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

<table>
<thead>
<tr>
<th>Aspect</th>
<th>FACTS</th>
<th>Cramer</th>
<th>Van den Broecke</th>
<th>LMS</th>
<th>De Jong</th>
<th>LVO models</th>
<th>Scenario explorer</th>
<th>DVTM</th>
<th>Golounov et al.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand-supply</td>
<td>Demand for all cars; Supply of cars &gt;5 years; Equilibrium mechanism</td>
<td>Demand and supply; Equilibrium mechanism</td>
<td>Demand</td>
<td>Demand</td>
<td>Demand</td>
<td>Demand</td>
<td>Demand</td>
<td>Demand</td>
<td>Demand</td>
</tr>
<tr>
<td>Level of Aggregation</td>
<td>Disaggregate</td>
<td>Aggregate</td>
<td>Aggregate</td>
<td>Disaggregate</td>
<td>Disaggregate</td>
<td>Disaggregate</td>
<td>Aggregate</td>
<td>Disaggregate</td>
<td>Disaggregate</td>
</tr>
<tr>
<td>Dynamic or static model</td>
<td>Static, but shift from new to old cars over time</td>
<td>Dynamic</td>
<td>Dynamic</td>
<td>Static</td>
<td>Static</td>
<td>Static</td>
<td>Static (except Meurs’ panel model)</td>
<td>Dynamic</td>
<td>Dynamic</td>
</tr>
<tr>
<td>Long or short run forecasts</td>
<td>Medium &amp; long &amp; long</td>
<td>Medium and Long</td>
<td>Medium &amp; Long</td>
<td>Long</td>
<td>Long (except Meurs’ panel model: short, medium and long)</td>
<td>Long</td>
<td>Short &amp; medium</td>
<td>Short &amp; medium</td>
<td></td>
</tr>
<tr>
<td>Theory</td>
<td>Strong basic assumptions, can be at odds with theory</td>
<td>Economic market equilibrium theory</td>
<td>No strong links</td>
<td>Can be based on random utility theory</td>
<td>Strong links</td>
<td>Some links with random utility theory</td>
<td>No strong links</td>
<td>Some links with random utility theory</td>
<td>Strong links</td>
</tr>
<tr>
<td>All cars</td>
<td>All</td>
<td>All</td>
<td>All</td>
<td>All</td>
<td>Private cars</td>
<td>All</td>
<td>All</td>
<td>Private cars, no rare, expensive brands</td>
<td>All</td>
</tr>
<tr>
<td>Car use</td>
<td>Included as kilometrage, but insensitive</td>
<td>Not included</td>
<td>Not included</td>
<td>In other submodels</td>
<td>Included, kilometrage only</td>
<td>In other submodels</td>
<td>Included, kilometrage only</td>
<td>Not included</td>
<td></td>
</tr>
<tr>
<td>Data requirements</td>
<td>Moderate</td>
<td>Light</td>
<td>Light</td>
<td>Heavy</td>
<td>Heavy</td>
<td>Very heavy</td>
<td>Light</td>
<td>Very heavy</td>
<td>Very heavy</td>
</tr>
<tr>
<td>Recent estimates</td>
<td>Updated 1999</td>
<td>No recent update</td>
<td>No recent update</td>
<td>No recent update (car ownership)</td>
<td>No recent update</td>
<td>No recent update</td>
<td>Updated 1999</td>
<td>Data of 1993/4</td>
<td>New model on recent data</td>
</tr>
<tr>
<td>Special treatment of business cars</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Car types</td>
<td>Weight, fuel type, vintage, private/business, 1st/2nd car</td>
<td>Old/new, 1st/2nd car</td>
<td>No car types</td>
<td>1st/2nd car</td>
<td>1st/2nd car</td>
<td>No car types</td>
<td>Fuel type, energy use, private/company 1st/2nd car</td>
<td>Brand-model; many distinctions Defined</td>
<td>No type outputs; brand-model inputs</td>
</tr>
<tr>
<td>Impact of income</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Impact of car cost</td>
<td>Fixed and variable (but no policy runs reported)</td>
<td>None</td>
<td>Fixed cost (variable cost in other submodels)</td>
<td>Fixed and variable (also on car use)</td>
<td>None</td>
<td>Fixed and variable (also in car use)</td>
<td>Fixed (no policy runs have been reported)</td>
<td>Fixed (no policy runs have been reported)</td>
<td></td>
</tr>
<tr>
<td>Aspect</td>
<td>FACTS</td>
<td>Cramer</td>
<td>Van den Broecke</td>
<td>LMS</td>
<td>De Jong</td>
<td>LVO models</td>
<td>Scenario explorer</td>
<td>DVTM</td>
<td>Goloumov et al.</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------------------</td>
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<td>-----------------</td>
<td>----------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-------------------</td>
<td>---------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Car quality impacts</td>
<td>Need to work through car cost</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Through price and depreciation</td>
</tr>
<tr>
<td>Impact of licence holding</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Socio-demographic impacts</td>
<td>Age, household size</td>
<td>Generation effect</td>
<td>Age, gender, education, marital status, employed</td>
<td>Age, gender, household size, workers in household</td>
<td>Age, gender, household size, occupation</td>
<td>Included</td>
<td>Age, household size, education, employed</td>
<td>Included</td>
<td>Limited number of variables</td>
</tr>
<tr>
<td>Impact of public transport quality</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>In some models</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Impact of style of driving on fuel efficiency</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Spatial component</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Link to LMS zones</td>
<td>No</td>
<td>No</td>
<td>Link to large zones</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Experience in policy simulation</td>
<td>Applied very many times</td>
<td>Applied long ago for a base-case</td>
<td>Applied long ago for different scenarios</td>
<td>Only one independent application, long ago</td>
<td>Several policy runs, long ago</td>
<td>Some not applied, others long ago, no policy runs</td>
<td>Applied regularly</td>
<td>Several policy runs, 7 years ago</td>
<td>No applications reported</td>
</tr>
<tr>
<td>Scrappage included</td>
<td>Yes, insensitive</td>
<td>Yes, insensitive</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes, sensitive</td>
<td>Yes, insensitive</td>
</tr>
</tbody>
</table>
### Table 2. Comparison of types of car ownership models

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


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