the number of cars owned. FACTS has been quite successful for this and less so for type choice (but please note that the possibilities of FACTS for future runs for large cost changes will be rather limited). This type choice model then could give more detailed outcomes than the present 18 car types and cost and other influences on type choice would be separated. This is in our view the most urgent improvement needed for FACTS. Most of the resources required for developing the preferred model (especially collection of new data, both RP and SP; estimation of the type choice model) are also needed for the type choice model in fall-back option 1. In other words, the most expensive part of the preferred option is also included in this fall-back option. This makes fall-back option 1 easier and somewhat faster to develop and less sophisticated than the preferred model, but not much cheaper than the preferred option (see section 7.4).

The main difference between the preferred model and fall-back option 1 is that the former contains a disaggregate dynamic component for the number of cars (the duration or Markov models) and the latter does not: the number of cars follows from the FACTS mechanisms. Both models will have a new vehicle type choice model. The preferred model will be more suitable than FACTS for giving the short run (1-5 years) impact over time and will also be able to produce more policy sensitive forecasts of the number of cars than FACTS.

7.3 Fall-back option 2

Both the preferred option and option 2 require the acquisition of new data on choice of vehicle brand-model-vintage combinations, which would lead to considerable survey cost. The basic idea of fall-back option 2 is to start from presently available data, notably the OVG, and construct new models that can be based on these data sources and nevertheless will lead to an improvement of FACTS in the main problem areas. The current OVG questionnaire contains the following questions on the car, which the main user of the car should answer:

- Fuel type (LPG, diesel, petrol)
- Approximate annual kilometrage
- Vintage (year of interview, 1 year before, 2 years before, ...11 year before, older)
- Weight in kg

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- Private or company ownership
- Lease-car or not.

We would prefer a vehicle type choice model with brand-model-vintage as choice alternatives, for reasons described above. However, the OVG does contain all the distinctions that are of the highest priority (see chapter 6) for a new car ownership model. It will be difficult if not impossible to add the 'priority 2' distinctions when using OVG, because these rely on finer segmentations than the OVG can give.

Advantages of using the OVG are:

- It contains all the information on persons and households that is used in the LMS.
- It has a very large sample size and can also be used as repeated cross section (or even pseudo-panel); the questions on the car have been the same for several years now.
- It already exists: no new data collection needed.

Disadvantages of using the OVG (in comparison to new data collection, tailored to generate the data required for the preferred model) are:
- The choice alternatives in reality are more detailed; variables for the number of elementary alternatives will have to be added to the type choice model and could become very important; variables for brand-royalty and similar effects can not be estimated.
- The OVG gives the number and type of cars at a certain point in time, not the car type choice conditional on a vehicle transaction (though by selecting the cars of the same year as the survey, type choice for new cars can be approximated). We do not know when the car was purchased. So we can only relate the type choice, which took place at an unknown previous point in time, with the current household and person attributes. It also does not contain attributes of the previous car, which can be helpful in predicting the type of the next car.
- The OVG does not give information on transactions, so it can not be used to estimate a disggregate duration or Markov panel model for vehicle transactions.
- The OVG does not contain SP data, so it can not be used to get SP observations on large cost changes, future car types (including electric cars and hybrids) and accelerated scrappage schemes.

In fall-back option 2, the OVG would be used to estimate a fuel type-weight-vintage-ownership choice model. FACTS would be retained to produce the number of cars in the household. For car use, FACTS would be enhanced or the LMS would be used.

7.4 Development of the preferred model and fall-back models

Data collection

In the Netherlands there are no recent data, which can link number of vehicles owned and brand-model-vintage of the vehicle to household types. The OVG does not

contain brand and model and the PAP has been abandoned. New data would need to be collected both for the preferred and the fall-back model 1[2].

The DVTM was estimated on a new mail-back questionnaire, developed for this project, which was distributed to members of the existing panel of car drivers of the Consumentenbond and ANWB. The original duration, type choice, car use and energy use models were estimated on the 1992 wave which contained retrospective questions on the last car transaction (about 4,000 car drivers). Later, the duration models and type choice were re-estimated using information on actual transactions (not retrospectively) from three waves of panel data: 1992, 1993 and 1994. There were no SP experiments in this data set.

The data used by Brownstone et al. (2000) came from two waves of a panel survey in California. First, respondents were recruited by telephone (also to customise the SP), then they had to complete a mail-back SP interview. The RP data on actual vehicle purchases came from comparing wave 1 and wave 2, which were 15 months apart, for the same respondents. Wave 1 had almost 5,000 households and wave 2 almost 3,000.

Sample sizes of several thousands respondents are needed to estimate the type choice models. For the transaction models similar sample sizes are required. This makes SP interviews with an interviewer and a laptop too costly. Two waves is better than retrospective questions, because the long run memory of respondents might not always be very reliable: the question is whether people accurately recall their last car transaction. Given that expensive cars need to be included as well, the Consumentenbond/ANWB car panel is not sufficient.

One option would be to carry out a new survey that starts by recruiting respondents (by phone). Two waves (with net sample sizes of 5,000 and 3,000 respectively) mail-back interviews or computer-assisted telephone interviews (CATI) will then cost 100,00-150,00 Euro in total. This includes SP experiments on new car types (electric, hybrid, other fuels), large cost changes and on accelerated scrappage schemes, but not much can be saved by only asking RP questions. If the first wave contains retrospective data on the last vehicle transaction, a preliminary duration model of car ownership can be estimated on this data, as was done in the DVTM project, which can later be replaced by a duration model on observed transactions between two waves of data.

Another option would be to use the Consumentenbond car panel again, with an additional survey among owners of expensive cars (including many typical company and lease-cars). The Consumentenbond car panel still exists and AVV is considering using it for a new annual questionnaire. The fieldwork cost per wave for the questionnaire that was used for the DVTM in 1992-1994 was about 18,000 Euro. The questionnaire for the new model will probably be longer (SP experiments need to be added). Whether this option is attractive depends to a large extent on the possibilities for selecting owners of expensive cars. If the car registration data can be used for this, this selection can be done at low cost. However, if the registration data could not be

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[2] Unless the CBS could be convinced to add vehicle brand and model to the OVG questionnaire.

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used, owners of expensive cars would have to be selected by methods like randomly calling households (possibly in wealthier areas) and asking for the car brand-model combination. This would be an inefficient procedure and would reduce the savings that could be expected from using the existing Consumentenbond car panel and a relatively small new survey instead of a full new survey. The field work cost estimate, that follows later in this chapter, is only an indication, roughly based on the cost in 1992-1994. We have not asked the Consumentenbond for a new cost estimate.

The optimal time between the two waves in the Netherlands depends on the amount of changes in the household location and in the car ownership status. Both of these change probably at a lower rate than in the US and therefore the optimal interval will be between 18 and 24 months.

Model structure and estimation

The preferred model system consists of:

- Duration models for the time between vehicle transactions (and the type of transaction: disposal, replacement, acquisition, also scrappage) to explain the total number of cars. An alternative option for this would be a Markov-type panel model. Duration models predict the time until the next vehicle transaction in continuous time, which can be simulated by looking at any possible time interval. Markov models use a pre-determined time interval and predict changes in vehicle holdings between two such time periods.

- Vehicle type choice models for the choice of a brand-model-vintage alternative for all vehicle transactions that involve purchasing a(nother) car. These choice alternatives can be aggregated to get the composition of the fleet in terms of most of the required distinctions. Some less important distinctions need to be made by a post-processing procedure.

- Regression equations for the use of every car in the household, measured in terms of annual kilometrage, or through a logsum linkage with the LMS.

- A micro-simulator for 'birth' and 'death; of households and transitions between households types over time; a simpler but less consistent (in terms of dynamics) alternative would be to reweigh a given sample of households in each time period.

- Possibly a model for the number of business cars (company-owned and lease cars), depending on (sectoral) economic development , which need to be allocated to households. Private car ownership could be made conditional on the outcome of this.

- An allocation procedure to the 1308 LMS zones (also post processing).

Such models have been developed before, particularly as components of the Dutch Dynamic Vehicle Transactions Model (DVTM) and/or the model for the likely penetration of electric and hybrid cars for California.

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Vehicle type choice models and panel models for the number of vehicles can be estimated with ALOGIT, developed by Hague Consulting Group. This includes the possibility of mixed logit models, as have been used for the California model for type choice and as would be needed for panel models (to account for the correlation over time of the same respondents). Probit models, as have been used in some Markov models, can also be estimated by ALOGIT (by using simulated maximum Likelihood methods). Duration models can be estimated with the LIMDEP software, as was done in the DVTM project. This also goes for regression equations for annual kilometrage (instrumental variables estimation).

Indication of the required time and budget

Below we provide indicative money and time budgets for the preferred model and the fall-back option. However, this is not a project proposal. RAND Europe is interested in doing research on this, and if AVV would request it, we would be happy to submit a proposal with a more detailed cost estimate.

Preferred model:
- Survey design: 50,000 Euro
- Fieldwork:
  - full new survey: 125,000 Euro, or
  - Consumentenbond car panel plus new survey among owners of expensive cars using registration data: 85,000 Euro, or
  - Consumentenbond car panel plus new survey among owners of expensive cars selected without using registration data: 100,000 Euro
- Model specification and estimation: 125,000 Euro
- Testing and implementation: 60,000 Euro
- TOTAL: 320,000-360,000 Euro.

Fall-back option 1:
- Survey design: 40,000 Euro
- Fieldwork:
  - full new survey: 100,000 Euro, or
  - Consumentenbond car panel plus new survey among owners of expensive cars using registration data: 75,000 Euro, or
  - Consumentenbond car panel plus new survey among owners of expensive cars selected without using registration data: 90,000 Euro
- Model specification and estimation: 50,000 Euro
- Changing FACTS and integration of models: 40,000 Euro
- Testing and implementation: 40,000 Euro
- TOTAL: 245,000-270,000 Euro.

Fall-back option 2:
- Acquiring OVG for several recent years: PM
- Model specification and estimation: 50,000 Euro
- Changing FACTS and integration of models: 40,000 Euro
- Testing and implementation: 40,000 Euro
- TOTAL: 130,000 Euro.

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Time required for data collection and model development:
- Preferred model: 3 years
- Fall-back model 1: 2.5 years.
- Fall-back model 2: 1 year.

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8. Summary and recommendations on new car ownership model

Background and objectives

RAND Europe has carried out out a research project on car ownership modelling, called 'Audit of car ownership models', for the Transport Research Centre (AVV) of the Dutch Ministry of Transport, Public Works and Water Management.

In this report, a review was presented of existing models for car ownership. This review contains a description and comparison of existing Dutch car ownership models and a review and comparison of recently developed models in the international literature and models used in practice. The provision of this review was one of the objectives of this project. The other objective was to recommend on directions for potential development for improving the AVV car ownership models.

The car ownership model that AVV uses for most applications is the so-called FACTS model (Forecasting Air pollution through Car Traffic Simulation). FACTS also provides the future total number of cars that is used as an external total in the Dutch national Model System (LMS) for traffic and transport.

The background of this audit is the desire of AVV to obtain information on the basis of which a well-founded decision can be made on the development of an improved car ownership model, that can produce robust and sensible car ownership forecasts for all kinds of variants of variabilisation of the road tax (MRB) and car purchase tax (BPM).

As part of this project, a number of policy advisers was interviewed about what types of outputs are required from a car ownership model, what should be the forecasting horizon and what should be the policy variables to be simulated.

AVV's current car ownership model

FACTS is a model that can provide car ownership (number of cars and 18 car types) and car use, with short run times. In a backcasting exercise, the total number of cars was backcasted adequately, but the composition of the fleet, especially in terms of fuel types, was predicted rather badly. The forecasts for future years for the total number of cars were also in line with those from other models. The 'psychological car cost' which was included in FACTS after this exercise, might have solved the car fleet composition problem to some degree, but causes other problems in predicting the composition of the car fleet by household type. The number of car types that can be distinguished in a model and selected on the basis of variable and fixed cost only is limited. It might well be that FACTS has already passed the threshold for the number

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of car types that can credibly be handled in this way. This means that the car type choice component in FACTS can not be extended to include more distinctions, whereas the policy advisers require many more distinctions within the car fleet. Furthermore FACTS uses assumptions that might turn out to be over-restrictive for simulating more radical policy measures. A number of variables are not at all or scarcely policy-sensitive: car use for a given car, business car ownership, scrappage. Making these variables policy-sensitive would make the model more interesting for policy makers and increase its range of possible applications. In summary: FACTS seems to work well enough for the total number of cars owned (whether this is sufficient for future runs with large cost changes remains questionable), but improvement is needed for the composition of the fleet, business car ownership and car use.

Recommendations: the preferred model

We recommend to develop a new model system. The preferred model system consists of:

- Duration models for the time between vehicle transactions (and the type of transaction: disposal, replacement, acquisition, also scrappage) to explain the total number of cars. An alternative option for this would be a Markov-type panel model.

- Vehicle type choice models for the choice of a brand-model-vintage alternative for all vehicle transactions that involve purchasing a(nother) car. These choice alternatives can be aggregated to get the composition of the fleet in terms of most of the required distinctions. Some less important distinctions need to be made by a post-processing procedure.

- Regression equations for the use of every car in the household, measured in terms of annual kilometrage, or through a logsum linkage with the LMS.

- A micro-simulator for 'birth' and 'death; of households and transitions between households types over time; a simpler but less consistent (in terms of dynamics) alternative would be to reweigh a given sample of households in each time period.

- Possibly a model for the number of business cars (company-owned and lease cars), depending on (sectoral) economic development , which need to be allocated to households. Private car ownership could be made conditional on the outcome of this.

- An allocation procedure to the 1308 LMS zones (also post processing).

Such models have been developed before, particularly as components of the Dutch Dynamic Vehicle Transactions Model (DVTM) and/or the model for the likely penetration of electric and hybrid cars for California.

This preferred new model could be used for a **large number of applications**:

- It can explain the number of cars in the Netherlands and the distinction between households with 0, 1 or 2 and more cars, as well as the sensitivity of car ownership to fixed and variable car cost over time.

- The alternatives in the vehicle type choice model can be aggregated in many different ways to give the composition of the fleet in terms of: fuel type, weight, vintage, new or second hand, industry type code, year that the type was officially approved, energy consumption label and safety label. Other distinctions could be obtained by post-processing the outcomes. If data allows, vans can be added here too.

- The model can be used to predict the likely penetration over time of new vehicle technologies, such as electric and hybrid cars and cars using other fuels (e.g. hydrogen).

- The model can also provide forecasts of the fleet distinguishing between privately owned cars and business cars.

- The model can give forecasts for the short run (such as government revenues and income effect on different population groups, one year ahead, two years ahead, etc.) and long run (such as emissions more than 10 years ahead).

- The model can predict car use as well, including effects of fixed and variable car cost on car use.

- The model can be linked with available emissions modules and with the national traffic and transport model system LMS.

- The impacts of variabilisation, subsidies and fuel tax policies could be tested with the preferred model, as well as accelerated scrappage subsidies and fiscal policies affecting the lease car.

Recommendations: fall-back option 1

Developing the above model would require a major effort, especially since new data on car ownership and car types owned by households would need to be collected. This data collection will include at least two waves (panel data) and both revealed and stated preference data. A fall-back option would be a further extension and major adaptation of FACTS.

It may be possible to add a policy-sensitive car use equation (also with a random component) to FACTS, to replace the random procedure. This would make car use more sensitive to policy changes. The possibility of linking to the LMS, with the advantages and disadvantages discussed above, remains.

Also, it might be considered to replace the FACTS car type choice component by a disaggregate type choice model, and let the existing FACTS structure explain the number of cars owned. FACTS has been quite successful for this and less so for type choice (but please note that the possibilities of FACTS for future runs for large cost

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changes will be rather limited). This type choice model then could give more detailed outcomes than the present 18 car types and cost and other influences on type choice would be separated. This is in our view the most urgent improvement needed for FACTS. Most of the resources required for developing the preferred model (especially collection of new data, both RP and SP; estimation of the type choice model) are also needed for the type choice model in fall-back option 1. In other words, the most expensive part of the preferred option is also included in this fall-back option. This makes fall-back option 1 easier and somewhat faster to develop and less sophisticated than the preferred model, but not much cheaper than the preferred option.

The main difference between the preferred model and fall-back option 1 is that the former contains a disaggregate dynamic component for the number of cars (the duration or Markov models) and the latter does not: the number of cars follows from the FACTS mechanisms. Both models will have a new vehicle type choice model. The preferred model will be more suitable than FACTS for giving the short run (1-5 years) impact over time and will also be able to produce more policy sensitive forecasts of the number of cars than FACTS.

Recommendations: fall-back option 2

Both the preferred option and option 2 require the acquisition of new data on choice of vehicle brand-model-vintage combinations, which would lead to considerable survey cost. The basic idea of fall-back option 2 is to start from presently available data, notably the OVG, and construct new models that can be based on these data sources and nevertheless will lead to an improvement of FACTS in the main problem areas. The current OVG questionnaire contains the following questions on the car, which the main user of the car should answer:

- Fuel type (LPG, diesel, petrol)
- Approximate annual kilometrage
- Vintage (year of interview, 1 year before, 2 years before, ...11 year before, older)
- Weight in kg
- Private or company ownership
- Lease-car or not.

We would prefer a vehicle type choice model with brand-model-vintage as choice alternatives, for reasons described above. However, the OVG does contain all the distinctions that are of the highest priority (see chapter 6) for a new car ownership model. It will be difficult if not impossible to add the 'priority 2' distinctions when using OVG, because these rely on finer segmentations than the OVG can give.

In fall-back option 2, the OVG would be used to estimate a fuel type-weight-vintage-ownership choice model. FACTS would be retained to produce the number of cars in the household. For car use, FACTS would be enhanced or the LMS would be used.

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Annex 1. Memo on interviews with policy advisers (in Dutch)

Dit is memo 1 in het project Audit Autobezitsmodellen dat RAND Europe voor AVV uitvoert, waarin verslag wordt gedaan van meningen en wensen inzake een nieuw autobezitsmodel.

In het kader van de inventarisatie van de ervaringen met en meningen over de op dit moment in gebruik zijnde autobezitsmodellen is een viertal interviews afgenomen van ongeveer 1,5 uur met in totaal acht personen. De interviews waren telkens met twee vertegenwoordigers van de volgende organisaties:

- Ministerie van Financiën (dhr J. Schaap en dhr. J.W. In 't Velt)
- Ministerie van VROM (dhr. R. Bouman en dhr. L. Zuidgeest)
- Ministerie van V&W, DGP (dhr. J. Busstra en mevr. O. Teule)
- RAI vereniging (dhr. T. Hooning en dhr. L. Bingen)

Het interview met vertegenwoordigers van de RAI vereniging was iets anders van aard dan de andere drie. De RAI betreft de vereniging van automobiel importeurs en vandaar dat hier hier minder over beleid is gesproken en meer nadruk is gegeven aan de effecten van nationale en Europese regelgeving op de automobiel branche.

Binnen de interviews werd geen strak vragenschema aangehouden en werd veel ruimte gegeven om meningen en aandachtspunten in de eigen volgorde naar voren te brengen. Aan de hand van een checklist werd gedurende het interview gecontroleerd of er nog onderwerpen waren die nog niet besproken waren. Aan het einde van elk interview werd een lijst gemaakt van de genoemde aandachtspunten en werd gevraagd of beide deelnemers hier een prioritering in wilden aanbrengen. Het verslag van elk interview is aan de betrokkenen voorgelegd, en soms ook aan anderen, waarna het commentaar is verwerkt. Onderstaande samenvatting is gebaseerd op de finale versie van de verslagen, welke als bijlagen zijn bijgevoegd. De samengevatte resultaten worden per onderzoeksvraag weergegeven.

Welke beleidsmaatregelen dient het verbeterde model te kunnen simuleren?

Bij deze vraag is met name ingegaan op de vraag welke aangrijpingspunten voor beleid nu gemist worden binnen de bestaande modellen en welke aangrijpingspunten in de toekomst mogelijk toegevoegd zouden moeten kunnen worden aan een nieuw model.

De beperking tot uitsluitend personenwagens binnen de huidige modellen komt bij beleidsmakers (ministeries) telkens terug als een ernstig gemis. Met name het ontbreken van vrachtwagens en bestelauto's wordt vaak en nadrukkelijk genoemd.

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Uitbreiding van voertuigtypen met andere motorvoertuigen (bijv. motoren) of niet-motorvoertuigen (brommers) is in de toekomst gewenst. Daarnaast ziet men graag onderscheid naar eigendomsvormen, waaronder op den duur ook deel-auto's en 'witkarren' kunnen vallen.

Voor de km-heffing is informatie nodig over omvang en samenstelling van wagenpark naar gewicht, brandstof, woonregio en volgnummer van de auto in het huishouden. Hiermee kunnen ook veranderingen in aankoopgedrag worden geëvalueerd. Woonregio en volgnummer van de auto kunnen bijdragen aan het bepalen van het effect van km-heffing op autobezit en eventueel parkeerdruk. Inzicht in het type auto dat als 2e of 3e wordt aangeschaft en kilometrages van alle auto's naar volgnummer in huishouden is ook gewenst. Voor de toekomst moet heffing naar plaats en tijd van gebruik in het model ingepast kunnen worden. Voor evaluatie van de effecten van km-heffing is uitgaan van een gemiddelde gebruiker onvoldoende, er is inzicht nodig in de specifieke (inkomens-)effecten naar gebruikerstype.

Om het beleid inzake accessoires met een te verwachten gunstig milieu of veiligheidseffect te kunnen evalueren is inzicht in de penetratie van deze accessoires gewenst. Met name worden hier de zogenaamde BPM-vrije accessoires genoemd, maar ook zaken als airco en cruise control. Ook kan hiermee onderzocht worden of de variabilisatie (verlaging BPM) eventueel 'omgezet wordt' in extra accessoires.

Ter evaluatie van de verkeersveiligheid kan mogelijk gebruik gemaakt worden van een indicator als catalogusprijs of jaar van typekeuring. In de catalogusprijs zijn zaken als zuinigheid, emissies en standaard veiligheid verwerkt. De typekeuring vindt plaats op basis van een standaarduitvoering inclusief standaard veiligheidsvoorzieningen. Voor nieuwe auto's kan een veiligheidsaanduiding worden opgenomen, bijv. een etikettering op basis van Euro NCAP resultaten.

In het kader van milieubeleid is ook informatie over de penetratie van nieuwe (schonere) autotypen nodig. Voor de toekomst dient voor nieuwe auto's de energie-etikettering en informatie over emissies te worden opgenomen. Ook mogelijkheden voor een evaluatie van een (versnelde)sloopregeling voor (vracht)wagens die niet voldoen aan de Euronormen is gewenst.

Welke omvang kunnen de veranderingen in vaste en variabele kosten bij extreme beleidscenario's aannemen?

Maximale variabilisatie treedt op als de aanschaf- en houderschapbelasting tot nul gereduceerd worden en alle kosten doorgerekend worden via het gebruik. Dit lijkt vooralsnog onhaalbaar en ongewenst. Een deel van de vaste kosten zal gehandhaafd blijven. Een groter deel van de vaste kosten (ca. 66%) zal over een langere periode gespreid kunnen worden overgeheveld naar de variabele kosten. Hierbij wordt de snelheid van overheveling mede bepaald door de omvang van de onrust die de markt kan dragen. VROM geeft bovendien aan dat doorberekening van milieukosten nog niet goed mogelijk is. Differentiatie naar brandstoftype vindt plaats door accijns, hiervoor inzetten van de BTW is niet toegestaan.

Vermindering (deels afschaffing) van BPM zal grote effecten hebben op de 2e-handsmarkt. Door de relatief hoge BPM zijn jonge Nederlandse 2e-hands auto's

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relatief duur. Hierdoor is er al jaren een stuwmeer van gebruikte auto's. De autobranche is een voorstander van restitutie van BPM bij uitvoer wat mogelijk een deel van de problemen kan oplossen. De toetreding van nieuwe EU-partners wordt ook in dit licht als een welkome maar tijdelijke oplossing gezien. Een vermindering van BPM zal tot wijzigingen leiden, zowel op de interne 2e handsmarkt, als op de export van gebruikte auto's.

Welke uitvoer moet het model kunnen leveren?
Welke segmentaties in het wagenpark en in de bevolking zijn belangrijk/noodzakelijk in een nieuw autobezitsmodel?

Deze vragen zijn enigzins overlappend en aanvullend. Naast bestaande uitvoer over omvang en samenstelling van het personenwagenpark, dient een nieuw model inzicht te geven in samenstelling wagenpark
- naar voertuigtype (naast personenwagens, ook vrachtwagens, bestelwagens, motoren, niet-motorvoertuig en mogelijk bussen)
- binnen auto's naar autotype (typecode industrie)
- gewicht en brandstoftype
- eigendom (privé, zakelijk en lease)
- leeftijd/bouwjaar
- woon- of bezitregio (gedetailleerd, minimaal LMS)
- volgnummer van auto in huishouden (1, 2 en 3+)
- kilometrages naar autotype en volgnummer in huishouden
- jaar van typegoedkeuring (als indicator van standaard veiligheid)
- (nieuwe auto's) energie etikettering en Euro NCAP indeling (schoon en veilig)

Gewenst is ook inzicht in de penetratie in het wagenpark van
- BPM-vrije accessoires en overige accessoires
- veiligheidsvoorzieningen (extra air-bags, ABS etc)
- voorzieningen met milieueffecten (cruise control, airco)

Het model dient aanzienlijk meer differentiatie te geven in huishoudkenmerken. De bestaande differentiatie moet ten minste worden gehandhaafd, maar toegevoegd moeten worden:
- meer huishoudtypen (meer differentiatie in omvang, samenstelling en wellicht toevoegen lifecycle indicator)
- inkomenseffecten per gebruikersgroep
- aantal auto's in huishouden
- typen auto's in huishouden naar volgnummer auto
- woonregio (zo gedetailleerd mogelijk of zoals in LMS)

Voor welke toekomstjaren dient het model prognoses te leveren?

Beleidsmakers hebben zowel aan een korte als een lange termijn prognose behoefte. Vanuit Financiën en V&W is behoefte aan een korte horizon van ten hoogste 12 maanden om op korte termijn uitspraken te kunnen doen over effecten en effectiviteit. Daarnaast blijft een lange termijn prognose nodig, omdat veel wijzigingen een lange doorlooptijd vergen. Voor de langere termijn dient tenminste de gemiddelde levensduur van een auto gedekt te worden, ca. 15 jaar. Er is ook behoefte aan

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prognose-horizons van 2 tot 5 jaar, met name om penetratie van nieuwe auto's, auto-typen, aandrijvingstypen en eventueel accessoires in het autopark te kunnen evalueren.

Dient het model aangrijpingspunten te hebben om mogelijke reacties van aanbieders en financiers in te bouwen?

Inzicht hierin is wel gewenst, maar wordt niet bij beleidsmakers als even belangrijk ervaren. De RAI tekent hierbij aan dat wanneer beleid zoveel mogelijk Europees afgestemd wordt en standaardisering van techniek en methodiek wordt nagestreefd de mogelijkheden voor fabrikanten, importeurs en branche om hier gericht op in te spelen vergroot worden. Een versnipperd beleid maakt invoering onnodig duur en daardoor moeilijker te implementeren. De branche is niet onwelwillend, maar het moet wel technisch en financieel haalbaar zijn. Een tussentijdse oplossing zijn vrijwillige afspraken of convenanten, zoals bijvoorbeeld de invoering van de zogenaamde 'dode hoek spiegel'.

De autobranche staat positief ten opzichte van alternatieven van het huidige autobezit, zolang de markt niet teveel verstoord wordt. Nieuwe bezitsvormen (mobiliteits-abonnement, private lease) kunnen mogelijk opgenomen worden als nieuwe eigendomsvormen.

Hoe grijpt Europese regelgeving in in de uitwerking van nationaal beleid?

De procedures voor Europese afstemming van beleid en regelgeving zijn langdurig en werken soms vertragend. Toch is afstemming en gezamenlijk beleid de methode om de automobiel industrie te beïnvloeden. De Nederlandse markt alleen is te klein om significante wijzigingen in productie of ontwerp van nieuwe auto's te kunnen verwachten. Ontwikkeling en aanpassing van de industrie vergt tijd en veel geld. Wijzigingen worden alleen ingezet bij voldoende groot belang en komen meestal pas na jaren op de markt beschikbaar.

Europees beleid kan ook de concrete uitwerking van nationaal beleid doorkruisen. Met name de harmonisatie van prijzen en belastingen wordt hier genoemd. Harmonisatie van de netto inkoopsprijs van nieuwe auto's zal leiden tot hogere inkoopsprijzen in Nederland, hierdoor valt een mogelijk verlaging van BPM voor de consument deels weg en kan het draagvlak voor maatregelen zoals bijv. km-heffing afnemen.

Wanneer in het kader van de Europese regelgeving de uitzonderingspositie van de verkooporganisatie van de autobranche wordt opgeheven (regeling loopt af in 2002) verdwijnt een belangrijk controlemiddel op het toegestane wagenpark en de te innen belastingen (BPM etc).

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Bijlage 1: Verslag interview Ministerie van Financiën inzake Audit Automodellen

Min Fin: dhr. J. Schaap, dhr. JW In 't Velt
RAND Europe: mevr. R. Hamer
datum: 18 oktober 2001
duur: 1,5 uur

Financiën ervaart de benadering van V&W en met name AVV vaak als zeer technisch en voornamelijk gericht op vervoerskundige aspecten van autobezit en autogebruik. Financiën is vanzelfsprekend meer gericht op de financiële aspecten zoals heffingen, opbrengsten en inkomenseffecten. Financiën is bovendien meer reactief en moet inspelen op de dagelijkse werkelijkheid. Dit spanningsveld is tot nu opgevangen middels o.a. ad hoc onderzoeken, en inzet van de eigen studiedienst

Een tweede verschil in inzicht met betrekking tot het gebruik van de modellen betreft de horizon (in tijd). Vervoerskundigbeleid (en onderzoek) is vaak een kwestie van lange adem, terwijl Financiën juist snel inzicht wil hebben in de (financiële) effecten om deze in het budget te kunnen verwerken. Bij milieubeleid, waar beleidsdoelen in bijv. 2010 worden ge-evalueerd, is eenzelfde spanningsveld.

Financiën is zeer geïnteresseerd in financiëel gerichte output, zoals o.a.
- de gebruikte (prijs)elasticiteiten
- onderscheidingen in voertuigtypen die verschillen in fiscale behandeling (bijv. bestelauto's zakelijk en privé gebruik)
- inkomensgevolgen voor
  - bevolkingsgroepen (soort 'kostenplaatjes' zoals door CPB worden opgeleverd)
  - bedrijfsleven
  - overheid (inkomsten)
  - maatschappij als geheel (economische effecten)

Er worden twee aspecten genoemd die vertragend werken op beleidsvorming en implementatie. Enerzijds is dit de doorlooptijd voor het verkrijgen van de juiste gegevens. Het betreft hier niet perse modelresultaten, als wel specifieke statistieken die deels als input dienen voor prognoses van opbrengsten en (financiële) effecten. Een tweede 'rem' wordt ervaren door de Europese regelgeving, de procedures om beleid Europees af te stemmen worden als zeer tijdrovend ervaren.

In de discussie over mogelijk **toekomstig beleid** dat wellicht ook met een nieuw autobezits/gebruiksmodel zou kunnen worden doorgerekend of ge-evalueerd werden de volgende mogelijkheden genoemd:
- nieuwe eigendomsvormen, zoals deelauto
- nieuwe gebruiksvormen, bijv. 'witkarren'
- reguleren van gebruik, bijv. door vergunningen of fysieke beperkingen
- nieuwe voertuigen binnen fiscaal beleid brengen (bijv. kentekens en (wegen)belasting voor brommers en scooters)

Meer direct voorziet Financiën mogelijkheden omringende landen te volgen in beleid. Met name refereert men hier aan Duitsland, waar voor zware vrachtwagens in 2003

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een kilometerheffing (km-heffing) zal gaan gelden (ipv een vignet). Dit is veel eerder dan voor personenauto's.

In het kader van **variabilisatie** van de kosten voorziet Financiën dat een deel van de huidige vaste kosten gehandhaafd zullen blijven , mogelijk kan tot ca. 2/3de van deze lasten op termijn overgeheveld worden naar de variabele lasten. Differentiatie van BTW-heffing, bijv. naar brandstofsoort is binnen de Europese regelgeving niet mogelijk. De huidig 'paarse diesel regeling' wordt opgeheven. Dit betreft de huidige fiscale differentiatie tussen normale en laag zwavelige diesel. Wellicht dat een soortgelijke regeling ook voor normale (ongelode) en laag zwavelige (ongelode) benzine tot de mogelijkheden kan gaan behoren na Europese afstemming. Het ministerie ontvangt regelmatig verzoeken experimenten met schonere brandstof (bijv. bussen op aardgas) fiscaal te ondersteunen. Installatiekosten voor aardgas zijn echter zeer veel hoger dan voor LPG waardoor particulier gebruik vooralsnog niet voorzien wordt. Aardgas wordt fiscaal gelijk behandeld aan LPG-3.

Binnen het **milieubeleid** levert Financiën bijdragen door schonere auto's te stimuleren middels bijv. verlaging van de MRB en zuinige personenauto's via de BPM. Hiervoor dienen echter wel heldere en handhaafbare criteria te worden geformuleerd door bijv. het Ministerie van VROM, en op heldere wijze gecommuniceerd worden naar o.a. kopers.

In het kader van **veiligheid** volgt Financiën in haar voorschriften vaak beleid dat door andere ministeries wordt geformuleerd. Hier wordt met name de achterruit van de bestelwagen genoemd. Voorheen diende een bestelwagen een dichte achterruit te hebben om in aanmerking te komen voor de fiscale voordelen. In het kader van de veiligheid is deze eis vervallen. Hierdoor is echter ook een van de onderscheiden tussen zakelijke bestelwagens en zogenaamde 'privé' bestelwagens vervallen. Veel zogenaamde 'ruimte auto's' die zeer populair zijn ook voor privé gebruik, zijn fiscaal als bestelwagen te behandelen. Een nieuw autobezitsmodel moet hier op in kunnen spelen.

Bij heffingen naar gewichtsklasse speelt ook een veiligheidsaspect mee. Lichtere wagens kunnen minder veilig zijn. Financiën meent dat hier mogelijkheden kunnen liggen voor differentiatie, maar net als bij zuinige auto's moeten de criteria helder en handhaafbaar zijn.

Een **nieuw model** dient in ieder geval alle oude onderscheiden te bevatten, zoals onderscheid naar
- gewichtklasse,
- brandstof,
- woon-regio en
- catalogusprijs.

Een aantal onderscheiden dienen aangescherpt te worden, het betreft hier onderscheiden met een fiscaal of financieel effect zoals bijv.
- eigendomsvormen (zakelijk/lease/privé, bestelauto's zakelijk en privé),
- inkomenseffecten voor gebruikersgroepen (zie hiervoor genoemd).

Daarnaast moet op termijn (voor km-heffing) differentiatie mogelijk zijn naar
- plaats en
- tijd.

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Variabilisatie van o.a. BPM, MRB, BTW, subsidie van veiligheid en zuinigheid zijn hierboven reeds besproken.

Op dit ogenblik wordt niet voorzien dat het ministerie behoefte heeft aan output dat gerelateerd is aan andere financieringsvormen zoals genoemd in checklist (bijv. gratis kilometers of benzine bij aankoop) immers de heffing (op kms of brandstof) wordt wel voldaan, alleen door een ander dan de bezitter.

Meer belang wordt gehecht aan de problematiek van de prijsstelling. In Europese landen worden autoprijzen vastgesteld rekeninghoudend met de belastingdruk. Als deze wijzigt, kan het voordeel deels weglekken naar de dealers of autoproducenten in plaats van naar de consument. Dit heeft budgetaire en inkomenseffecten.

Bij differentiatie van heffing naar brandstoftype kan de penetratiesnelheid van nieuwe autotypen in het wagenpark wel een budgetair effect hebben en dit is wellicht wel van belang mits model prognoses levert met een korte horizon.

De diverse aspecten genoemd in dit interview zijn alle van belang voor beleid en beleidsontwikkeling. Met betrekking tot het belang dat Financiën aan de diverse aspecten geeft binnen het opzetten van modelmatig onderzoek zijn de genoemde aspecten in drie prioriteitsklassen opgedeeld.

Aspecten met een hoge prioriteit binnen de opzet van modelmatig onderzoek zijn:
- korte tijdshorizon (minimum 1 jaar, maximum 2 jaar) (zeer belangrijk!)
- financiële elasticiteiten
- onderscheid naar voertuigtypen (anders dan auto's)
- onderscheid naar eigendom (privé/zakelijk/bestel privé/ bestel zakelijk/deelauto etc..)
- aansluiting met Europees beleid

Minder prioriteit hebben
- onderscheid naar nieuwe autotypen (hybride)
- prognoses van inkomenseffecten in bevolkingsgroepen
- brandstofaccijnsdifferentiatie
- prognoses van reacties in maatschappij (branche/bedrijfsleven/economie)

Lage prioriteit hebben
- veiligheid
- milieu (subsidie zuinige auto's)

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Bijlage 2: Verslag interview Ministerie van VROM inzake Audit Automodellen

Min VROM: dhr. R. Bouman, dhr. L. Zuidgeest
RAND Europe: mevr. R. Hamer
datum: 26 oktober 2001
duur: 1,5 uur

VROM mist met name het vrachtverkeer in de huidige modellen. Daarnaast wordt als een gemis ervaren dat differentiatie naar gewicht, brandstofsoort en eventueel voertuiggrootte naar de beleving van VROM ontbreekt. Dit laatste is mogelijk van belang voor de kilometerheffing (kmheffing). In huidige modellen wordt gewerkt met 'gemiddelde rijder' en beleid is uitgezet zodat gemiddeld er niets verandert. VROM voorziet kmheffing gedifferentieerd naar gewicht en brandstofsoort (net als MRB nu). Bij kmheffing differentiatie tussen 3ct/km en 25ct/km is mogelijk dat accijns op diesel oploopt (van f 1,30/l nu) naar f 2,50/l.
Op dit moment is de mogelijkheid naar gewicht/brandstofsoort te differentiëren binnen het model zeer belangrijk. In de toekomst is ook differentiatie naar emissies gewenst (mn. CO_2, NOx, fijn stof etc. en wellicht ook geluid). Dit is van belang voor doorberekening van de kosten, bijv. naar Euronormen.
Differentiatie naar ruimte is voor VROM ook belangrijk, ivm differentiatie naar stedelijkheid of iets dergelijke, differentiatie naar tijd wordt nu als minder belangrijk ervaren.

Naast onderscheid naar gewicht is mogelijk onderscheid naar voertuiggrootte gewenst omdat vaak veiligheidsvoorzieningen gewicht toevoegen. Probleem hierbij is dat gewicht en brandstoftype van alle voertuigen bekend is, en voertuiggrootte niet. Enige informatie mbt de emissies is ook per auto niet bekend. Het verzamelen van informatie over grootte en met name emissies is een tijdrovende en kostbare zaak, waardoor dit vooralsnog niet als haalbaar wordt gezien. Een alternatief ligt wellicht in differentiatie naar catalogusprijs, omdat hierin vaak zaken als zuinigheid, veiligheid, emissies e.d. verdisconteerd zijn.

VROM is zeer geïnteresseerd in inzicht in instroom van nieuwe auto's en penetratie van nieuwe autotypen. Premies voor schonere of zuinige auto's zijn al geïmplementeerd. VROM ziet mogelijkheden voor een versnelde sloopregeling waarbij met name gedacht wordt aan vrachtauto's die niet voldoen aan de Euro-normen 0 en 1, en op termijn ook wellicht Euronorm 2. Vanuit VROM is belangstelling voor inzichten/prognoses mbt directe gedragsveranderingen zoals

- in aankoopgedrag van consumenten (en de naijleffecten op het wagenpark, waaronder duur van totale vervanging)
- in verkoopgedrag van autobranche (aanpassing inkoopsprijs, verkoopacties gewilde en minder gewilde auto's etc)
- weglekeffecten (verminderingen van lasten die niet doorgegeven worden naar consument, maar binnen branche worden gehouden, onderzoek geeft aan dat dit tot ca. 10% kan oplopen)

Er is nu onderzoek naar de verwachte reactie van consumenten op afschaffing BPM (Mu-consult doet SP onderzoek hierna), en verwachting is groei van aandeel zwaardere auto's en uiteindelijk totaal zwaarder wagenpark. Door gedifferentieerde kmheffing kan een tegenbeweging ontstaan, waardoor bijv. zwaardere dieselauto's langzaam uit het wagenpark zullen verdwijnen. Kmheffing zal ook effecten hebben op

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de 2e-handsmarkt: door vermindering/afschaffing BPM (en invoering kmheffing) worden in ieder geval nieuwe auto's maar mogelijk ook 2e-hands auto's goedkoper.

VROM geeft prioriteit aan modeloutput naar gewicht, brandstoftype en mogelijk grootte, en uitbreiding met vrachtwagens. Daarbij dient gesegmenteerd te worden naar aantal auto's per huishouden, in- en uitstroom van voertuig-/autotypen en een gemiddeld kilometrage per autotype of autoklasse. Bij dit laatste is complicatie mogelijk: bij toename van aantal auto's per huishouden, kan kilometrage per auto afnemen. Dit komt niet geheel goed tot uiting in kilometrage per autoklasse.

VROM ervaart de bestaande overeenkomsten en Europese regelgeving inzake vracht- en luchtverkeer, waarbij doorberekening van veel externe kosten niet mogelijk is, als een duidelijke belemmering van de sturingsmogelijkheden van nationaal beleid.

Binnen het kader van de inventarisatie ten behoeve van modelmatig onderzoek van het wagenpark/het autobezit geeft VROM zeer hoge prioriteit aan de volgende aspecten:
- opname vrachtauto's in model (gedifferentieerd naar Euronorm)
- onderscheid naar gewicht, brandstof, en eventueel voertuiggrootte
- onderscheid naar eigendomsvormen (zakelijk/privé/lease)
- mogelijkheden voor onderscheid naar emissies
- opname van reacties aanbieders (verkoopgedrag/ marge bijstelling/ weglek-effecten)
- uitstroom oude auto's
- versnelde sloop mn van vrachtwagens (die niet voldoen aan Euronormen).

Beleidsmatig belangrijk en binnen het model met hoge prioriteit op te nemen zijn:
- inzicht in instroom nieuwe auto's
- premies op zuinige auto's
- opname bestelauto naar zakelijk/privé
- differentiatie naar plaats
- opname directe reacties, bijv. aankoopgedrag consumenten
- korte termijn prognoses (horizon van 1 tot 2 jaar)
- lange termijn prognoses behouden (horizon van 5 tot 14 jaar)
- aantal auto's naar brandstof/gewicht en evt. grootte
- gemiddelde kilometrage per autoklasse.

Voor VROM zijn binnen een nieuw model minder belangrijk:
- differentiatie naar tijd
- differentiatie naar catalogusprijs
- inzicht in wijzigingen in 2e-handsmarkt

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Bijlage 3: Verslag interview Ministerie van V&W, DGP inzake Audit Automodellen

Min V&W DGP: dhr. J. Busstra, mevr. O. Teule
RAND Europe: mevr. R. Hamer
datum: 15 november 2001
duur: 1.5 uur

De invalshoek van V&W vertegenwoordiging in dit gesprek is enerzijds beleid met betrekking tot de eisen waaraan voertuigen en bestuurders moeten voldoen alvorens op de weg toegelaten te worden (Busstra), anderzijds de effecten van met name de kilometerheffing (km-heffing) (Teule). Een derde vertegenwoordiger (Pilgrim) die betrokken is bij beleidsvorming inzake ketenmobiliteit, zal gevraagd worden om schriftelijk op dit verslag te reageren. In dit gesprek wordt niet modal-split beïnvloeding als beleidsdoel betrokken.

V&W mist in de huidige modellen een indicator voor verkeersveiligheid van de voertuigen. In principe is elk nieuwe generatie (ook binnen een type) veiliger dan de vorige. Als indicatoren zijn mogelijk bouwjaar, maar beter nog jaar van typegoedkeuring. Daarnaast wordt elk jaar (in overleg met Financiën en VROM) een lijst van accessoires opgemaakt die vanwege verwachte veiligheids- of milieueffecten vrijgesteld zijn van BPM. Enig inzicht in de mate waarin deze accessoires (zoals bijv. cruise-control, ABS etc.) penetreren in het wagenpark zou evaluatie van deze maatregel mogelijk maken. Daarnaast is inzicht in penetratie van ook andere accessoires (die niet van BPM zijn vrijgesteld) interessant. Overigens wordt volgens V&W de heffingsgrond voor MRB en km-heffing vastgesteld op basis van het ledig gewicht bij typekeuring. Dit betekent dat hierin alle standaard veiligheidsvoorzieningen zijn opgenomen, en extra voorzieningen weliswaar bijdragen aan het werkelijke gewicht van het voertuig, maar niet meetellen in de heffingsgrondslag.

Vanuit de km-heffing is informatie nodig over omvang en samenstelling van het wagenpark inclusief andere voertuigtypen. Met name is opname van bestelauto's en bussen belangrijk. Daarnaast dient onderscheid te zijn naar eigendomsvormen (zakelijk, privé, lease en eventueel op termijn ook bijv. deelauto's etc.). Het personenwagenpark wordt nu onderscheiden naar brandstoftype en gewicht, toevoeging van gemiddeld verbruik of type aandrijving (bijv. hybride auto's) is vanuit milieu oogpunt op termijn gewenst. Wellicht kan de energie etikettering die nu ingevoerd wordt nieuwe auto's hierbij als een indicator voor verbruik dienen. Op dezelfde wijze kan voor toekomstige toepassingen wellicht ook veiligheidscategorie toekenning worden opgenomen. Hierbij kunnen uitkomsten van Euro NCAP tests als input dienen.

Het evalueren van het effect van km-heffing op het autobezit per huishouden vergt meer gedetailleerde output dan nu mogelijk is. Onderscheid naar autobezit dient in ieder geval te worden uitgebreid naar 1, 2 en 3+, waarbij informatie over type van 2e, 3e enz. auto gewenst is. Hiervoor kan wellicht gewerkt worden met de typecodering die binnen de industrie gehanteerd wordt. Zo gedetailleerd mogelijk informatie met betrekking tot de regionale spreiding van het autobezit, met name ook voor meer-auto-huishoudens, zou inzicht kunnen leveren in de effecten van o.a. km-heffing op bijv. het parkeerbeleid en de parkeerdruk. Heffing naar gewicht, brandstoftype en

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woon- of bezitsregio wordt voorzien, km-heffing naar plaats en tijd moet op den duur in het model kunnen worden ingebracht.

Vanuit het Europees voornemen tot harmonisatie is reductie van de BPM tot 0% gewenst, maar dit moet geleidelijk gebeuren om verstoring van de markt te voorkomen. Het is mogelijk dat het draagvlak voor km-heffing minder groot wordt als de verlaging van BPM deels wegvalt tegen de Europese harmonisatie van de nettoprijs van nieuwe auto's, waardoor in Nederland de netto prijs zal stijgen.

Vanuit het perspectief van km-heffing is een korte evaluatie-horizon van 1 jaar gewenst. In ieder geval dient deze korter dan 5 jaar te zijn. Vanuit veiligheids- en milieu oogpunt is inzicht in de snelheid van vervanging van het wagenpark belangrijk en dient daarom een horizon van tenminste 15 jaar ook in het model mogelijk te zijn. Het is niet duidelijk of effecten van beleid op bewuster aankoopbeleid in een model zijn op te nemen. Voor een deel uiten deze zich via prognoses van omvang en samenstelling van wagenpark. Is binnen een nieuw model inzicht te krijgen in of verlaging van BPM leidt tot het kopen van andere auto's, of juist wagens met lage km-heffing?

Naar aanleiding van het gesprek is door V&W aangegeven dat in een nieuw model met prioriteit dient te worden opgenomen:
- verschillende eigendomsvormen
- bestelauto's (, bussen en vrachtwagens)
- penetratie van BPM vrije accessoires
- penetratie van andere accessoires (airco, etc)
- gedetailleerde info autobezit (regionale spreiding en 1,2 en 3+)
- penetratie nieuwe autotypen en aandrijvingsvormen (hybride auto's)

Wat lagere prioriteit hebben
- verbruiksindices per type (energie etikettering)
- veiligheidsindices per type (etikettering)
- penetratiesnelheid BPM vrije accessoires
- penetratiesnelheid overige accessoires
- penetratie nieuwe auto's
- gereden km's met onderscheid naar plaats en tijd

Variabilisatie van brandstofheffingen is nu al geïmplementeerd, en heeft voor de toekomst wel belang wanneer bijv. beleid wordt opgezet voor ketens van CO_2 neutrale bandstoffen. Vooralsnog heeft het wat minder prioriteit binnen modelontwikkeling.

De bestaande detaillering dient overigens behouden te blijven, bijvoorbeeld het onderscheid naar huishoudentypen zoals bijv. in LMS.

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Bijlage 4: Verslag interview RAI Vereniging inzake Audit Automodellen

RAI: dhr. drs. Theo Hooning, dhr. Leo Bingen
RAND Europe: mevr. R. Hamer
datum: 5 november 2001
duur: 1,5 uur

De RAI is de vereniging van importeurs, de twee vertegenwoordigers hier zijn beide secretaris van de afdeling auto's. De RAI merkt op dat de Nederlandse overheid onvoldoende rekening houdt met het feit dat Nederlandse (NL-)markt (zeker per merk) zeer klein is. Te klein om te kunnen verwachten dat ten gevolge van nationaal beleid autofabrikanten tot grote produktiewijzigingen zullen overgaan. Er dient onderscheid gemaakt te worden naar beleid dat technische aanpassingen vergt (zoals schonere en zuinigere auto's) en beleid dat geïmplementeerd kan worden door een los apparaat aan te bieden. Beleid wat technische aanpassingen vergt heeft een langere aanlooptijd nodig en gemeenschappelijke afspraken, hierbij is bestendig beleid noodzakelijk met nadruk op Europees verband. Bij beleid dat opgelost kan worden middels losse apparatuur is het eenvoudiger voor fabrikanten om op ad hoc basis en voor kleinere markten er op in te spelen.

Hoofdkantoren (zoals in Detroit etc.) zullen veelal niet op de hoogte zijn van nationale verschillen in beleid. Regionale hoofkantoren in Europa zijn wel op de hoogte, en spelen daar zoals gezegd waar mogelijk op in door het aanbieden van losse toevoegingen. Voorbeeld hiervan is de kilometerheffing (kmheffing), wat nu geen zaak is van de fabrikant, maar wat wordt opgevangen door het aanbieden van een apart registratiekastje. Wellicht dat kmheffing tot andere toekomstkeuzes kan leiden. Op dit moment (medio 2001) was het beleid met nadruk gericht op schonere auto's, vanaf 2002 wordt sterker ingezet op zuinigere auto's. De huidige nadruk op schonere auto's heeft wel tot versnelde reactie van de fabrikanten geleid.

Nederland lijkt vaak voorop te willen lopen met beleid, en poogt daarbij soms de afgesproken tijdpaden te versnellen. Dit wordt als weinig effectief of haalbaar gezien omdat de NL-markt eenvoudigweg te klein is om invloed uit te oefenen. De invloed van fabrikanten is hier marginaal, maar er is wel verandering mogelijk door consumentengedrag of bijv. afspraken met vervoerders. Voorbeeld is het convenant tussen V&W en vervoerders dat alle Nederlandse vrachtwagens uitgerust worden met een 'dode hoek spiegel'. Implementatie kost geld, dat maar voor een klein deel wordt gesubsidieerd. Belangrijker probleem is echter dat er zoveel verschillende typen spiegels nodig zijn voor de verschillende typen vrachtwagens.

Wanneer beleid meer op Europees niveau afgestemd wordt is meer interesse en reactie van fabrikanten te verwachten. Hiervoor is wel nodig dat er standaardisering van techniek en methodiek wordt nagestreeft en RAI wijst hier op de input van de Raad van Advies. Ook is een realistisch tijdpad noodzakelijk. Als voorbeelden worden genoemd het Europees beleid :
- mbt schone motoren (emissies: NOx, fijnstof normen in 2008) en geluid (middels evt. bandentechniek wat weer een andere branche is waar apart mee onderhandeld dient te worden; hier is concentratie van activiteit nog groter, waardoor schaalfactor bij beleid nog meer speelt)

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- mbt zuinige motoren: er is een convenant met EU en autoindustrie (KAMA, AMO en deel VS via Opel/Ford) om tot maximale CO2 uitstoot van 145 g/km te komen in 2008
- veiligheid, mn interne en externe botsbestendigheid

Een andere insteek is de controle mogelijkheden. Op dit moment is er een uitzondering op het verdrag van Rome voor de selectieve distributie van personenwagens (middels stelsel van dealers en invloeden op verkoopprijzen die samenhangen met belastingheffing zoals BPM). Deze uitzondering liep af in 1995 en is verlengd tot 2002. Hierdoor zijn afspraken met de branche mogelijk die ook gecontroleerd kunnen worden. Wanneer markt wordt geliberaliseerd, bijv. middels toestaan van Internetsales, wordt controle moeilijker (zo niet onmogelijk), bovendien wordt inning van o.a. BPM dan problematisch. Als een nieuw systeem veel problemen gaat opleveren zullen door de ACEA (Europese vereniging van fabrikanten) acties worden ondernomen met doel aanpassing.

De automobielbranche staat positief tegenover veel alternatieven voor het huidige autobezit en –gebruik. Al enige jaren propageert RAI 'Rijden met reden' waarbij minder gedacht wordt in termen van autogebruik, en meer in mobiliteit. Voorbeelden zijn o.a. een abonnement bij een dealer (of merk) waarbij gebruik gemaakt kan worden van variabele autotypen. Er is momenteel ook al een 'mobiliteitabonnement' of 'private lease' systeem waarbij financiering/reparatie&onderhoud en verzekeringen ondergebracht zijn. De autobranche is voorstander van alternatieven zolang de marktverstoring niet te groot wordt.

Per jaar komen enkele 10-duizenden 2e handsauto's Nederland in en ook de export is aanzienlijk. Informatie hierover kan opgevraagd worden bij de RDC (dhr. C. Bogerd 020 – 5497171) en bij Eurostat. De enige beperking bij invoer is dat de auto dient te voldoen aan EU normen en –typegoedkeuring voor deze op de weg mag. Bij invoer wordt BPM geheven, terwijl bij uitvoer geen BMP wordt gerestitueerd. Dit laatste zou interessant kunnen zijn omdat dan de vervangingsnelheid van de markt verhoogd wordt. Door de BPM-heffing geldt voor de Nederlandse 2e handsmarkt dat met name de jongere 2e hands auto's relatief duur zijn. Hierdoor is er een stuwmeer van gebruikte auto's in Nederland. Opening van een nieuwe markt is een mogelijkheid om dit stuwmeer te laten slinken. Nederlandse handelaren proberen dan ook vaak als eerste op nieuwe markten te opereren. De toetreding van Polen zal weinig effect hebben, omdat hier de eerste hausse al voorbij is. Meer wordt verwacht van toetreding van de Baltische staten en Slovenië.

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