

DYNAMO: A NEW DYNAMIC AUTOMOBILE MARKET MODEL FOR THE NETHERLANDS

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1. INTRODUCTION

Prognoses about the ownership of cars and mobility in the future play an important role when preparing policies in the field of Traffic and Transport. Car ownership refers not only to the size of the vehicle fleet but also its composition in terms of characteristics, ownership relations and other relevant variables. These prognoses are not only of importance for important consequences of car ownership and their use (the environment, safety, etc.) but also form important input for traffic models.

MuConsult has developed a new dynamic automobile market model for AVV (Dutch Transport Research Centre) and MNP (Netherlands Environmental Assessment Agency) in which the effects of general developments and government policy on the size, composition and use of the Netherlands car fleet can be modelled for the period 2003-2040.

The requirements that the new car ownership model must fulfil are that it must allow the dynamics of the car market to be simulated and forecasts made concerning the following items:

- ▶ Number of cars per household
- ▶ Type of fuel
- ▶ Weight class
- ▶ Age of the car
- ▶ Consumption
- ▶ Type of owner (private versus lease/company cars)
- ▶ Use, that is the number of kilometres driven
- ▶ Type of household (in relation to car types)
- ▶ Income effects on groups of households
- ▶ Effects on government revenues

The following developments and measures must be able to be simulated in the model:

- ▶ Demographic, socio-economic and other societal trends
- ▶ Changes in the costs of car ownership and the use caused by subsidies and levies on the possession and use of cars and on fuels
- ▶ Developments in technology relevant to car types

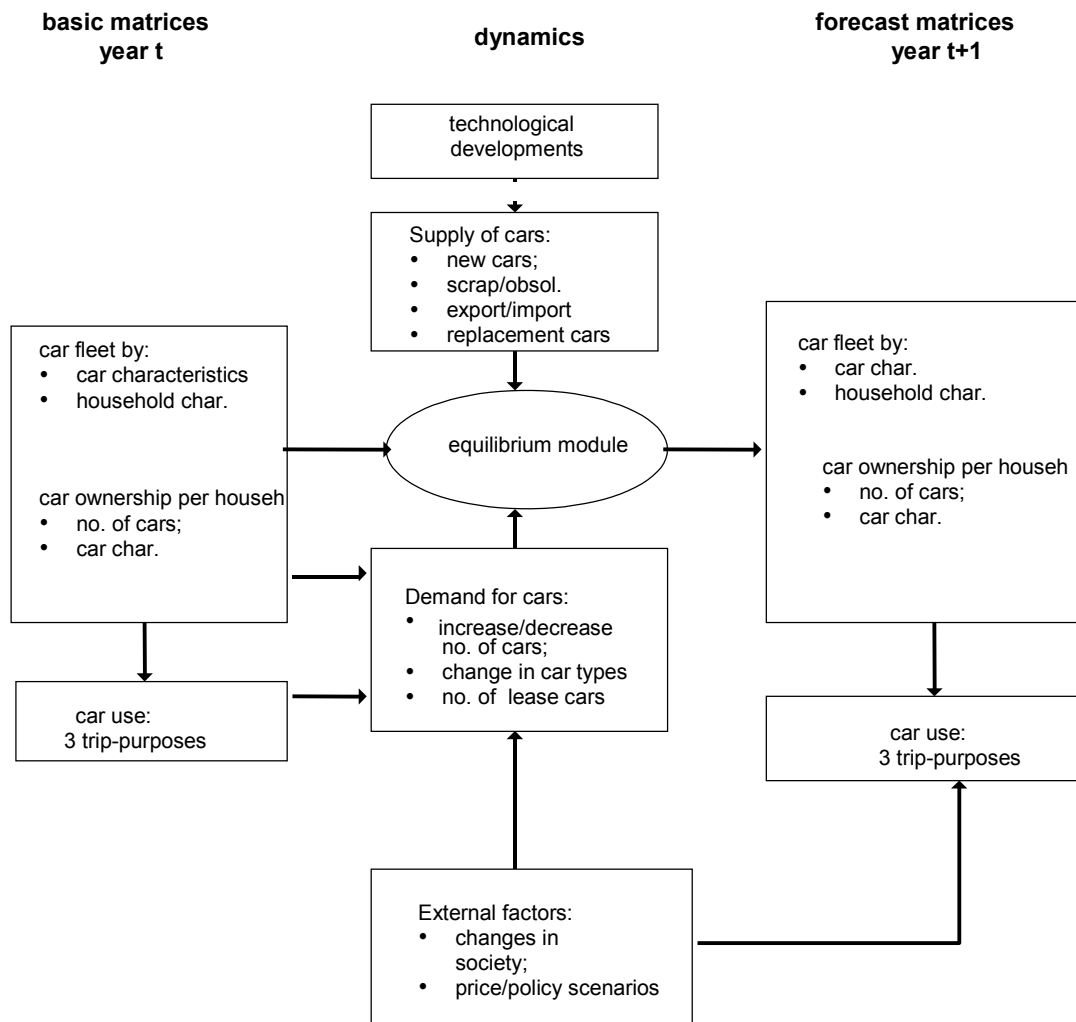
This paper describes the model "DYNAMO" (version 1.3) that has been developed. Section 2 describes the underlying conceptual model and Section 3 the general

structure of Dynamo. The following four sections discuss four modules of Dynamo; the size of the car fleet (Section 4), the composition of the car fleet (Section 5), the equilibrium model determines prices in the second-hand car market so that supply and demand for cars remains in balance (Section 6) and the model that determines the number of cars to be scrapped (Section 7). An application for the complete model is described in Section 8. Section 9 gives the most important conclusions and includes a discussion of possible extensions and improvements of the present version (Dynamo 1.3).

2. CONCEPTUAL MODEL

Figure 1 shows the main principles of the car ownership model. It is a dynamic model. Changes are predicted on the basis of a good description of the car fleet and car ownership and use in the base year (in the *basic matrix*), which leads to insight in the characteristics of the car fleet and the car ownership in a following year.

Figure 1: Conceptual model of car ownership



Changes in car ownership, the car fleet and the use of cars can be caused by the influence of external factors, such as developments in society and price/policy scenarios.

These external factors influence the **demand for cars** (number of cars, types of cars) and also influence the number of kilometres driven for different purposes. An increase in income, for instance, can lead to both changes in the number of cars and in the demand for larger cars. An increase in the taxes on diesel fuel can reduce the demand for diesel-powered cars, but also the number of kilometres driven with diesel-powered cars.

Alongside this, naturally, is the **supply of cars**. Changes in this can take place by the launching of new models, by scrapping, and through export and import, and second-hand cars can be put on the market by people who are intending to change their car.

Supply and demand are related to each other in the so-called **equilibrium module**. The price mechanism is used in this model to create balance between supply and demand. For example, if the petrol price goes up, less new petrol cars will be sold. At the same time people owning a petrol-powered car could decide to dispose of this earlier, which will have a depressing effect on the second-hand price of petrol-powered cars.

The result of the module is a new basic matrix with characteristics of the car fleet, car ownership, the number of kilometres driven, and the development in the equilibrium prices of cars. Trends over time are obtained by repeatedly running the model. These results can then be incorporated into environment modules that establish the effects on environment indicators (CO₂, acidifying substances, etc.) The results can also be included in The National Model System (Dutch abbreviation: LMS).

3. THE GENERAL STRUCTURE OF DYNAMO

The model describes the car ownership of households. This is not done at the level of individual households but at the level of the *type* of household. A household type is described by four characteristics.

- ▶ Size of household (total number of persons in the household): single, two persons or more than two persons households
- ▶ Number of persons in employment: 0, 1, or more than 1 person in employment
- ▶ Age of the oldest person in the household: younger than 35 years, 35 to 65 years, or 65 years and older
- ▶ Real disposable income in the household: low (maximum Euro 18,151), average (Euro 18,185 – 38,571), high (more than Euro 38,571)

The combination of these characteristics produces 71 separate household types for use in the model. This is called the household matrix (**H**-matrix).

In a similar way, cars are categorised into car types on the basis of four car characteristics.

- ▶ Age of the car: less than 1 year, 1–3, 4–6, 7–10, older than 10 years
- ▶ Fuel: petrol, diesel or LPG
- ▶ Weight: maximum 950 kg, 951 – 1150 kg, 1151 – 1350 kg, > 1350 kg
- ▶ Car ownership: private ownership, lease / company car

The combination of these characteristics produces 120 separate car types. This results in an automobile matrix (the **A**-matrix). An important difference between these two matrices is that the household type functions as input data for the car ownership

model for the prognosis years (i.e. exogenous, not modelled within the car ownership model), while the car types matrix is actually an outcome of the model.

The combination of household types and car types is called the **AH**-matrix (AutomobileHousehold matrix). The AH-matrix describes the car ownership in a particular year for each household type and thereby forms the core of the car ownership model. The aim of the model is to predict the composition of the AH-matrix from year to year (i.e. the values for the cells). The AH-matrix has 8,520 (= 71 x 120) cells.

The AH-matrix in the base year (2003)

Data from the Centre for Vehicle Technology and Information (in Dutch: *RDW*) has been used for the characteristics of the active car fleet in 2003. A sample of about 10% of the active car fleet at the end of December 2003 (more than 600,000 individual vehicles) was obtained from the RDW, with a large number of characteristics of these vehicles. The A-matrix for 2003 was constructed on the basis of this information and other data about the composition of the Netherlands car fleet.

The mobility of the population of the Netherlands has been determined in the Dutch National Travel Survey (*OVG*). This also recorded a great many background variables of persons and households, including car ownership. This source has been used for determining the H-matrix for 2003.

The final AH matrix for 2003 was obtained by crossing the “A” and “H” matrices, ensuring that the limiting totals agreed for all characteristics used to determine these matrices. Various other sources with data concerning car ownership of households were also used as well as the data from the OVG and the RDW.

Modular structure of DYNAMO

The car ownership model Dynamo consists of a large number of modules. We will not consider modules for the administration of the calculations and the data in this paper, but concentrate on the modules for the actual model:

- **D(Household)** This determines the development in the number of households per household type. This is regarded as an external development in the car ownership model, whereby use is made of scenarios developed by the Bureau for Economic Policy Analysis (*CPB*). Once the type of scenario has been chosen the number of households remains fixed for the whole period.
- **D(Car use)** This determines the number of kilometres driven for particular purposes (per household x car type), the average number of kilometres driven per household (per household type) and the number of kilometres driven (per car type). Developments or policy with reference to variable costs of car ownership are incorporated in the model via this module.
- **Scraping or accident** The probability that the car will be scrapped or will remain in the active car fleet for a further year is determined per car type. See Section 7 for a complete description of this module. An additional 0.108% of all cars disappear from the car fleet annually as a result of accidents.
- **ImExport** The present version of DYNAMO assumes a constant total for import and export as was the case its predecessor (*FACTS*). This total is taken as - 1.15% for every car type in the active car fleet.

- ▶ **HHNumber** This determines the number of cars demanded for each household type subdivided into 0, 1, 2, or more than 2 cars. See Section 4 for a complete description of this module.
- ▶ **DHHLease** This determines the number of lease/company cars for each household type. In this version this is actually determined outside of the actual car ownership model, on the basis of the method that was developed for FACTS. The distribution of car types among lease cars is assumed to be constant in this model and the same as the distribution in the base year 2003.
- ▶ **Type choice** This determines the distribution of car types for each household type. See Section 5 for a complete description of this model.
- ▶ **Emod** This determines the equilibrium prices for the 48 car types on the second-hand market as a function of the demand for private cars and the supply of private cars. See Section 6 for a complete description of this module.
- ▶ **Environment** This determines the emissions produced by the car fleet. The environment module from FACTS has been included in DYNAMO for this purpose.

After all the calculations for the year t have been carried out the results are saved and calculations for year $t+1$ can be started.

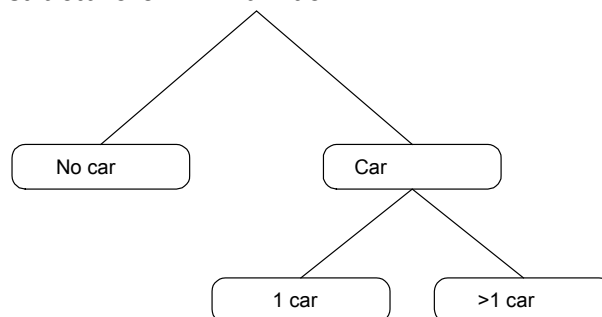
4. THE MODULE HHNUMBER

The module HHNumber models the total number of cars that are in the ownership of households at time t . The number of households that owns 0, 1, 2, or more than 2 cars is determined for each of the 71 household types. The sum of these values for the households is the total demand for cars at time t .

Model specification

A nested structure (Figure 2) for HHNumber was found to be the most suitable form for the car ownership model after an extensive investigation of possible model specifications had been carried out. The top nest concerns the choice of whether or not to have a car and the bottom nest the number of cars present in the household if there is car ownership.

Figure 2: *Nested structure of HHNumber*



The choice for this model has been made on the basis of data availability and the overall model fit, as well as the predictive capability of the model. In order to test this the car fleet of 1998 and 1990 was backcasted for the specifications investigated.

The explanatory variables for the top nest in the model are:

- ▶ alternative specific dummies for

- □income groups
- □household sizes
- □age groups
- □the number of persons in employment in the households
- □Logsum variable of the bottom nest

The explanatory variables for the bottom nest in the model are:

- □car price index, the real car price (= index of price of a car / general price index)
- □the number of kilometres driven per household
- □alternative specific dummies for
 - □income groups
 - □household sizes
 - □age groups
 - □the number of persons in employment in the households
- □Logsum variable from the Type choice module

One of the alternatives was always used as reference in each nest and one of each of the alternative specific dummies was the reference category. This means that no parameters were estimated for this.

The variable “Car price index” is a measure of the development of the purchase price of cars relative to the development of the general price level. The number of kilometres driven per household is the *total* number of kilometres driven per household (provided there is car ownership). Note that changes in the variable costs of car ownership enter the model through this variable. This is because a change in the variable costs of car ownership will change the number of kilometres demanded and, therefore, the car ownership.

The logsum of type choice represents the most attractive car from which people can choose. If the car costs increase it will become less attractive to own one or more cars. This will result in a higher probability that households do not own a car in the top nest.

Model estimation

The model was estimated in two rounds. The coefficients for the household characteristics as well as the logsum associated with the choice between 0 and 1+ cars was estimated in the first round on the basis of pooled OVGs from the years 1990 - 1998. The other parameters were estimated in the second round. This choice was necessary because of the availability of data. The second model was estimated on the basic matrix (2003) of Dynamo, since there was no information available about type choice, annual kilometres driven or the development in the price of cars in the OVG. Therefore, it was not possible to carry out an integral estimate of the model. Despite this, consistent estimates (for very large samples these do come within the range of actual values) were obtained because alternative specific variables were involved each time, but the t values in the models will not be correct. We regard this as a minor problem. The Multinomial Logit model was used each time.

The results of the model estimates are shown in Table 1. The household variables that are not shown (e.g. low income) are the reference categories, which all have a value (coefficient) equal to zero.

Table 1 Results of model estimates HHNumber, first round

Variable	Coefficient	t
<i>Top nest (>0 cars is reference)</i>		
Logsum parameter bottom nest	0.100	37.8
0 cars, average income	-1.019	66.1
0 cars, high income	-1.583	89.2
0 cars, two persons household	-1.474	112.7
0 cars, > two persons household	-1.681	98.9
0 cars, 35-64	-0.862	57.4
0 cars, >64	-0.267	14.3
0 cars, 0 employed in household	0.727	50.6
0 cars, >1 employed in household	0.008	0.3
	R² =0.436	N =270,910
<i>Bottom nest (>1 car is reference)</i>		
1 car, average income	-0.587	22.3
1 car, high income	-1.437	62.0
1 car, >2 persons income	-0.845	55.3
1 car, 35-64	-0.179	7.2
1 car, >64	-0.231	6.0
1 car, 0 employed in household	-0.229	8.8
1 car, >1 employed in household	-0.352	23.1
	R² =0.530	N =225,308

Each of the estimated parameters in the model has the expected sign.

- □ If cars become more attractive the probability of ownership of a car increases (the logsum refers to the alternative “>1” car; this is the reference alternative for all other variables)
- □ The higher the income the lower the probability of not owning a car
- □ The larger the household the lower the probability of not owning a car
- □ The middle age category has the greatest probability of owning a car, and the oldest the lowest probability of owning more than 1 car
- □ The more persons in employment in the household the lower the probability of not owning a car, and the lower the probability of owning 1 car.

Second round: effects of car price, kilometres and logsum type

The parameters associated with the price index, the number of kilometres driven and the logsum type choice were determined in this round on the basis of the AH-matrix 2003 with 71 items. The value of the logsum for type choice is determined on the basis of the coefficients of the type choice model (see Section 6).

A linear logit model was estimated for the car ownership shares. The car prices, the average number of kilometres and the logsum associated with the type were added to each cell. The results are shown in Table 2. Account has been taken of the number of households in each of the cells when determining the t values.

Table 2 Results of model estimates HHNumber, second round

Variable (>1 car is reference)	Coefficient	t
(α) Car price index	4.792	11.9
(β) Household kilometres	-0.145	97.3
(γ) Logsum type choice	-0.155	6.0
	R² =0.946	N =34,454

The model has a good fit and the signs are also plausible.

- α) As the relative fixed car costs become higher it becomes more attractive for people to own one rather than two cars.
- β) As the number of kilometres driven per household increases it becomes less attractive to own one car.
- γ) As the car types become more attractive it becomes less attractive for people to own one car.

Constants were added to the model in both nests for each household type as the last step in the model, so that the model exactly predicts the size of the car fleet in 2003.

5. The module Type choice

The module Type choice only concerns private cars. So, from the total demand for cars (from HHNumber) the lease cars are deducted first.

Model specification

The model is estimated on the basis of road pricing research carried out by MuConsult in 2001/2002 for the Ministry of VROM (Housing, Spatial Planning and Environment) and AVV. It concerned the effects of the introduction of road pricing on car ownership, car use and the composition of the car fleet. Detailed research into the consequences of the introduction of road pricing on the composition of the car fleet was carried out with the help of an SP choice experiment.

Only the data from the owners of a new or second-hand private car (562 households) referring to the type of car(s) owned (RP) or to be purchased (SP) was used for the car ownership model.

The Multinomial Logit model on the basis of the combined SP-RP data was used for estimating the type choice model. The alternatives were the 60 car types that could be chosen by private households. The choice of model specification was again made after extensive specification research, during which both the overall model fit and the extent to which model specification could backcast the car fleet of 1990 and 1998 were considered.

The variables included in the model are:

- \ln (Purchase price).
- the variable costs per year.
- the amount of road tax (MRB).
- the \ln (number of variants of each type of car available) “ \ln (Size)”.
- alternative specific dummies for weight class x income group.
- alternative specific dummies for the age group of the car.

The variable \ln (Size) is a measure of the number of models of a particular car type on offer. This is because the car fleet consists of many more models than the car types that are distinguished in the car ownership model. It is known from psychological literature that the more variants there are in a particular class the more attractive that class becomes. Account can be taken of this in a choice model with aggregated alternatives (60 car types) by including this number of underlying models as an explanatory variable.

Model estimation

The model estimates of the price variables (with the exception of the MRB) are based on the combined RPSP data. All other variables in Table 3 are based only on the RP data. Parameters were also estimated for the specific SP variables and the scale parameter that is necessary when estimating a combined SP/RP model. Only variables that are used in the module Type choice are shown. *Effects-type* coding has been used for the alternative specific dummy variables here.

Table 3 *Coefficients in the type choice module*

Variable	Coefficient	t
<i>Costs</i>		
Ln(Purchase)	-2.000	1.8
Variable costs	-0.587	3.1
MRB	-0.683	12.8
<i>Supply</i>		
Ln(Size)	0.511	4.8
<i>Weight class x income</i>		
Low income: <951kg	-0.162	0.4
Low income: 951-1150kg	-0.239	1.2
Low income: 1151-1350kg	0.054	0.2
Low income: >1350kg	0.346	- ¹
Average income: <951kg	-1.353	3.7
Average income: 951-1150kg	-0.147	0.8
Average income: 1151-1350kg	0.666	4.0
Average income: >1350kg	0.834	- ¹
High income: <951kg	-1.477	3.7
High income: 951-1150kg	-0.785	3.4
High income: 1151-1350kg	0.600	2.8
High income: >1350kg	1.663	- ¹
<i>Age class</i>		
New	1.298	2.4
1 - 2 years	0.239	0.7
3 - 5 years	0.177	2.0
6 - 10 years	-0.441	1.5
>10 years	-1.273	- ¹
Observations (respondents x choice sets)	RP: 562 x 1	SP: 1016 x 12
Alternatives in choice set	RP: 60	SP: 6

1: reference category

Table 3 shows that car owners prefer:

- ▶ □ large and new cars, whereby this preference for vehicle size is greater with a higher household income.
- ▶ □ less expensive cars both in purchasing and use.
- ▶ □ car types for which there are a large number of variants available (Ln(Size)).

Naturally, in practice the owner considers the balance between the preference for large and new and the associated costs.

After estimating the model on the basis of individual respondents in the road pricing research the model had to be made suitable for use within the structure of the AH matrix for 2003, so that the type choice distribution for that year could be predicted exactly. In order to do this the development of the different cost variables in the period 2001 – 2003 was first determined on the basis of available data. A large number of constants were then applied to the model (for each household type x car

type) so that the private car fleet for 2003 was exactly predicted by the module Type choice.

6. The module EMOD

The module HHNumber gives the total *demand* for cars and the module Type choice the desired distribution across the different car types (for cars in private ownership), in both cases for the actual car prices during period t . The existing car fleet (i.e. the car fleet from period $t-1$, that has become 1 year older and from which some cars will have disappeared because of scrapping, export and import, and accidents) determines the total *supply* of cars in period t , whereby DYNAMO assumes that new vehicles are available without restriction.

However, supply and demand will in general not be in equilibrium. The module EMOD adjusts the second-hand car prices so that this will be the case.

Determination of the equilibrium prices in EMOD

The following iterative rules are used to determine the equilibrium prices.

1. Start with the prices from the previous period, thus (market) prices in the second-hand market from period $t-1$.
2. Determine the supply and demand of second-hand cars as described above, whereby the exogenous prices for the current period are used for new cars.
3. Determine the size of the demand surpluses or shortfalls $V_k - A_k$.
4. Change the price of every second-hand car type using the product of the demand

$$\Delta P_k = c(V_k - A_k)$$

surplus and a constant $c (>0)$.

5. Go back to step 2 using the adjusted prices and carry out the next steps until the price adjustment is almost zero. At that stage the market equilibrium has been reached.

The result of this algorithm is a set of 48 equilibrium prices for second-hand private cars. A new “market” price is determined on the basis of these equilibrium prices and the prices from the previous period(s). Together with the 12 new prices that have been fed into the model via the input file this gives the total vector of car prices in period t .

Estimation of delays in the car price

The behavioural principle used is that consumers do not react immediately to price changes, but that there can be a certain delay in the reactions. For instance, people who want to purchase a car in year t tend to base their intentions on the price levels of cars in the previous year. It is even possible that this may result in a delay over several years.

In order to determine coefficients where there are possible delays a series of time-related data is necessary. This time-related data for the prices in the second-hand market was available for the period 1998-2003 (source: CBS, Statistics Netherlands, car price index figures). As well as this the AH-matrices for the period 1998-2003 are available that show the size and composition of the car fleet in combination with household characteristics.

A grid-search method has been used to determine the parameters. The basic function is:

$$P_t = a P_t^{\text{EMOD}} + b P_{t-1} + c P_{t-2} + d P_{t-3} + \dots,$$

where $a + b + c + d + \dots = 1$.

Combinations of these coefficients are used in the car ownership model, and lead to results in terms of car price indices, size and composition of the car fleet. These are then compared with the actual trends. The combination that gives the best forecast of the previous factors is selected.

The result of this is that the price of year t counts for 0.1, that for year $t-1$ for 0.8 and for year $t-2$ for 0.1 again. Price makes the model dynamic in this way.

Second and higher order effects

The modules HHNumber – Type choice – EMOD are gone through a number of times within one year in Dynamo 1.3. In this way, price changes in the second-hand market have an effect in the same year on the size and composition of the car fleet. This is particularly important when calculating the effects of policy scenarios. In practice the effect will already become visible in the same year and not just one year later.

Figure 4 Iterative process within 1 year of HHNumber, Type choice and EMOD

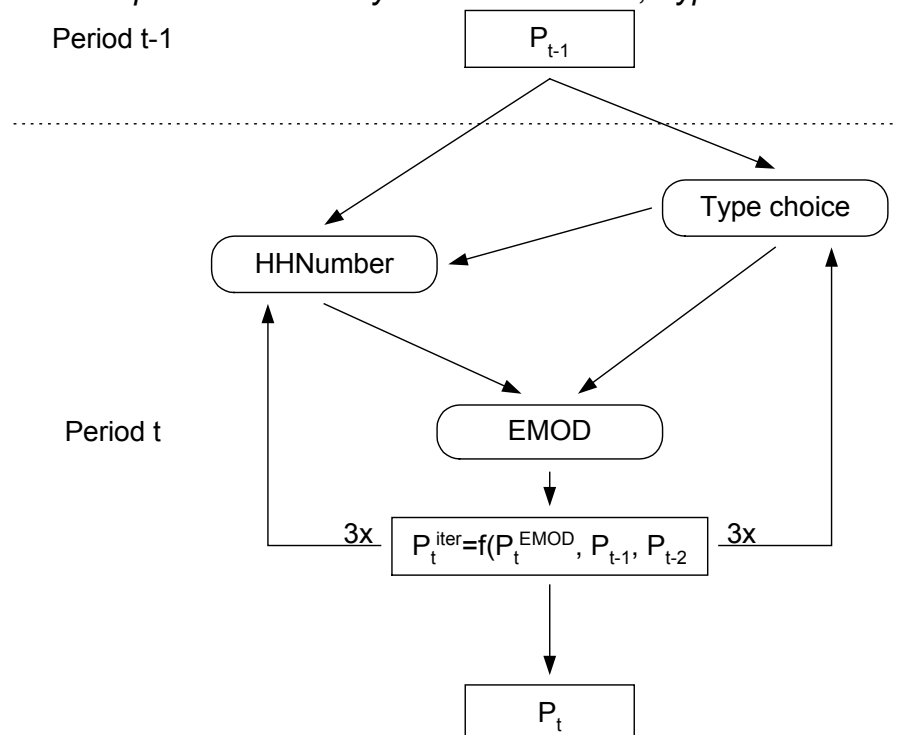


Figure 4 shows this iterative process, the arrow between modules Type choice and HHNumber represents the logsum from Type choice, which is one of the variables in HHNumber. After going through EMOD once using the second-hand car prices from period $t-1$, supplemented with the new prices for period t , the whole system is gone through another 3 times after which the definitive second-hand equilibrium prices for

period t , and the final market prices are determined. A large number of calculations of the model have shown that carrying out additional iteration has almost no further effect on the results.

7. The module Scrapping

Dynamo has a scrapping module that shows the probability that cars with specific characteristics will be scrapped. The module is based on data and analyses that were carried out for the Ministry of VROM. The ministry wished to have insight in the way different variations of so-called scrapping subsidies would have an effect on the probability that a car would be scrapped and whether or not the owner would then buy another car.

Part of the data collected has been used for Dynamo for the development of the scrapping module. Extensive specification research was carried out for the VROM study and a model prepared which could be used to calculate the effects of policy variants. The results of these exercises have been used for the development of a logit model that describes the chance of whether or not a car will be scrapped.

This probability is calculated on the basis of the following *utility* equations:

$$\begin{cases} Utility_{scrapping} & = C_{scrapping} + C_{Condition} \\ Utility_{no\ scrapping} & = C_{no\ scrapping} + 0,548 * (residual\ value - subsidy) - 1,066 * repairs^3 \end{cases}$$

where the residual value, the subsidy and the annual repair costs are measured in thousands of Euros. The constant ($C_{condition}$) determines the effect on the scrapping probability of the conditions for payment of the subsidy. The constants $C_{scrapping}$ and $C_{no\ scrapping}$ are the calibration constants that ensure that the model reproduces the exact probabilities of scrapping for 2003.

When the prizes of older second-hand cars change as a result of the difference between supply and demand the scrapping probability will then also change in the dynamic scrapping model. The scrapping probability will decrease if the car becomes worth more and increase if it becomes worth less.

8. Application

A number of model predictions have already been made using DYNAMO. This section outlines the type of results that can be obtained by using Dynamo. We look specifically at the effects of an increase in the fuel costs by 10% from 2004. The results of this are compared with the results from a reference scenario, assuming stable price values for most variables in the model in comparison with the reference year 2003.

Table 4 Outline results from a 10% fuel price increase

Variable	2003	2010	2010 (ref)	Effect
Size of car fleet (x1,000)	6,908	7,526	7,588	-0.81%
Share of fuels				
Petrol	81.2%	76.8%	77.0%	-0.2
Diesel	14.8%	20.6%	20.4%	0.2
LPG	4.0%	2.6%	2.6%	0.0
Average car kilometres driven	16,542	16,392	16,447	-0.33%

Table 4 gives the results for a number of variables, fully aggregated over household and car types. The year being viewed is 2010, thus we are looking at the effect over a relatively short period. Note that the underlying results are obtained for *all* car and/or household types. It would go too far though to present these very detailed results here.

The size of the Dutch car fleet increases in the reference scenario from almost 7 million vehicles in 2003 to almost 7.6 million in 2010. The effect of a higher fuel price is a slight drop by 0.81%. The effect on the fuel type is caused mainly by the difference in fuel prices in the base year. Because diesel is significantly cheaper than petrol an equal increase of 10% makes this fuel relatively cheaper. This increases the share of diesel by 0.2 percent relative to the situation of the reference scenario. LPG is in fact even cheaper, but because of the very low share of this fuel in the car fleet, only marginal effects in terms of the market share take place. The higher fuel prices also lead to a reduction in the average number of car kilometres driven by 0.33%. The total number of kilometres driven by all the cars together drops by more than 1%.

The effects discussed in the above application are relatively small, seeing that the calculations for the scenario lead to only small price changes. Much greater effects can occur with larger price changes, or if only one or several types of car becomes more or less expensive either to purchase or in use.

As well as this scenario, a large number of other scenarios have already been calculated using this model. Table 5 shows some resulting *output* elasticities on the size and use of the car fleet in 2010, from price changes in 2004.

Table 5 Output elasticities by price changes (effect in 2010)

Price measure taken	Elasticity	
	Size of car fleet	Total car kilometres driven
-10% purchase tax on new cars (BPM) ¹	0.094	
-10% road tax (MRB)	<0.001	
+10% fuel prices	-0.08	-0.11
+0.72% higher new prices	-0.26	

1: On average the BPM is about 25% of the new price

When considering the results shown in Table 5 it must be remembered that Dynamo is a *dynamic* model, in which there is also a delay in the effect on car prices. Effects can be dampened or actually amplified, particularly when strongly aggregated data is being viewed. After all, households can decide to change to the purchase of a different type of car when the ownership or use of a particular type becomes less attractive. Then there may be almost no effect on the total car ownership, for example, but within this there can have been considerable shifts between the types of car.

In short, the total dynamic effect of a price measure is the result of several underlying processes in car ownership (HHNumber), car use (D(Car use), Scrapping and Type choice, that may reinforce each other but can also dampen each other. In all cases these processes are a direct (the measure itself), and/or indirect (EMOD), consequence of changes in car prices and car costs.

9. Conclusions and discussion

The effects of policy measures on the areas of the size, use and composition of the Dutch car fleet can be mapped for the period 2003 - 2040 using the car ownership model DYNAMO (version 1.3) that has been developed.

This is a dynamic model, in the sense that effects operating in one year work through into the following year. The heart of the model is formed by the equilibrium module EMOD, in which the prices of second-hand cars are so adjusted that an equilibrium is formed between supply and demand, both for the car fleet as a whole and for each household type separately. However, developments in car prices have a delayed effect and are a function of theoretical equilibrium prices from the current year and the market prices of 1 and 2 years previously. The size, use and composition of the car fleet are all functions of household and car characteristics, including the fixed and variable car costs.

The car ownership model (version 1.3) is certainly not yet perfect. There are still all sorts of improvements and extensions possible. In a number of cases, for example, pragmatic choices have been made up to now, partly because no suitable data was available as yet for developing model specifications. These include the following.

- □ The lease module D(HHLease)). At present a fixed distribution of car types is used in this and the number of lease cars demanded is not a function of price variables in the model.
- □ Import and export (ImExport). The same fraction is used for every car type at present, independent of price variables in the model.

In both cases it would be a useful extension to develop the modules further in terms of the model and to make them also partly dependent on the price variables in the model.

As well as this, fine tuning and improvements are possible with other modules, such as:

- □ the way in which general car fleet developments in the future are taken into consideration. Insight is needed, for instance, about how much the average lifetime and the weight of cars will increase in the coming years.
- □ the introduction of new types of fuel. Hybrid cars are becoming increasingly popular for example, but these cannot yet be distinguished as a separate fuel class.

Some of the potential improvements outlined above will be included in the following versions of Dynamo. In this way a car market model for the Netherlands will be developed which allows increasingly more effects of intended policy measures to be calculated in increasingly better ways.