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Scientific review of TREMOVE – a European transport policy assessment model

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Abstract

Scientific review of TREMOVE – a European transport policy assessment model

A review of the European policy assessment model TREMOVE carried out by IIASA (International Institute for Applied Systems Analysis), BIO Intelligence Services S.A.S., IEEP (Institute for European Environmental Policy) and the MNP (Netherlands Environmental Assessment Agency) has led to the conclusion that TREMOVE is a valuable model to apply to the analysis of the environmental and welfare impacts of transport policies. However, some limitations related to the structure, assumptions and treatment of uncertainty in TREMOVE have been identified that may diminish the model's potential to provide robust policy-relevant insights in all policy cases. These limitations are:

- TREMOVE is not designed for the assessment of policies that are expected to have a significant impact on incomes or production.
- The review has identified a number of issues related to the structure, assumptions and treatment of uncertainty that may diminish the model's potential to provide robust policy-relevant insights.
- Current assumptions in the car choice module are too crude to expect policy-relevant results for CO_2 policies for cars.
- TREMOVE is too highly dependent on an imported baseline for parameterization, and potentially sensitive to the assumptions embedded in the baselines (which are exogenous to TREMOVE itself). The process of importing a baseline is also time-consuming and highly data intensive and it makes TREMOVE difficult to understand.

Short- and long-term recommendations to improve the policy analysis performance of the model and to make the model less complex are formulated in the report.

Keywords: model, policy assessment, review, Europe, transport

Rapport in het kort

Wetenschappelijke review van TREMOVE - een Europees transport model voor beleidsevaluatie

Een review van het Europese transportmodel TREMOVE voor de evaluatie van verkeersmaatregelen uitgevoerd door IIASA (International Institute for Applied Sciences), BIO Intelligence Services S.A.S., IEEP (Institute for European Envronmental Policy) heeft als conclusie dat TREMOVE een waardevol model is om de milieugevolgen van transportmaatregelen te analyseren. Tegelijkertijd zijn enkele beperkingen ten aanzien van de modelstructuur en veronderstellingen over onzekerheden geïdentificeerd die het potentieel van het model om tot robuuste voorspellingen te komen kunnen ondermijnen. Deze beperkingen zijn:

- TREMOVE is niet geschikt voor het evalueren van maatregelen die een grote invloed hebben op inkomen of productie;
- De review heeft een aantal zaken aan het licht gebracht met betrekking tot de structuur, aannames en het omgaan met onzekerheden van het model die de robuustheid van eindresultaten nadelig beïnvloeden;
- De huidige structuur van autokeuze model is te elementair om beleidsrelevante resultaten met betrekking tot CO_2-beleid voor personenauto's te mogen verwachten;
- TREMOVE is met betrekking tot het parametriseren te afhankelijk van de geïmporteerde baseline (die volledig exogeen is) en mogelijk gevoelig voor de aannames die in deze baseline zijn verwerkt. Het importeren van de baseline is ook erg tijdrovend en data-intensief. Bovendien maakt het TREMOVE erg ondoorzichtig en moeilijk te begrijpen.

Korte en lange termijn aanbevelingen zijn geformuleerd die het model meer geschikt kunnen maken voor de beoordeling van beleidsmaatregelen, en het model minder complex maken.

Preface

We have welcomed the opportunity to work in this review alongside the TREMOVE team of Transport and Mobility Leuven (Griet De Ceuster and Bart Van Herbruggen) and with the European Commission (Jacques Delsalle). We thank them for their openness, particularly with respect to providing information and data on TREMOVE.

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Summary: conclusions and recommendations

The conclusion of the authors of this scientific review is that TREMOVE is a valuable transport policy analysis model. The strength of TREMOVE is that it represents a complete economic policy assessment tool which can be used for an extensive range of transport policies and their impacts, including changes in transport demand, modal choice, vehicle stock, fuel consumption and emissions. Moreover, the TREMOVE model incorporates feedback mechanisms, thereby allowing it to account for rebound and other indirect policy effects. Further, TREMOVE has become – purely by accident – an important European transport database because it contains a vast amount of detailed transport data on all of the transport modes for 21 European countries.

We identified four main limitations of the model:

1. The assumptions in TREMOVE restrict the range of policy assessments for which the model is suitable to only those that are expected to have a limited impact on incomes or production. TREMOVE assumes that incomes and production are unaffected by policy changes and that income elasticity of any transport demand is equal to 1. Accordingly, TREMOVE is not designed for the assessment of policies that are expected to have a significant impact on incomes or production. This limited range of TREMOVE is not a problem per se, but potential users of the model should be aware of this feature. TREMOVE can cope with policies such as emission standards for the emissions of regulated pollutants and modest transport pricing policies. However, a 'grey area' may be CO_2 policies: TREMOVE requires improvements to deal well with these policies (see point 3 below). In addition, TREMOVE is not suitable for general tax policies (for example, large-scale environmental tax reform) which affect incomes and production.
2. The review has identified a number of issues related to the structure, assumptions and treatment of uncertainty that may diminish the model's potential to provide robust policy-relevant insights. Many of these issues relate to assumptions regarding the elasticities of substitution (EoS), which play a large part in determining the behaviour of the TREMOVE demand module in response to policy measures or other market developments. Firstly, the wide range of uncertainties in estimates of transport demand and other elasticities is not represented in the model. Secondly, EoS are assumed to be constant across 21 countries and during the period 1995–2020, which may be unrealistic and limit the credibility of the model. Thirdly, the level of detail in the demand trees used in the transport demand module – and consequently requiring estimates of EoS – may be excessive, considering the high level of uncertainty associated with some of the elasticities. Moreover, the high level of detail represented in the module may be unnecessary given the types of questions TREMOVE seeks to answer. Fourthly, the elasticities applied in the transport demand module appear to

only represent short-run behaviour, and hence TREMOVE may underestimate the long-run response to policy and other stimuli, particularly in upper levels of the demand tree;

3. This review shows that the current assumptions in the car choice module are too crude to expect policy-relevant results for CO_2 policies for cars. Three main problems are identified here. The current modelling of car type choice behaviour in TREMOVE does not sufficiently represent car choice preferences of company car owners and lease car owners, who are expected to become more important in the future. Secondly, the current assumptions in TREMOVE result in a (potentially large) overestimation of the importance of future fuel savings as a factor in car choice. Thirdly, the degree of disaggregation of vehicle stocks is too crude to reflect real-life choices realistically;
4. TREMOVE is too highly dependent on an imported baseline for parameterization and is potentially sensitive to the assumptions embedded in the baselines (which are exogenous to TREMOVE itself). This process of importing a baseline is also considered to be time-consuming and highly data intensive, thereby making TREMOVE difficult to understand. Most stakeholders seem not to see clearly that the behavioural responses of TREMOVE are partly dependent on the characteristics of an imported baseline. Finally, this importation process makes TREMOVE relatively inflexible for carrying out scenario analysis. In ex ante policy analysis uncertainty is high because, for one thing, the future is uncertain. One possibility for dealing with this is to estimate the policy impacts of a policy in more than one 'future' (i.e., in more than one base case). To summarize: in TREMOVE this sensitivity approach is theoretically possible, but in a practical sense a flexible base case scenario approach is relatively hard to implement in TREMOVE.

The purpose of TREMOVE is to model policy impacts for almost all kinds of transport policies for 21 European countries and for almost all transport modes. This high level of ambition is impressive, but it also means that the model will inherently include a number of disadvantages. Firstly, the realizing of this level of ambition requires a large and complex model that is relatively difficult to manage. Secondly, the model and the model description have become so large and complicated that potential clients are unable to understand or use the model, consequently limiting their trust in what they consider to be a 'black box'. Thirdly, both the complexity and the shear abundance of the data required by TREMOVE divert the attention of stakeholders away from issues related to the policy analysis performance of the model, and how to improve this performance. Instead, stakeholder meetings often focus on data handling and baseline data issues, thereby inhibiting the process of improving the model and doing little to overcome the perceptions that TREMOVE is somewhat of a 'black box'.[1]

[1] This does not imply that we suggest not paying any attention at all to data problems and baseline issues, but the current focus in the stakeholder meetings seems to be for 100% on these issues, to the exclusion of the others.

Recommendations

In our recommendations we distinguish between suggestions for short-run and long-run improvements, as requested by the commissioner of this review. Our short-run recommendations are based on the premise that the current structure of the model is maintained. In the long-term recommendations we take a more radical approach and include suggestions which (may) alter the design of the current model.

Short-term recommendations

a. It is advisable to incorporate into TREMOVE any newer version of COPERT (European emission factor model) as soon as the latter becomes available. The COPERT emission and fuel consumption model is maintained in Europe (long-term contract for the European Environment Agency). Instead of having to transcribe the emission factor equations from COPERT into TREMOVE, it could be advised to have both models working together, so that any newer version of COPERT can be used as soon as available.
b. In the current contract for developing a newer TREMOVE version (TREMOVE 3), the set of price elasticities and elasticities of substitution (EoS) will be reviewed and validated. Based on the analysis presented in this report we recommend that this review and validation focus on the following points. (1) The wide range of uncertainty of the elasticities and how these uncertainties can be reflected in the model should be explored. Based on long-term recommendations (see page 13) a start could be made to evaluate whether there is a reason to reformulate the transport demand module decision tree over the longer term to reduce complexity and to reconcile the level of detail with the (very high) level of uncertainty in some estimates of elasticity. (2) Country-specific elasticities (in close contact with European country experts) should be researched. (3) The transport demand module should be reformulated to better represent long-run elasticities.
c. In the Term of Reference for TREMOVE 3.0 it is stated that the contractor for the newer TREMOVE 3.0 version should ensure that it is possible to introduce transport baseline data from alternative sources – at the European, national or regional/urban level – easily into TREMOVE. In doing so, the possible impacts of baseline assumptions on the robustness of the policy insights provided by TREMOVE could be explored with scenario analysis. This would go some way towards addressing the significant uncertainties associated with future demand levels and vehicle stock characteristics, which represent key uncertainties that may undermine the reliability of TREMOVE results (comment 5). The other key uncertainty relates to parameter estimates in the model. One set of uncertain parameters is the EoS, which remain uncertain even if recommendation b (see above) is carried out. Accordingly, some parameter sensitivity analysis should be performed on these elasticities, with each policy analysis exercise focussing on the sensitivity of those elasticities likely to be

most relevant. One possibility for carrying out this recommendation is to take an actual policy run and vary important baseline assumptions (in doing so, implicitly new baseline scenarios are used) and important elasticity values.

d. The European Commission currently funds a TREMOVE-related project on: (1) car purchasing behaviour; (2) the importance of the company car market and (3) the impact of company car taxation on the environmental performance of cars. The analysis in this report shows that the results of this project are highly relevant to improving TREMOVE's capability to assess the impacts of car fuel efficiency (or CO_2) policies. A parameter requiring special attention in this project is the discount rate. In TREMOVE the assumption is that vehicle choice will be driven by full lifetime running costs with only the standard discount rate of 4%. It seems important to move away from this assumption, because in reality consumers use implicitly far higher discount rates. Another issue in this project could relate to the degree of disaggregation of vehicle stock required in the model to reflect real-life choices realistically. Of course in defining this 'ideal' degree of disaggregation the issue of data availability should be taken into account.

e. To improve the role of stakeholders in the TREMOVE development process, it seems advisable to run TREMOVE with 'example' policy runs and discuss the plausibility of the results with stakeholders and potential users. One possibility is to have these discussions based on the 'Euro 5' and 'CO_2 + Cars' policy runs, both of which will be published before the end of 2006. Within this framework in which the current situation would be compared to the results of policy runs with 'Euro 5' and 'CO_2 + Cars', it would become clearer to stakeholders, model developers and the EC just how the model works, and what are its strong and weak points with respect to policy impact assessment. The desired result would be that the stakeholder process would then direct the development of TREMOVE towards improvement to ensure that it remains a high-quality policy assessment tool.

f. Paragraph 3.4 of this report contains different detailed suggestions aimed at improving model use and making usage more transparent (the suggestions are not repeated here).

Long-term recommendations

g. Currently, the implicit goal of TREMOVE is to be suitable for analysing all kinds of transport policies, for all transport modes, for 21 countries. In our view, a long-run option may be to make the model smaller – for example, by limiting the model to 'only' road transport. In doing so, the model may become more transparent, and the model developers can focus entirely on how to improve the (relatively difficult) modelling of road transport policies.

h. In guiding this process – the development of a policy analysis tool for transport policies – the EC should be able to state clearly their expectations of the performance of the model, based on their assessment of just what will be the focus of EC transport policy analysis in the coming years (expectation management). As already noted, one pertinent subject of discussion may be whether – over the longer term – it is really necessary to have one integrated transport policy analysis model for all transport modes. A price will be paid for abandoning some transport modes, and some current features of TREMOVE (some integration and modal choice impacts will be lost). On the other hand, it should not be forgotten that for a wholly integrated transport model there is also a price tag: the inherent complexity makes this kind of large model relatively hard to manage and less transparent for potential users and stakeholders.

i. If kilometre charging policies and CO_2 policies for road transport are important options in future EC transport policy (see expectation management, bullet g) it is important to include an improved car choice model and a light-duty and heavy-duty vehicle choice model in TREMOVE.
j. Coupled with the parameter sensitivity analysis for the EoS (short-term recommendation b), there may be a case for reformulating the transport demand module decision tree over the longer term to reduce complexity and to bring the level of detail more in line with the (very high) level of uncertainty in some estimates of elasticity. However, it may be premature to abandon the current formulation, so it is recommended that a reduced-form formulation be developed for use in parallel.
k. A long-term improvement could be to incorporate a 'simple' forecasting module into TREMOVE. In doing so, the complexity of the current calibration process with an imported baseline would be reduced. In our view TREMOVE should not become a (formal) EU transport forecast model, or a SCENES competitor. TREMOVE will remain a policy analysis tool, and one which uses different baselines to deal better with the uncertainties in policy analysis than is currently the case. By making it relatively easy in TREMOVE to forecast transport emissions in different baselines, the model will become a far more flexible policy analysis tool that will show politicians the emission and welfare impacts of new policy options in different (uncertain) futures.

1. Introduction

TREMOVE is a European policy assessment model that has been developed to study the effects of different transport and environment policies on the emissions of the transport sector (De Ceuster *et al.*, 2005). The model estimates – for the period 1995–2020 – the changes in transport demands, modal shifts, vehicle stock renewal, emissions of air pollutants and the welfare level for different policies. TREMOVE also models the impacts of the different policies on passenger and freight transport in the EU15 plus six additional countries.

The European Commission (EC) has asked for a review of TREMOVE with the aim of assessing – from a scientific perspective – how TREMOVE uses scientific and economic perceptions and knowledge for the purpose of evaluating the environmental and economic effects of transport policies. The EC has stated that the findings of the review will be used to improve the modelling framework currently in use to develop an air quality policy in the transport sector. As such, the EC wishes to ensure that both the scientific basis and the results from integrated assessment models used in policy development during the upcoming years are transparent, scientifically credible and appropriate for the purpose for which they are intended.

This report documents the results of the scientific review. The review has been carried out by four European partners[2] in the execution of the fifth specific contract under the Framework Contract with DG Environment of the European Commission on Economic Analysis in the Context of Environmental Policies and of Sustainable Development (ENV.G1/FRA/2004/0081).

The overall design of the model is assessed in chapter 2. The adequacy of TREMOVE input and output data is assessed in chapter 3 and the manner in which the model system addresses uncertainties is evaluated in chapter 4.

The methodology adopted for this review is rather straightforward: the model structure, the underlying assumptions and the quality of the input data are assessed on the basis of relevant studies reported in the literature, interviews and contributions from stakeholders during meetings. We also reviewed how policy measures are implemented in the model, and to which extent model results comply with outputs from other studies and models. The application of the model was analysed by participating in a TREMOVE training session. The limitations of the adopted approach in TREMOVE are identified and (where possible) recommendations for improvement of the model are formulated (see Summary).

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2. Aim of the model and model design

2.1 Aim and general design of the model

TREMOVE is designed to estimate the effects of different transport and environmental policies. To accomplish this aim, TREMOVE consists of 21 parallel country models and one maritime model. The contents of the 21 parallel country models are summarized in Table 2.1.

Table 2.1 Contents of the parallel country models in TREMOVE

Module	Contents
Transport demand module (output: Δ pkm; Δ tkm)	This module describes how the implementation of a policy measure (or a package of measures) will affect the baseline allocation of demand across different modes and different vehicle categories. The key assumption is that transport use will determine the volume of transport and the preferred mode of transport based on the generalized cost for each mode
Vehicle stock turnover module (output: Δ total fleet; Δ km for each year according to vehicle type and age)	This module describes changes in the number, age and type of vehicles in stock. These changes relate to changes in transport demand (see above), in price structure and/or specific policy scenarios.
Fuel consumption and emissions module (output: Δ fuel; Δ emissions. Both from tank-to-wheel)	This module describes changes in fuel consumption and emissions according to changes in transport demand and vehicle stock (see above). New policies (new emission standards, new CO_2 voluntary agreements) can also be evaluated in the module. The module uses COPERTIII (with adapted fuel consumption) for estimating road transport emissions.
Life-cycle emissions module (output: Δ fuel; Δ emissions. Both from well-to-tank)	This module enables the calculation of changes in emissions during the production of fuels and electricity.
Welfare cost module (output: Δ consumer surplus; Δ producer surplus; Δ taxes/ subsidies; Δ external costs)	This module describes the welfare effects of a policy change. Welfare effects are defined as the discounted sum of changes in consumer surplus, producer surplus and benefits of tax recycling and changes in external costs.

The outputs from the vehicle stock and fuel consumption and emissions modules are fed back into the demand module. As fuel consumption, stock structure and usage influence usage costs, these factors are important determinants of transport demand and modal split (De Ceuster *et al.*, 2005).

In our view the general design of TREMOVE is strong: the model is ‘rich’ with respect to its transport database as well the completeness of its model structure. The core of the model comprises the economic demand module, the vehicle stock module and the fuel consumption and emissions module, all of which are closely connected. As such, TREMOVE is capable depicting impacts on transport demand, vehicle stock, modal choice, emissions and welfare implications of both price and non-price policies. In TREMOVE pricing policies will affect transport costs, thereby resulting in changed vehicle sales (in the amount of sales and/or in vehicle-type choice), in changed transport demand and in modal shift. In TREMOVE, non-pricing policies, such as new emission standards, result in changes in the emission characteristic of newly sold vehicles, but the model also takes into account the fact that the higher costs associated with cleaner technologies will affect vehicle sales, transport demand and modal choice. A particularly strong property of TREMOVE that due to the design of the model it estimate 'rebound' effects: in the scientific literature changes in energy demand (or transport demand) due to the use of fuel-efficient technologies is addressed as the 'rebound effect' (see, for example, Birol and Keppler, 2000; Greening *et al.*, 2000).

The strength of TREMOVE – its completeness and feedback mechanisms – is also possibly its weakness. The broad design and aim of TREMOVE creates pressure from a variety of sources to use the model to assess and validate a very wide range of policies – even under circumstances where TREMOVE may not be the most appropriate tool to use. During an interview the developers of the model (TML Leuven) stated that while the core of the model has remained unchanged during the past 10 years, the model itself has been extended with all kinds of interesting new possibilities and sub-modules. The risk of implementing such an 'extension approach' is that the developers of such extensions have to apply their limited resources to a very broad range of subjects, data problems, modules and sub-modules, among others, thereby making the model 'completer' but not necessarily stronger per se. Another major risk is that TREMOVE becomes so large and so complex that very few would understand the model in detail, resulting in a reluctance to use the model, or in it being used inappropriately.

2.2 To what extent does the structure of each module provide a scientifically credible representation of reality?

Transport demand module

From a structural perspective, the transport demand module in TREMOVE appears to be reasonable and credible given the aims of the model. Specifically, this module seeks to determine the effects of policy measures or other factors (e.g., oil prices) on transport prices and demands, relative to a baseline scenario. To measure these effects, the transport demand module of TREMOVE applies a highly disaggregated transport demand tree for each country, with 276 different transport possibilities (De Ceuster *et al.*, 2005, pp. 23, 28). Choices between these possibilities are determined by elasticities based on own-price, cross-price and income.

An important factor for assessing the suitability of the transport demand module's structure, however, is the fact that the demand baseline used by TREMOVE is intrinsically exogenous (and is provided by the SCENES model) (De Ceuster *et al.*, 2005, pp. 18-19). Researchers familiar with modelling are well aware that assumptions incorporated into the baseline scenario can seriously impact on how a model responds to alternative policy scenarios. This means that any weaknesses in the projections of the SCENES transport demand model are passed on to TREMOVE. However, a review of SCENES and the SCENES' results is beyond the scope of the review presented here. Furthermore, it has become clear from discussions with stakeholders of the model that the implications of this 'imported baseline aspect' of TREMOVE is not well understood by most potential users. These users do not see clearly that assumptions of transport demand and generalized costs in the baseline determine – at least in part – the behavioural responses of the model. This means that if TREMOVE is applied by users who are not familiar with transport baselines (and the assumptions underlying these baselines), the result could be an erroneous policy impact.

Let us therefore assume that the scenarios imported from SCENES are themselves credible. Once this assumption is made, the structure of TREMOVE appears to be robust since the application of elasticities captures many elements of transport behaviour – including irrational behaviour and existing trends – for which other modelling approaches may be less suited. There are also important limitations with this approach, however, because elasticities themselves are usually only valid within a small range. This means that TREMOVE is probably less suitable for modelling the impact of more radical policies or comparable market changes, particularly where these represent a major departure from historical experience[3].

One potential structural drawback is that non-transport activities – i.e., the rest of the economy – are modelled in a very aggregate manner in the transport demand module, so potential opportunities to substitute non-transport goods, services or production inputs are not well represented. The extent to which this undermines the credibility of the transport demand module depends on whether the aggregate representation is still able to capture important substitution opportunities provided by non-transport activities. This is an issue we return to in section 2.3 below.

Another structural issue worth noting is that some, relatively minor, transport options are excluded. For example, substitution between short-distance sea freight and road and rail is excluded due to data problems (De Ceuster *et al.*, 2005, p. 28). Clearly, TREMOVE cannot provide credible insights into short-sea shipping and the impact of related policies.
Overall, and notwithstanding the limitations discussed above, from a structural perspective the TREMOVE demand module appears to be reasonable and credible given its aims.

[3] Importantly, this limitation is relevant only for estimating changes relative to a baseline scenario. That is, TREMOVE is structurally suitable for exploring the impact of policies that do not represent a radical departure from historical experience across a range of radical scenarios, but not for exploring the impact of radical policies, even in a single scenario.

Vehicle stock turnover module

This module seems to be designed primarily to calculate the impacts of policy on the emissions of regulated pollutants from the transport sector. The level of disaggregation of the vehicle stock within the model is adequate for this purpose (see Appendix 1 for more details).

Conversely, the current structure of the vehicle stock turnover module handles continuously variable factors considerably less well, the most obvious examples being fuel consumption and carbon dioxide. This deficiency is a significant problem if the intention is to continue to use TREMOVE for assessing carbon dioxide-related policy instruments, and it will need to be actively addressed. The main problems would appear to be:

- In TREMOVE car choice is limited to 12 car types, which differ in fuel consumption, whereas in reality car-type choice (for cars which differ in fuel consumption) will be on the scale of hundreds. This could mean that TREMOVE is not subtle enough with respect to possible car-type choices to provide a realistic estimate of the impacts of policies to improve fuel efficiency on CO_2;
- The nested logit models are estimated on current country parameters (including country-specific dummies) that reflect current behaviours associated with car-type choice. However, as ‘new’ types of car owners (company cars, lease cars) may become more important in many EU countries in the future, it is possible that TREMOVE overestimates fuel efficiency improvements due to pricing policy, because these owners tend to be far less price sensitive than the private car owner;
- Annual costs are calculated using a standard discount rate of 4%. However, there is good evidence that purchasers apply very high discount rates to future cost savings (with cars as with other appliances). One implication of applying the low discount rate for consumers is that TREMOVE will model substitution to more fuel-efficient cars ‘too easily’.

It is important to note that these issues are addressed currently in a EU funded project on: (1) car purchasing behaviour, (2) the importance of the company car market and (3) the impact of company car taxation on the environmental performance of cars. The results of this project (by IEEP) will provide data for amendments to the Commission’s transport and environment policy assessment model, TREMOVE.

Fuel consumption and emissions module

The impacts of policies on emissions and fuel consumption can be estimated in this module of TREMOVE. This module provides a reasonable representation of reality. For road transport the model is based mainly on extended COPERT III methodology on emission factors and fuel consumption. The COPERT III methodology is considered to be the state-of-the art knowledge on emission factors and fuel consumption in Europe. The model description is quite clear about the way the COPERT III figures are extended (see De Ceuster *et al*., 2005, pp. 136 – 142).

New COPERT IV factors will be implemented when available. As such, consideration can be given to the manner in which emission factors for the most recent or future emission standards are generated and to how lessons learnt from the ARTEMIS results are properly reflected. This process should be carried out with the developers of COPERT IV (LAT) and the ARTEMIS shareholders, most of whom are already involved in the development of TREMOVE, which in our view guarantees that this process of renewal will take place in due course.

Life-cycle emission module

In TREMOVE a restricted life-cycle assessment module is implemented, which focusses on the fuel cycle. The application of this module enables the estimation of the impact of policies on the ‘operational’ emissions of vehicles to be extended to impacts on the emissions in the fuel cycle: emissions during the production, distribution and use of fuel (and electricity) are taken into account in this module. Within its ‘restrictive’ design the module gives a credible representation of reality.

It should be noted, however, that the module is currently not detailed enough for an in-depth analysis of life-cycle emissions. In particular, the well-to-tank emissions from CNG and biofuels (biodiesel and bio-ethanol), which are strongly dependent on the specific fuel production pathway being considered, is oversimplified: TREMOVE uses one fuel-specific emission factor for all well-to-tank emissions. For a more detailed analysis, a range of fuel-specific well-to-tank emission factors should be used depending on the pathway that is used for the fuel production (CONCAWE, 2006).

For TREMOVE to be able to conduct a proper assessment of policy options regarding biofuels (e.g., mandatory addition of 5.75% biofuels to all fuels), it will be necessary to extend the life-cycle module in TREMOVE. However, such an extension would add to the complexity and data intensiveness of the TREMOVE model, which directly conflicts with our long-term recommendations (see Summary). In addition, it can be argued that the well-to-tank emissions are really not a ‘transport issue’. Greenhouse gas emissions that occur during the production of biofuels should be reported under the sector Agriculture according to IPCC guidelines (IPCC, 1997). Although it is ultimately the responsibility of the EC to clearly state its intentions regarding the applications of the life-cycle module, no further detailing of this TREMOVE module would add to the model’s transparency or to its main purpose, which is the assessment of different transport and environment policies on the emissions of the *Transport* sector.

Maritime module

The Maritime module in TREMOVE is a stand-alone module. Maritime transport demand is considered to be exogenous in TREMOVE, and it is assumed that maritime movements are not affected by policy measures on land-based transport and vice versa. In addition, TREMOVE does not include an endogenous link between total maritime transport demand

and maritime costs and prices. The maritime module is based mainly on data from the ENTEC study (ENTEC, 2002). The module does not contain endogenous fleet stock modelling, although this does not mean that fleet changes cannot be introduced exogenously in order to calculate the impact of policy options on, for example, the treatment of ships engines (De Ceuster *et al*., 2005, pp. 161). We feel that the representativeness of the module baseline results is good and that the exogenous modelling of policy options is technically sound.

However, due to its stand-alone character the maritime addition to the TREMOVE model can only be used specifically for shipping policy options. Modal shift effects cannot be modelled in the current design of the module. The EC should decide whether they believe modal shift policies to be environmentally relevant and, if so, the maritime module should be extended to include cross modal relations.

The review committee feels, however, that since cross-price elasticities in freight transport are very small and the environmental benefits of a shift to non-road freight transport are negligible (if not negative) due to the stringent emission standards for road transport compared to non-road transport, the usefulness of the maritime module is limited. In addition, an extension would add to the complexity and data intensiveness of the TREMOVE model, which is in direct conflict with our long-term recommendations (see Summary). We believe a smaller model whose purpose is more narrowly defined would support the usefulness of the TREMOVE model.

Welfare module

The aim of the welfare module in TREMOVE is to assess the welfare impacts of transport policies. The TREMOVE welfare measure is based on the difference between the calculated welfare measure in the base case and that of the simulation case. The term ‘simulation case’ refers to the TREMOVE run including the new policy. In TREMOVE the welfare measure of a policy is computed as the differences in consumer surpluses, producer surpluses[4], government income and external effects. The impact on government income is estimated using a factor that takes the efficiency of tax regimes into account (see further in this review). From a theoretical point of view the welfare module is credible, and reflects the current knowledge in welfare economics.

TREMOVE is a partial equilibrium model. Consequently, in the policy runs income and production levels remain constant compared to the base case (see De Ceuster *et al.*, 2005, p. 170), which implies that indirect (or wider economic) impacts of a policy measure cannot be taken into account. This also means, as noted in the analysis of the transport demand module

[4] In the applications of TREMOVE, the difference in producer surpluses is often simplified to the difference in producer costs, which is an understandable step due to lack of data on price levels for which producers are willing to sell their products or services. As a proxy in the welfare module this approach is defendable in our

(see previous section), that TREMOVE is less suitable for modelling the impact of more radical policies or other market changes.

The treatment of taxes in the welfare module deserves mention. Dependent on the specific transport policies implemented, government revenues can increase or decrease. In TREMOVE, the chosen approach has been to value the increase in tax revenues using the value of marginal cost of public funds (see De Ceuster *et al*., 2005, p. 171). Although this approach is theoretically correct, we believe that the results of its application in the welfare module of a transport policy are rather speculative and do not reflect reality per se. This observation is explained in more detail in the following paragraph.

In TREMOVE it is assumed that transport taxes replace labour or general taxes. The TREMOVE report mentions that the labour market in many European countries is among the most distorted of markets in the economy. Therefore, if transport taxes enable authorities to avoid more taxes on labour, or to reduce these taxes, the welfare value for the transport taxes raised is more than the actual figure raised (in reality the situation is slightly more complicated, but for the details we refer the reader to De Ceuster *et al.*, 2005, section 7.2.2, pp. 171 and 172). In the case of the 'heavy duty truck road infrastructure charging simulation' (Van Herbruggen and Van Zeebroeck, 2005), TREMOVE estimates that if the additional government revenue is used to decrease the level of general taxes, the welfare effect is lower than the decrease in producer costs. In this case, the policy leads to a modest welfare loss (modest in comparison with the total amount of charges paid). On the other hand, if the revenues are used to reduce the distortionary labour taxes, the overall effect is then significantly positive (Van Herbruggen and Van Zeebroeck, 2005). This example illustrates just how greatly the assumptions of revenue use can affect welfare results. Van Herbruggen and Van Zeebroeck (2005) treat this impact correctly: they show both results. However, we remain in our belief that TREMOVE is vulnerable to political misuse when this possibility exists to calculate welfare impacts using additional welfare gains if revenues are used to make the labour market less distorted. While it could make the welfare results of transport policies positive, this would occur solely under the assumption that governments, from an economic point of view, make any one of a number of sensible policy choices: for example, making the most distorted market less distorted. And, of course, it is highly uncertain if politicians will do that in reality.

The Term of Reference for TREMOVE 3 includes 'Definition of a set of values for marginal cost of public funding coefficients corresponding to different revenue recycling options in the different member states'. We consider this statement as being a potential improvement as it can be shown in TREMOVE that the value of the marginal cost of spending public funds in other less distorted markets will be more modest.

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opinion, but if a CBA on a policy has to be carried out, it would be advisable to know the supply curve (the

2.3 What are the limitations of the model structure and of the implied system boundaries (problem framing and model simplifications), and to what extent may these restrict the validity of the conclusions and policy advice?

Demand elasticities

As mentioned, the baseline scenario used in TREMOVE relies on the output of the SCENES model (ME&P, 2002) (although one stated aim of the modelling team is to allow alternative sources of demand projections to be used, nonetheless, the problem described above and below is still applicable). SCENES is used to calibrate TREMOVE in the following manner. Firstly, SCENES (or an alternative) estimates quantities and prices of different transport activities; secondly, these quantities and prices are used in TREMOVE, in conjunction with estimated elasticities of substitution (EoS), to calculate preferences (Keller's alpha), expenditures and quantities from the lower to the higher nodes in the demand tree (De Ceuster *et al*., 2005, pp. 40, 41).

These variables together determine own- and cross-price elasticities throughout the demand tree and, consequently, determine the behaviour of the model and how it responds to policy or other market developments of interest. Accordingly, as discussed above, whether the model behaves in a reasonable manner and provides useful insights is influenced by the characteristics of the baseline scenario employed. However, as already stated, a review of the SCENES model – from which the baseline input is obtained – is beyond the scope of this review of TREMOVE.

A very important property of TREMOVE model is that of the critical inputs determining how it behaves, the EoS are not taken from the SCENES model. Instead, EoS are specified using an iterative approach so as to 'match price elasticities in the literature' (De Ceuster *et al*., 2005, p. 41). Despite this effort by the stakeholders to calibrate the model to empirical data, some specific assumptions regarding the EoS may still be inappropriate and, as such, potentially limit the validity of the conclusions and policy advice derived from the transport demand module. These include the following.

- Most notable is the assumption that the EoS are constant across space and time (De Ceuster *et al*., 2005, pp. 35; model files: TREMOVE\Model\Demand Module\Country Input\..\demandcountry05.prn) – that is to say, the extent to which different alternative travel options can act as substitutes is assumed to be the same across 21 European countries and the same in 2020 as in 1995, even though economic, social and infrastructure features vary across time and space. The assumption that EoS are identical appears to be highly questionable, despite the fact

relationship between supply and price).

that price elasticities vary because these are estimated according to quantities and prices, as discussed above[5].

- Other specific parameterizations and assumptions regarding the system boundary and other factors in the model further limit the applicable range of policy assessment and potential validity. One clear limitation arises because within the transport demand module relative prices, preferences, and EoS are all ‘constant … with respect to income’ and therefore income elasticity always equals 1 for ‘any element in the CES tree’ (de Ceuster *et al*., 2005, p. 36). Conceptually this is inconsistent with an overabundance of empirical evidence. Moreover, for policy simulations the model assumes that ‘income remains unchanged compared to the baseline’ (De Ceuster *et al*., 2005, p. 41). This assumption is also made for production (De Ceuster *et al*., 2005, p. 28).

Vehicle choice model

Regarding the car choice module, we expressed our doubt in section 2.2 that TREMOVE is capable of correctly estimating the policy impacts of fuel efficiency (or CO_2) policies for cars. The main reasons are, firstly, that TREMOVE seems to overestimate the importance of the role of future fuel savings in the decision-making process related to car choice; in other words, TREMOVE seems not to account sufficiently for vehicle parameters other than purchase costs, fuel expenditures and acceleration in the car choice decision. These ‘neglected’ parameters include driving performances, appearance, status, among others. Second, for passenger cars, the degree of disaggregation of vehicle categories in TREMOVE is too crude to reflect many real-world choices (such as a change of model choice within a class) realistically.

The ongoing study of IEEP (and related workshop June 2006) will address these issues (see section 2.2).

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Welfare analysis

The evaluation of the welfare module in section 2.2 demonstrated that TREMOVE is limited in assessing the wider economic impacts of transport policies.

The welfare module should not be considered to be a cost-benefit analysis (CBA) tool. There are a number of reasons for this assessment. Firstly, indirect impacts of policies cannot be taken into account (as already noted, this point is probably less relevant for more moderate policies). Secondly, the pricing (or monetization) of external effects is based on damage costs (except for the CO_2 values). Theoretically, in CBA the shadow price of 1 kg more or less

[5]Moreover, this raises some questions about how the iterative procedure to match price elasticities was conducted: recall that EoS, where specified, ‘match price elasticities in the literature’ (De Ceuster *et al*., 2005, p. 41). It seems unlikely that a single EoS value would reproduce empirical price elasticities across all EU countries, given differences in demand and prices, etc. This lends further support to the notion that the use of constant EoS is inappropriate.

emission(s) due to a policy should be based on the abatement costs of the final kilogramme emission reduction that is needed to meet an emission policy goal or, for example, to reach a ‘safe’ air quality level. In this welfare module, the 1 kg extra (or less) of emission(s) due to a specific transport policy is valued on the basis of an estimated willingness-to-pay (to accept or to avoid) the damages or risks of these emissions. We refer the reader to Tables 70 and 72 in De Ceuster *et al.* (2005, pp. 174 and 175), where the external costs of emissions are based on the Value of a Statistical Life Year or the Value of Statistical Life. We stress that nowhere in the Model Description (De Ceuster *et al.*, 2005) or in the TREMOVE applications by Transport and Mobility, Leuven (for example, TML, 2005) is it assumed or suggested that in TREMOVE a CBA of policies is carried out. However, confusion remains with respect to the association of TREMOVE and CBA of policies, which is the reason we include a clear statement on this point in this review.

The revenue recycling approach in TREMOVE seems to breach with TREMOVE being a partial equilibrium model (see above). In the ‘labour market’ approach an indirect effect of a transport policy is forced: on a market other than the transport market changes are supposed to take place as a result of a policy on transport. These implied changes on the labour market could affect transport demand or vehicle stock. This is not modelled, which is defendable only in the case in which the transport policy impacts are relatively modest. However, we have some doubts in this area about the consistency of TREMOVE.

Conclusion

Taken as a whole, the assumptions implicit in the transport demand and welfare cost modules restrict the range of policy assessments for which these modules are suitable to only those that are expected to have a limited impact on incomes or production, either directly or through the income impact of price changes. However, this is not necessarily problematic, given that the types of policy analyses for which TREMOVE is used are unlikely to have a significant impact on overall production or incomes.

In our view TREMOVE can cope with policies such as those for emission standards for the emissions of regulated pollutants and modest transport pricing. A ‘grey area’ is that of CO_2 policies: TREMOVE has the potential to cope with these policies, but the model requires improvements to deal well with them. TREMOVE is not suitable for assessing the impacts of general tax policies which affect incomes and production.

3. Quality of input and output data

3.1 Is the quality of the input data obtained from official national sources and from other models sufficiently guaranteed?

In our view the EC and the TREMOVE team (TML Leuven) have sufficiently guaranteed the quality of the input data. All countries involved have had the opportunity to deliver country transport data and have had (and still have) the opportunity to check the TREMOVE database in order to assess if TREMOVE country data are in agreement with their 'own' data. In addition to the country data, the published description of the TREMOVE model (De Ceuster *et al*., 2005) clearly demonstrates that TREMOVE uses data from state of the art (scientific) literature, statistics and European models (PRIMES, SCENES and RAINS).

TREMOVE assimilates data from transport demand, vehicle stock, costs and taxes, fuel consumption and emissions that are not necessarily available in a consistent manner in all countries. The advantage of the model for some countries is that these data then become available and ultimately can be used to carry out their own policy assessments. Another advantage is that by integrating these data for use in TREMOVE, the model developers can occasionally detect inconsistencies in national transport statistics which can be used to improve these statistics. The disadvantage of this integration is that inconsistencies could arise between the TREMOVE data and (more detailed) national transport statistics when a single variable is being studied. These points indicate that it is very important for the validity of the model that EU countries be involved in the developmental process of TREMOVE in order to ensure the validity of the national data.

It has become apparent from interviews with the TREMOVE team and the EC that data gathering and handling has become a major task for the TREMOVE team, even though this should not really be within their remit or their responsibility. This problem is compounded by the fact that the construction of the TREMOVE baseline is an extremely 'data-hungry' process, and one that is likely to become ever more so over time. For the team to undertake a major data gathering exercise for each member state to the level that has to date only been done for Belgium (Logghe *et al.*, 2006) is most likely unrealistic. One possible alternative would be to increase the efforts at the national level in the member states to deliver detailed country information available for running TREMOVE.

3.2 How are users and stakeholders involved in the modelling process, and is this sufficient to ensure the transparency and acceptability of the results for policy advice?

In our view the manner in which users and stakeholders are involved in the modelling process does not provide an adequate safeguard to ensure that the results are sufficiently transparent and acceptable for policy advice. The main underlying factor for this view is that in the stakeholder process the focus to date has been on the baseline and technical issues related to vehicle stock, emission factors and fuel consumption. In addition, a discussion on whether TREMOVE is actually capable of estimating policy impacts correctly has still not taken place in the stakeholder meetings.

The result is that most stakeholders seem not to fully understand the policy analysis part of the model, which is worrying because this is why TREMOVE has been developed. Some of the stakeholders themselves criticize the lack of transparency of the model, especially with respect to its policy analysis performance (for example, as done by the ACEA representative). To be clear: we did not formally interview stakeholders and potential users. This observation is based solely on informal conversations and on the reactions of the stakeholders at the presentation of the first findings of this review on 30 March 2006 in Brussels.

3.3 Are the presentations of the results clear?

The presentation of results in the TREMOVE model is quite understandable although the extraction of the results from the pivot tables can be quite cumbersome. A simplification on that aspect would be useful. Also, it is currently very difficult and cumbersome to have pivot tables with different model runs together, which is the purpose of the model (comparing policy scenarios).

3.4 Is the model structure transparent?

The TREMOVE model has grown over the years to become a very comprehensive transport policy analysis model at the conceptual level. However, various modes of data transformations (between GAMS, Access and Excel) performed at the operational level make the model quite complex for a new user. Some of the important issues are discussed here with respect to structure and use.

Structure

The model structure has evolved as a function of the needs and the utilization of TREMOVE. In its present form a streamlining effort may be required in order to develop a logical and easy flow of information and data across various modules of the model. Some observations on the structure of the model are as follows:

- An overall flowchart of the model is presented in the model documentation, but too much information is presented in this single flowchart. Ideally, there should be an overall representation of the model at a macro scale; then, for each of the three core modules (transport demand module; vehicle turnover module; emission and fuel consumption module) and add-on modules (welfare cost module; life-cycle emissions module), a more detailed description of the structure as well as the flow of information should be provided.
- The absence of a detailed tree structure of GAMS scripts makes it difficult to understand the link between the different GAMS modules.
- There is a lack of information on the intermediate calculations. While certain intermediate files are optional, the user of the model may find it interesting to access the files in order to better understand the calculations and/or the construction of complex scenarios such as CO2CAR. It also helps in looking at the complete model pyramid and to understand the flow of calculations and the link between the data transformation at different steps.
- A description of the directory structure can be very useful to the user who wishes to understand the model at the operational level and the placement of different categories of files: input data, batch files, other configuration files, scenarios, results, among others.

Model Use

The following points present the main issues concerning model use:

- A description of the GAMS modules and the batch files external to the files is missing. As a display of good documentation practice, comments on each module/batch file are stored within the respective file, which does make the programmes very comprehensible. However, given the large number of files, it would be easier if this information is available externally so that one does not have to go into each of the files to understand the role of each module and batch file.
- The location dependency of the batch and configuration files is an important aspect of simplifying the installation and use of the model on a new computer. Absolute paths of files and directory are used in the batch files, and this creates the problem of portability on another computer which does not have the same drive names and directory structure as TML. The use of a relative path from the base directory where TREMOVE is installed would make it easy to reach all the files and the directory without having to modify any of the batch or configuration files.
- A description of the syntax for running batch files would also be very useful, especially when it is not necessary to run all of the batch files.
- A better description of input data in the ACCESS table can be provided to facilitate the modification of the input data.

- The distinction between base case and simulation runs can be made in the Model User Manual so the end user understand the implications and also when there is the need to run a base case again (for example, in the case of a welfare model).

4. Assessment of the approach towards uncertainties

4.1 Have the most policy-relevant uncertainties been adequately addressed?

The treatment of uncertainty appears to be one area of relative weakness of the TREMOVE transport demand module. The most relevant of the uncertainties can be classified into two broad categories.

The first of these is the uncertainty related to future travel demand (which is related to the uncertainty about future demographic, economic and social factors). This is clearly an important determinant of the effectiveness of future policy measures or market changes on demand[6]. However, this uncertainty falls within the scope of the SCENES model used to generate the future demand scenarios for TREMOVE (we return to this point in section 4.2).

The second key uncertainty relates to the behavioural responses modelled in TREMOVE. These responses are represented by the EoS, which are used to calculate preferences and other elasticities, including own- and cross-price. In other words, these elasticities are critical to the behaviour of the transport demand module with respect to how it responds to policy or other changes. As discussed above, the EoS are assumed to be constant across space and time; however, this assumption – in addition to the potential problems associated with it as outlined in section 2.2 – implicitly fails to account for uncertainties in how these parameters currently differ and may differ into the future. An additional exacerbating aspect is that a sensitivity analysis has not been conducted to determine the potential impact of the uncertainties in these values (we return to this in section 4.2). The importance of these variables, and the limited representation of uncertainty, makes it advisable to examine these elasticities in more detail.

Uncertainty in the behavioural response

As discussed in section 2.3, the EoS were estimated using an iterative process so as to reproduce literature estimates of price elasticities (De Ceuster *et al*., 2005, demandcountry05.prn, p. 41). Within this framework, we focus on the uncertainties reported in the literature on price elasticities, for which there is more information. However, given the limited resources available for the review of TREMOVE, only a rudimentary comparison with the literature on price elasticities was actually carried out.

[6] One simple illustrative example is that the amount by which a future policy might reduce fuel use depends on, among other factors, the level of fuel use in the future.

It is fairly clear that published studies generally report variations in price elasticities that cover a large range, although many have focussed on very specific areas or issues which are, unfortunately, not directly comparable to the elasticities reported in TREMOVE (review material from BTE 2001). When this aspect is assessed critically, we conclude that TREMOVE fails to capture the large variation and uncertainty reported in these published studies. It is encouraging, however, that the elasticities reported in Figures 11, 12 and 13 of the TREMOVE report (De Ceuster *et al*., 2005) are broadly consistent with the empirical data across an extensive database of studies on transport elasticities, although some small differences were identified[7]. This said, it is important to note that this comparison is restricted to elasticities for the United Kingdom in TREMOVE, since these are the only elasticities reported explicitly (De Ceuster *et al*., 2005, Figures 11–13).

Furthermore, during our critical assessment it became clear that the level of detail in TREMOVE means that it is not necessarily possible to find suitable literature references covering all of the elasticities represented in the transport demand module. In other words, for these elasticities not adequately supported by published studies, the uncertainty appears to be significantly higher. This implies that the model may both be too complex and attempting to represent within the demand tree poorly understood relationships for which data are sparse or non-existent. It is not clear if this additional complexity and speculative representation of some demand relationships provides any benefits. Conversely, however, it probably increases running times at very least and, in the worst case, leads to unexplainable results.

Based on the aspects raised in sections 2.3 and 2.4, it is clear that the validity of the TREMOVE responses on car stock and fuel consumption in the case of fuel efficiency policies need to be addressed.

Internal consistency

As a further effort to verify and explore of the validity of the substitution and price response behaviour of the model, we initiated a simple comparison of how preferences change over time within the framework of the baseline (reference) scenario. Specifically, reference values for Keller’s alpha were compared across time (recall that this variable is determined by a combination of the elasticity of substitution and baseline scenario inputs), and a number of these values were observed to vary significantly (De Ceuster *et al*,. 2005, model files:

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[7] Some specific comparisons are reported below. Extensively studied own-price elasticities, such as the short-run elasticity for fuel, are consistent with literature estimates, although they may fall at the lower end of the range (VTPI, 2005). Others, such as the monetary price elasticity of non-urban train travel and the monetary elasticity of peak bus transport, are in the right range relative to values reported in the literature (although the bus monetary elasticity reported in Figure 11 of the TREMOVE report for London may be somewhat higher than one would expect for a large city). The cross-price elasticities between private and network peak passenger travel also appear to be valid (De Jong *et al*., 1998, cited in BTE, 2001). The only elasticity that appears somewhat outside, or at the very edge of the range within the literature, is the air travel monetary price elasticity reported in Figure 12, which appears to be low for peak leisure trips (Nairn and Hooper, 1992; Oum *et al*., 1992; and Oum *et al*., 1990, all cited in BTE, 2001).

TREMOVE\Model\Demand\demandcalibref.gdx). In many cases this variation arose because the 1995 Keller's alpha value was an outlier from the 1996–2020 values. Without going into details of the baseline scenario or SCENES modelling, this observation appears to imply the existence of some inconsistencies in either the baseline scenario or the calibration data. Large deviations in the calculated preference values suggest that these preference values are somewhat inconsistent with empirical estimates (represented by the 1995 values) and, accordingly, that the response of the TREMOVE transport demand module to policy or other measures may be distorted[8].

Following discussions with the TREMOVE modelling team, it appears that these inconsistencies may arise due to the simultaneous use of two SCENES baselines – one starting in 1995 and another in 2000. This highlights the critical importance of the baseline formulation in calibrating the TREMOVE demand module, and the potential influence of the baseline on the model's response.

4.2 Is there an alternative formulation conceivable that could provide better policy-relevant insights into uncertainties? In view of the uncertainties, are the model results sufficiently robust for policy advice, or are there alternatives for attaining more robust conclusions?

In this section, the focus is once more on the two features of the model most susceptible to uncertainty – the baseline scenario and the behavioural responses (elasticities). Another feature (which will not be reported in any detail here) is related to the car stock module where the inherent risk is that in TREMOVE fuel efficiency policies are estimated to be cost-effective, while in reality this is not likely (for more detail see section 2.3).

Baseline scenario

It should be quite clear that by applying only a single reference scenario, which appears to be the standard approach to operating the TREMOVE model, very few policy insights can be elicited into how policies will be affected by uncertainties associated with future demand.

[8] It is difficult to assess how significant this is, but it appears to be fairly prevalent: in a random regional sample across all of the lower nodes, the total difference in Keller's alphas between 1995 and 1996 was observed to be around twenty-fold larger than the differences between 1996 and 1997. There are also some large changes between 1995 and 1996 in the upper tree, although these are smaller than the above-mentioned changes. More consistent variations in preference values were observed, and presumably these are in-built in the SCENES scenario. For example, in some regions an increasing preference over the period 1995–2020 for long-distance business trips by plane instead of by train is implied by the Keller's alpha values. Other strongly changing trends include a preference for passenger non-private long-distance commuting trips by non-road modes, and an at-first increasing preference for metropolitan commuting trips by bus, instead of train, until 2005 and then a reversal of this trend. It is not the place of this review to assess whether or not these – or other trends – implied in the underlying SCENES scenario are reasonable. Nonetheless, it is important to recognize that where there are large uncertainties about future preferences, the application of only a single baseline scenario may unreasonably compress the uncertainty range.

This uncertainty can be addressed in a fairly straightforward manner without the need for alternative model formulations by applying alternative complementary baseline assumptions – that is, through scenario analysis. One major drawback of this approach in TREMOVE is that additional modelling runs and time will be needed. However, it is possible that only a small number of additional scenario runs may be necessary to identify broadly robust trends and impacts. In other words, such a scenario analysis can be used as a reality-check of the results generated on the basis of a ‘central’ baseline scenario. This said, a scenario analysis is perhaps more easily said than done. Scenario analysis as proposed is especially useful if new or additional scenario assumptions can be modelled in a flexible way. This is not the case in TREMOVE for which the baseline approach is rather complex and inflexible. The Term of Reference for TREMOVE 3.0 mentions that the contractor for TREMOVE 3.0 should ensure the possibility of the easy introduction of transport baseline data from alternative sources, at European, National and/or regional/urban levels.

Parameter uncertainty

The second major source of uncertainty – the parameter uncertainty (i.e., elasticity and other assumptions such as the 4% discount rate applied to simulate consumer behaviour). The parameter uncertainty is perhaps more critical than baseline uncertainty, given that the model parameters directly affect the change that occurs as a direct result of the application of policy or other measures. In addition, there are 278 EoS parameters applied in the transport demand module (De Ceuster *et al.*, 2005, pp. 23, 28), and even those that are well understood are uncertain.

As discussed in section 4.1, some of these elasticities appear to be highly speculative due to the limited availability of data. The representation of the corresponding nodes in the demand tree therefore adds additional complexity to the model but may provide only limited insights into the decisions at the respective node. This indicates that there may be a good case for creating an alternative formulation of the model in which the number of EoS parameters is streamlined; this could be achieved with little or no reduction in the representation of robust detail and uncertainty.

Policy-relevant uncertainties associated with the EoS could be addressed explicitly with a parameter sensitivity analysis. This would involve the application of alternative parameterizations to a single baseline scenario, and policy exercise. Initial alternative parameterizations should focus on key uncertainties relevant to the specific policy exercise. An example of this would be infrastructure charging (of, for example, road freight vehicles) policies would imply a focus on the elasticities representing the choice between network and truck freight, and perhaps on others higher in the tree (urban vs. non-urban; freight transport versus ‘other’ inputs). As with the baseline sensitivity analysis, addressing the main policy-relevant uncertainties associated with EoS will probably only require a limited analysis of alternative parameterizations to identify the potential "response space" of key output variables.

It is important to note that it is not clear if an explicit alternative demand module formulation is necessary to address the uncertainties outlined above. Options such as stochastic modelling are possible, but these may be unnecessarily complex. Accordingly, scenario and parameter sensitivity analysis is proposed initially, but it is recommended that the issue be re-examined if these analytical approaches are unable to adequately support the identification of robust policy-relevant insights.

4.3 Is there a risk that the TREMOVE model provides policy advice that systematically underestimates or overestimates the costs or benefits of policy measures? What are the major reasons for a bias, if any?

It is not clear if the current formulation of TREMOVE is suitable for exploring uncertainties. The focus in the section is once again on the two features of the transport demand module most susceptible to uncertainty – the baseline scenario and the elasticities.
Clearly, by applying only a single reference scenario, which appears to be the standard approach to operating the TREMOVE model, very few insights will be obtained into how policies will be affected by uncertainties associated with future demand. Nevertheless, a single scenario can still provide useful insights into the potential effect of policies on the 'what if' basis that the scenario represents, which may be broadly applicable. Moreover, because TREMOVE seeks to assess the change arising from the application of a particular policy, rather than the absolute level of activity, the uncertainty associated with the baseline scenario is likely to be less important (although it still may have a significant impact on the results).

This uncertainty can be addressed in a fairly straightforward manner without the need for alternative model formulations by applying alternative complementary baseline assumptions – that is, through scenario analysis. One major drawback of this approach is the requirement for additional modelling runs and extra time to carry these out, but it is possible that only a small number of additional scenario runs may be necessary to identify broadly robust trends and impacts. In other words, such a scenario analysis can be used as a reality-check of the results generated on the basis of a 'central' baseline scenario.

This brings us to the second major source of uncertainty – the parameter (i.e., elasticity) uncertainty – which is perhaps even more critical than the baseline uncertainty, given that the elasticities directly affect the change arising as a result of the application of policy or other measures. An additional uncertainty is the number of EoS parameters applied in the transport demand module – 278 (De Ceuster *et al*. 2005, pp. 23, 28) – and even those that are well understood are uncertain.

As discussed in Section 4.1, some of these elasticities appear to be highly speculative due to the scarcity of data. The representation of the corresponding nodes in the demand tree therefore adds additional complexity to the model but may provide limited insights into decisions at this node. This indicates that there may be a good case for creating an alternative formulation of the model in which the number of EoS parameters is streamlined; this streamlining could be achieved with little or no reduction in the representation of robust detail and uncertainty.

Policy-relevant uncertainties associated with the EoS could be addressed explicitly with a parameter sensitivity analysis, which would involve applying both alternative parameterizations to a single baseline scenario and policy exercise. Initial alternative parameterizations should focus on key uncertainties relevant to the specific policy exercise; for example, a parameter sensitivity analysis of infrastructure charging (of, for example, road freight vehicles) policies would imply a focus on the elasticities representing the choice between network and truck freight and, perhaps, other elasticities higher in the tree – between urban and non-urban, and between freight transport and 'other' inputs. As with baseline sensitivity analysis, by addressing only the main policy-relevant uncertainties associated with EoS, it will probably only be necessary to carry out a limited analysis of alternative parameterizations to identify the potential 'response space' of key output variables.

It is important to note that it is not clear if an explicit alternative demand module formulation is necessary to address the uncertainties outlined above. Such options as stochastic modelling are possible, but they may be unnecessarily complex alternatives. Accordingly, we propose scenario and parameter sensitivity analysis initially, with the recommendation that the issue be re-examined if these analytical approaches are unable to adequately support the identification of robust policy-relevant insights.

There appears to be a potential risk that the transport demand module, and hence TREMOVE, systematically underestimates the impacts of policies and, consequently, may overestimate the costs of achieving a desired goal. This is related to the formulation of the EoS and preferences. Specifically, the simulation process outlined in section 2.6.6.2 of the TREMOVE manual (De Ceuster *et al*., 2005) appears to imply that the EoS and the preferences (Keller's alphas), which are determinants of price and other elasticities, are applied each year. This in turn suggests that the elasticities and preferences represented explicitly by the transport demand module are essentially short-run in nature. As discussed in section 4.1, some key short-run elasticities represented in the module appear to be consistent with estimates reported in the literature, thereby further supporting the conclusion that the transport demand module represents short-run responses.

The fact that only short-run elasticities are represented in the demand module may be reasonable for many of the activities represented in the module demand tree, since long-run changes are partly represented in the vehicle stock module (which presumably can in turn influence costs at the lower transport cost nodes) (De Ceuster *et al*., 2005, pp. 15, 199). However, this construction raises two important questions. The first question – 'whether the elasticities implicit in the vehicle stock module are reasonable?' – is not possible to answer without an extensive modelling exercise beyond the scope of this review. However, a more pertinent question relates to whether long-run elasticities associated with other activities (e.g., the higher-level decision branches in the demand tree) are represented anywhere in the model. It does appear that the choice between travel and 'other' activities is represented only as a short-run response. For example, in the Belgian report a policy run in TREMOVE (a 'mobility tax' scenario) resulted in fuel price increases at the filling station of around 9% for diesel and 13% for gasoline relative to the base case (Logghe *et al*., 2006). Thus, TREMOVE may underestimate aggregate long-run elasticities at higher levels of the demand tree, thereby overestimating the cost of policies. On the other hand, if the upper-level elasticities are intended to represent long-run values, then the model may respond too quickly and underestimate adjustment costs and overestimate short-medium term policy effectiveness.

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Appendix 1. Explaining car stock modelling

The desired car stock in the baseline is derived from the transport demand module, based on passenger kilometres, occupancy rate and annual mileage (De Ceuster *et al.*, 2005, pp. 77-89). It is assumed in TREMOVE that throughout the simulation period annual mileage per car category (small and large) remains constant and that the share of annual mileage of a car type within a category remains constant. This implies, for instance, that if in the category 'large' cars the so-called 'medium' cars are replaced by 'big' cars, the average mileage of big cars declines and the average mileage of medium cars increases, so that the weighted average mileage over medium and big cars does not change. The assumption is that if people (due to policy) choose for another car type, they will keep their original yearly mileage. It is important to see that the total of car kilometres in the policy run is mainly the result of the transport demand module, with some additional impact of the vehicle stock turnover module. In the vehicle stock module a nested logit model is used to estimate share of medium/big cars (including their fuel type) within the category 'large' cars. For the category small cars a nested logit model is used to estimate share of petrol/diesel cars. Recently, in both car categories hybrid car choice is included.

We give an example to be clearer because this is a difficult part of TREMOVE to understand. Suppose the policy option is an increase of fuel levies:

1. the generalised costs (euro/passenger kilometres) for the categories 'small' and 'large' cars increase. This results in lower passenger kilometre demands, both for the small as the large cars (dependent on the price increase and the elasticities used in the demand module). As the annual mileage per car category (small and large) remains constant in the vehicle stock turnover module (see before), this means that a X% decrease of passenger kilometres for 'large' cars results in a X% decrease of large passenger cars in the stock (ditto for the category 'small' cars);
2. the relative fuel price increase for small cars is different compared to the large cars. Even so, the elasticities differ for the small and large cars. This means that the impact on demand (the 'X%' in step 1) is different for the two categories 'small' and 'large'. As the yearly mileage remains constant per car category this implies that average yearly mileage (for all cars) in the policy run will differ compared to the base case.
3. Even so, shifts could occur in passenger kilometre demand from diesel cars to petrol cars (or vice versa). These shifts have no impact on the average yearly mileage of a car category, but the yearly mileage of diesel cars and petrol cars within a category will be different from the base case.

It is important to note that in TREMOVE an X% increase (or decrease) of demand in the policy run automatically results in an X% increase (or decrease) of number of cars. In other words: it is assumed that as a result of a policy people will buy more or less new cars. As

TML has considered, an alternative way of modelling would be that an X% decrease of demand would result in an X% decrease of the average yearly mileage (in doing so the number of cars compared to the base case would remain unchanged).

The ‘truth’ is somewhere in between these two modelling options (as remarked by TML), because it can be expected that due to policies which affect generalised costs of certain car types some people will adapt their yearly mileage and other will buy a new car type sooner or later compared to the base case.

Ideally, a ‘better’ policy analysis model would first model car ownership impacts of policies: will people keep their current car?, will they buy sooner or later another type of car compared to the base case? what other type of cars will they buy?, et cetera. These car ownership impacts would have to be modelled in close connection with car use modelling: to what extent will people use their preferred car choice? The ‘ideal’ model is even more complicated, because the notion of ‘people’ is too rough. Households with different level of incomes or company car owners will behave differentially. However, to model this ideal on the geographical scale of TREMOVE would be unrealistic. A tremendous amount of data would be required (data which are not available), and for TREMOVE the current model structure would have to be changed radically. And the model would have to be extended largely.

So, from a pragmatic point of view, we consider the current car stock modelling in TREMOVE satisfying. This statement is valid especially to modelling impacts of policies on CO, VOC, NO_x and PM emissions with TREMOVE, because the impact of, for example, pricing policies on these kinds of emissions is less vulnerable to the ‘precise estimated’ share of small, medium and big cars compared to the base case. The modelled impact of policies on petrol and diesel car share is currently relatively important for CO, VOC, NO_x and PM emissions. But as the EU emission standards for petrol and diesel cars become more similar in the future, a not very exact estimate of the diesel/petrol share becomes less relevant. The statement is less valid for estimating policy impacts on fuel consumption and CO_2 (see main text).