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TNO report

04.OR.VM.050.1/DE

Measuring and preparing reduction measures for CO2-emissions from N1 vehicles
- final report -

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Project code	009.01480/01.01
Research period	November 19 2003 - November 18 2004
Number of pages	101
Number of appendices	15
Number of figures	34
Number of tables	46

Summary

The European Commission aims to reduce CO_2-emissions from road transport. For M1 vehicles (passenger cars) a number of reduction activities are taking place, such as:, fiscal measures, a consumer information scheme (CO_2 labelling) and voluntary agreements (VA) between the Commission and representative manufacturer associations (ACEA, JAMA and KAMA). However, the category of N1 vehicles has until now not been included in these activities.

This situation has recently been changed since Directive 2004/3/EC was adopted, which amends Directive 80/1268/EEC (CO_2-emissions and fuel consumption) to extend its scope to N1 vehicles.

A first study to evaluate whether and which technology and policy measures could be implemented for reducing CO_2-emissions of N1 vehicles has been conducted by RAND in 2003. One of the conclusions from that study was the lack of CO_2-emission data for N1 vehicles. The main objectives of the underlying study, which is a follow up of the first study are to:

a) collect data on (and measure) CO_2-emissions and fuel consumption from N1 vehicles according to the procedure described in Directive 80/1268/EEC;
b) put forward proposals on the improvement of the amended Directive 80/1268/EEC applicable to N1-vehicles;
c) identify and CO_2-emission reducing policy measures regarding cost-effectiveness, and their legal and practical issues concerning the reduction of CO_2-emissions of N1 vehicles.

Below, the main objectives of this study are discussed in more detail in separate paragraphs.

CO_2-emissions and fuel consumption

Since CO_2-emission and fuel consumption data measured in accordance with the procedure described in 80/1268/EEC proved to be barely available for N1 vehicles, it was expected that measurements on the chassis dynamometer had to be conducted within the scope of this study on the 20 most sold vehicles. However, certain type approval databases and certificates appeared to contain appropriate information, while additional measurements have been carried out to validate these sources. In total, NEDC CO_2 emissions for over 30 N1 vehicles were found. In addition to this data, detailed information was obtained about the N1 vehicle market and especially regarding the distribution over classes and manufacturer associations. Both data-sets have been used to calculate the average specific CO_2 emission for each N1 class, manufacturer association and fuel type individually. These averages were also required to evaluate the effectiveness of applying different policy options. The specific average CO_2 emissions of new N1 vehicles for class and manufacturer associations were determined, and are presented in Table 0-1.

Table 0-1: Average CO_2 [g/km] for 2002 new N1 vehicles

	Gasoline				Diesel			
Average CO_2 [g/km] for 2002	**Class I**	**Class II**	**Class III**	**Total**	**Class I**	**Class II**	**Class III**	**Total**
ACEA	179	181	283	222	160	176	226	192
JAMA	-	220	291	259	-	161	238	203
KAMA	-	-	261	261	-	-	236	236
Total	179	184	283	222	160	175	227	192

Improvement of Directive 80/1268/EEC

The Council raised questions and concerns about the feasibility of the procedures that are implemented in Directive 80/1268/EEC regarding N1 vehicles. They have asked to:

- present the possibilities of obtaining representative CO_2-emission and fuel consumption data for completed multi-stage N1 vehicles and N1 vehicles whose emissions are measured according to Directive 88/77/EEC (design a model approach);
- indicate the effectiveness/relevance of the introduced family concept approach;
- prepare draft measures on the adaptation of this Directive to technical progress.

CO_2-emissions of specific N1 vehicles

Some types of N1 vehicles are being sold that are not yet completed when leaving the factory of the manufacturer. Different bodies can be built on these vehicles later on by converter companies depending on the needs of the customer. These vehicles are referred to as multi-stage vehicles. Depending on the type of body, most determinative parameters that affect CO_2-emissions and fuel consumption - being air drag, frontal area and vehicle mass - may be changed, which means that no representative CO_2-emission and fuel consumption data is available for this specific vehicle type. The same concern applies to vehicles with an engine that is type approved according to Directive 88/77/EEC.

The percentage of completed multi-stage vehicles and vehicles having an engine that is type approved according to Directive 88/77/EEC in the total fleet is expected to be rather high. Hence, correct CO_2 emission and fuel consumption data according to the procedure prescribed in Directive 80/1268/EEC for these specific vehicles is not available. Additional tests on the chassis dynamometer for each specific vehicle would deliver these data however that application of that procedure is rather expensive.

In order to find a cost-effective solution for this problem, the application of a modelling tool has been assessed. The Advisor model has been thoroughly evaluated to verify whether it could be used as a tool to predict the CO_2-emissions on the NEDC driving cycle for these types of vehicles. Validation measurements with varying mass and air drag on a number of vehicles have been carried out on the chassis dynamometer to provide additional detail about the prediction accuracy of the model. The average deviation between measurement and simulation result proved to be about ±2.5% in case the 13 mode test results are used, and could be improved to less than ±2% when emission maps containing the results of more mode points are applied.

The Advisor model has been used to predict CO_2-emission and fuel consumption of different N1 vehicle categories by changing parameters mass and air drag. The results of these simulations were evaluated in order to find out whether relationships exist between CO_2 emissions and fuel consumption on one side and mass and air drag on the other. Apart from studying these relationships, also the effect of changing transmission ratios has been assessed. Since no measurement data regarding different transmission ratios was available, the validation of Advisor model - as conducted on changing mass and air drag - has not be carried out.

The study mentioned above showed that almost linear relationships exist between CO_2-emission/fuel consumption and mass/air drag/transmission ratios. The effects are summarised in Table 0-2 and different for each N1 vehicle category.

Table 0-2: Increase of CO_2-emission and fuel consumption by criterion

		Effect on CO_2 and fuel consumption		
Parameter	**Change**	**Class I**	**Class II**	**Class III**
Mass	+220kg	4.0%	3.0%	2.2%
Air Drag	+15%	3.5%	3.5%	3.5%
Transmission ratios	+8%	5.0%	6.0%	8.0%
Overall		12.5%	12.5%	13.7%

Family concept

By adopting Directive 2004/3/EC, also an extension of the CO_2 and fuel consumption type approval for N1 vehicles was introduced. In fact, this means that not all vehicle variants have to measured but vehicles can be clustered assuming that CO_2 and fuel consumption within the cluster will be within a certain range. Two different approaches can be applied. The first one - a 'derogation rule' - prescribes that the emissions of a vehicle may not be 6% higher than the CO_2 emission and fuel consumption of the reference vehicle. The second one - the family concept - requires that certain parameters should be equivalent or within prescribed limits. In fact, the parameters that have to be within certain limits and their limits are mentioned in Table 0-2. However, it is not clear how the allowed parameter variation of the family concept relates to the 6% allowed difference in CO_2-emissions.

As can be observed from the 'Overall' line of Table 0-2, these criteria are not the same: the 6% CO_2 difference will be exceeded if a combination of maximum allowed parameter tolerances is applied.

From Table 0-2 it is clear that the 8% range of overall transmission ratios should not be allowed as it causes significant increase of the CO_2-emission and fuel consumption. In order to limit the deviation close to 6%, no change in overall transmission ratios should be allowed. It is therefore concluded that in order to make the vehicle family concept more efficient and applicable, its criteria should be redefined. The following definitions are recommended for the vehicle family concept, to keep the CO_2-emissions and fuel consumption within a range of 6%. A possible definition could be that members of a family are vehicles which:

- are up to 110 kg for class I and up to 220 kg for classes II and III heavier than the family member tested;
- have up to 15% greater frontal area than the vehicle tested;
- have a different overall transmission ratio than the family member tested due solely to a change in tyre sizes, and
- conform to the identical parameters as already defined in 2004/3/EC.

Improvement of the procedures currently applied
The tests that have been conducted provided additional insight into the procedures that are applied for granting type approval for N1 vehicles, especially the issue of setting driving resistance. For M1 vehicles, the common procedure is to conduct coast down measurements on the road to derive representative settings; for N1 vehicles the table values provided in Directive 70/220/EEC are applied. Since the table value procedure links driving resistance with vehicle mass, vehicles having the same mass but different body (in fact different frontal area and air drag) are tested on the same setting. For the purpose of collecting more representative CO_2-emission and fuel consumption data, the table values procedure should be improved by taking into account mass and body style (air drag) of the vehicle.

Evaluation of policy measures
Policy options
A thorough study has been conducted to identify the most promising policy options for the reduction of CO_2-emissions and fuel consumption from N1 vehicles.

From the measures that have been identified the most practical and feasible options are the introduction of an Emission Limit Value (ELV) - provided that a suitable 'utility' parameter if found which links the limit value to a certain utility of the vehicle - or a Voluntary Agreement (VA). Also other options could be promising however these will most probably not be introduced specifically for N1 vehicles but for M1 vehicles as well.

A monitoring mechanism - like is effective for M1 vehicles - could also be adopted for N1 vehicles since CO_2-emission and fuel consumption measurements will become obligatory. This will provide additional insight for better understanding of the existing emissions profile of the future N1 vehicle fleet.

Scenarios
In order to get an indication on the total CO_2-emissions produced by the complete N1 fleet up to the year 2020, a 'Business As Usual' scenario has been assessed. In addition, several scenarios have been defined in order to address the effect they have on total CO_2-emissions. The scenarios differ in technological options that are applied (low and high cost packages, assuming the introduction of a less stringent respectively a stringent CO_2 reduction rate), introduction years of the measure (2012 or 2015) and a different trend towards the date the measure will be effective (linear or step); in total 9 scenarios.

The cost-effectiveness of the different scenarios has been evaluated on the basis of **societal costs** (manufacturer costs of technology and fuel excluding tax) and **costs to the consumer** (retail price for technology and fuel price including tax). The cumulative achieved CO_2 reductions and cumulative additional costs (including fuel cost savings) are estimated for different years. Table 0-3 shows the results of the exercise that has been carried out.

From the Table it can be observed that both a CO_2 emission reduction and a cost saving can be achieved when applying low cost technology packages (less stringent reduction rate). However, since the total European N1 fleet is expected to grow from 16 million vehicles in 2002 to 26 million in 2020, higher reductions are required to keep the total CO_2 emissions on the 2002 level. Furthermore, the cost-effectiveness of the scenarios that assume a linear trend is better than the ones that expect the step-trend. Therefore, it is concluded that a monitoring mechanism that sets intermediate targets will improve the cost effectiveness of the measure.

Table 0-3: Cost effectiveness of different scenarios (Euro/tonne CO_2) - 'societal costs' and 'costs to the consumer'

cost effectiveness of different scenarios (Euro/tonne CO_2 reduction)
- societal costs

year	*2002*	*2005*	*2010*	*2015*	*2020*
Linear;2012;low cost	0	-105	-25	-13	-22
Linear;2015;low cost	0	-80	-56	-36	-24
Linear;2012;high cost	0	205	114	141	119
Linear;2015;high cost	0	115	67	95	105
Step;2012;low cost	0	0	0	1	-13
Step;2015;low cost	0	0	0	10	-2
Step;2012;high cost	0	0	0	157	126
Step;2015;high cost	0	0	0	149	124

cost effectiveness of different scenarios (Euro/tonne CO_2 reduction)
- costs to the consumer

year	*2002*	*2005*	*2010*	*2015*	*2020*
Linear;2012;low cost	0	-339	-179	-157	-174
Linear;2015;low cost	0	-291	-244	-205	-182
Linear;2012;high cost	0	293	110	163	119
Linear;2015;high cost	0	113	17	71	90
Step;2012;low cost	0	0	0	-130	-158
Step;2015;low cost	0	0	0	-116	-140
Step;2012;high cost	0	0	0	196	132
Step;2015;high cost	0	0	0	178	128

Abbreviations and Definitions

AAA:	L'Association Auxilaire de l'Automobile
ACEA:	Association des Constructeurs Européens d' Automobiles (European Automobile Manufacturers Organisation)
ANFAC:	Asociación Española de Fabricantes de Automóviles y Camiones
CCFA:	Le Comité des Constructeurs Français d'Automobiles
CoC:	Certificate of Conformity
C_w:	Air drag coefficient of the vehicle
EUDC:	Extra-Urban Driving Cycle
ESC:	European Stationairy Cycle for Heavy Duty Engine
ELV:	Emission Limit Values
ETS:	Emission Trading System
FA:	Frontal area of the vehicle [m^2]
FC:	Fuel Consumption
GVW:	Gross Vehicle Weight
JAMA:	Japanese Automobile Manufacturer Organisation
KAMA:	Korean Automobile Manufacturer Organisation
LCV:	Light Commercial Vehicle
n.a.:	not available
NEDC:	New European Driving Cycle
NGO:	Non-governmental organisation
RM:	Reference Mass
TA:	Type Approval
UDC:	Urban Driving Cycle
V:	Vehicle speed
VA:	Voluntary Agreement

Base vehicle (92/53/EEC) means any incomplete vehicle, the vehicle identification number is retained during subsequent stages of the multi-stage type-approval process

Completed vehicle (92/53/EEC) means a vehicle resulting from the process of multi-stage type-approval, which meets all the relevant requirements of the Directive

Incomplete vehicle (92/53/EEC) means any vehicle that still needs completion in at least one further stage in order to meet all the relevant requirements of the Directive

M1-vehicle class definition (92/53/EEC):
Motor vehicles with at least four wheels designed and constructed for the **carriage of passengers** and comprising no more than eight seats in addition to the driver's seat (the vehicle implicitly weighs less than 5 tonnes).

Multi-stage type approval (92/53/EEC):
The procedure, whereby one or more member states certify that, depending on the state of completion, an incomplete or completed vehicle type satisfies the relevant technical requirements of Directive 92/53/EEC.

N1-vehicle class definition (92/53/EEC):
Motor vehicles with at least four wheels designed and constructed for the **carriage of goods** and having a maximum mass not exceeding 3.5tonnes.

Reference Mass definition (70/220/EEC):
Mass of vehicle in running order minus 75 kg (driver) plus 100 kg (uniform mass).

Reference Mass N1-vehicle classes (70/220/EEC) before being amended by 98/69/EC

Class I	RM =< 1250 kg
Class II	1250 kg < RM =< 1700 kg
Class III	RM > 1700 kg (but less than 3.5 tonnes)

Reference Mass N1-vehicle classes (70/220/EEC) after being amended by 98/69/EC

Class I	RM =< 1305 kg
Class II	1305 kg < RM =< 1760 kg
Class III	RM > 1760 kg (but less than 3.5 tonnes)

Contents

Appendices

1 Introduction

1.1 Background

With an increasing amount of light commercial vehicles (LCV or N1 vehicles) in the European transport fleet, the CO_2-emissions from N1 vehicles become more important (13% of total road transport). Until now, the N1 vehicle classes CO_2-emissions have not been part of any Community level action to reduce CO_2-emissions. Passenger cars however are dealt with using the strategy described in "COM (95) 689 final". Because of this situation the Commission was asked by the European Parliament and the Council to study possible actions to reduce CO_2-emissions from N1 vehicles as well.

One of the most promising options is a structure of monitoring and labelling the CO_2-emissions of N1 vehicles, similar to the approach for M1 vehicles. In order to evaluate the M1 set-up in a N1 context, the Commission granted a first study to RAND Europe [Lu, 2003] from which the conclusions and recommendations were accepted. In addition to the effort of this first study, Directive 80/1268/EEC (CO_2-emissions and fuel consumption) has been amended by Directive 2004/3/EC in order to extend its scope to also cover N1 vehicles.

Both initiatives can be seen as a first step to reduce CO_2-emissions of N1 vehicles. However, there still proved to be some open questions about the feasibility of the introduced family concept for N1 vehicles and the application of the amended Directive to multi-stage vehicles and vehicles which engines are type approved according to Directive 88/77/EEC. Both issues need further investigation to improve the procedure currently prescribed. Within the framework of the earlier project it proved difficult to obtain information on the N1 vehicle market in Europe. Furthermore, only few data was available on actual CO_2-emissions and fuel consumption of N1 vehicles, since these vehicles did not have to comply with a prescribed procedure. This situation has changed by the introduction of Directive 2004/3/EC; a general procedure to measure CO_2-emissions can now be applied to N1 vehicles as well. Moreover, a more detailed evaluation of different policy measures should be conducted in order to determine a feasible and cost-effective roadmap for reducing CO_2-emissions of N1 vehicles.

For these reasons, the Commission published a call for tender on the 'Study contract on measuring and preparing reduction measures for CO_2-emissions from N1 vehicles' (reference: ENV.C.1/ETU/2003/0030) in order to assess the above mentioned issues. A consortium consisting of TNO Automotive (Delft - The Netherlands), LAT/AUTh (Thessaloniki - Greece) and the Brussels office of IEEP (Brussels - Belgium) responded to this call for tender. On the 19th of November 2003, DG Environment of the European Commission has awarded the project to this consortium (contract number B4-3040/2003/364181/MAR/ C1). The work for this study ended in November 2004. This is the final report of the study.

1.2 Scope and Objectives

The European Commission aims to reduce CO_2-emissions from road transport. For M1 vehicles, policies to include fiscal measures, a consumer information scheme (CO_2 labelling) and voluntary agreements (VA) between the Commission and representative manufacturer associations (ACEA, JAMA and KAMA) have been made. However, until now these agreements do not include the category of N1 vehicles.

The first study that has been carried out on this topic led - amongst others - to the inclusion of N1 vehicles in the CO_2-emissions and fuel consumption Directive 80/1268/EEC, since for N1 vehicles these figures were barely available. The underlying study starts where the previous one has ended; the main objectives of it are to:

a) collect data on (and measure) CO_2-emissions and fuel consumption from N1 vehicles according to the procedure described in Directive 80/1268/EEC;
b) put forward proposals on the improvement of the amended Directive 80/1268/EEC applicable to N1-vehicles;
c) identify and CO_2-emission reducing policy measures regarding cost-effectiveness, and their legal and practical issues concerning the reduction of CO_2-emissions of N1 vehicles.

Before the amendment to Directive 80/1268/EEC was adopted, the Council raised questions and concerns about the feasibility of the implemented procedures applicable to N1 vehicles; these are also mentioned in Article 3 of Directive 2004/3/EC. Therefore, the study's emphasis was shifted from the detailed evaluation of different policy options to the objective to put forward proposals on the improvement of Directive 80/1268/EEC specifically to the parts that refer to N1 vehicles. The Council's questions and concerns are threefold:

- present the possibilities of obtaining representative CO_2-emission and fuel consumption data for completed multi-stage N1 vehicles and N1 vehicles whose emissions are measured according to Directive 88/77/EEC (design a model approach);
- indicate the effectiveness/relevance of the introduced family concept approach;
- prepare draft measures on the adaptation of this Directive to technical progress.

In May 2004, 10 additional countries joined the European Union. At the start of the project it was decided to extend the scope of the study and to include - if possible - these accession countries in the data collection and evaluation processes as well.

The study has a direct link with the procedures (amongst others Decision 1753/2000 by the Council) applicable to M1 vehicles (passenger cars) to monitor CO_2-emissions for this category of vehicles and the corresponding annual reports.

1.3 Project structure and responsibilities

The work for the study was structured into four main tasks:

Task 1 - Collect further data and information
Task 2 - Modelling methodology and model validation by measurements
Task 3 - Scenario studies and policy option evaluation; incorporation in the Directive
Task 4 - Project management

Taking into account the specific expertise, experience and network of the three consortium partners, the project was further subdivided into separate work packages (WPs). Further details on the WPs and the responsible consortium partner can be found in Appendix A.

In order to exclude the influence of different laboratories on the CO_2-emissions of the 20 most sold vehicles in the EU, it has been decided to conduct the measurements for that objective on the chassis dynamometer of TNO-Automotive. The list of 20 most sold N1 vehicles in Europe and the fleet average calculation are derived for the year 2002, being the year for which most recent data was available at the time of the project was started (November 2003).

Before the actual work was started, the conclusions and recommendations of the first study [Lu, 2003] were evaluated to get an indication of the issues that have been already assessed and to determine the starting point of the underlying study.

1.4 Structure of the report

After this introductory section, this report continues with the following sections:

- Section 2 (Legislative background) presents an overview of the European Directives relating to N1 vehicles, and shortly describes the issues that in this report will be addressed in detail, such as the family concept, and the extension of the scope of Directive 2004/3/EC to cover N1 vehicles as well.

- Section 3 (CO_2-emission inventory) sets of with an assessment of the data gathered in the previous study, identifies the areas where more data are needed, followed by the information that is collected in the scope of this study. This consists of a description of the N1 market in the EU including new registrations and fleet statistics, measured and available CO_2 and fuel consumption figures for N1 vehicles, and additional data necessary for updating the EU average CO_2-emission factors.

- Section 4 (CO_2-emission calculations and analysis) looks into the possibilities of calculating CO_2-emissions by the use of a vehicle emission model. The purpose of this is to perform dedicated simulations as input for the discussion on the evaluation of the family concept, the issue of multi-stage N1 vehicles, N1 vehicles whose engine is type approved according to Directive 88/77/EEC and to predict CO_2 and fuel consumption for laden N1 vehicles in real-use.

- Section 5 (Technological options for CO_2 reduction) gives a state of the art technology description and identifies technological options to reduce CO_2-emissions from N1 vehicles together with a rough estimation of the associated costs.

- Section 6 (Current status and policy options for CO_2 reduction) starts with an inventory of activities that will be or have been carried out by manufacturers, NGO’s and Member States to reduce CO_2-emissions of the N1 vehicle class. All possible policy options are identified, together with their potential for reducing CO_2-emissions, using the base case scenario from Section 2 as a starting point. Thorough analysis of the different policy options, also taking into account technical progress and cost-effectiveness, results in concrete proposals that could be introduced in legislation.

- Section 7 (Scenario study) discusses the rather straightforward scenario study that is carried out. Besides the ‘Business As Usual’ scenario, eight other scenarios have been defined. These differ in technology packages to be applied (low and high cost with associated reduction rates, effectively a less stringent respectively a stringent reduction), introduction years (2012 and 2015) and expected trend to be followed to the year in which the measure will become effective (linear or step). The cost-effectiveness of these scenarios is addressed in different years (2002, 2005, 2010, 2015 and 2020).

- Section 8 (Conclusions and recommendations) summarises the main findings of the project.

2 Legislative background

In order to have a clear view on the regulative context of N1 vehicles and for better understanding of the scope of the study, a summary is made of the European Directives that relate to CO_2-emissions and N1 vehicles. It is important to have a good understanding of this legislation since it defines the conditions and the limitations that this study should follow in order to comply with the EU established procedures. In the first section all relevant Directives and documents that are applicable within the context of CO_2-emissions and N1 vehicles are summarised; also the link between different Directives is explained. The other sections provide further background information on the individual Directives 80/1268/EEC, 88/77/EEC and 92/53/EEC.

2.1 Summary of relevant Directives

The first effort, to control type approval from road vehicles date back to the early 70's (Directive 70/156/EEC). Emissions for vehicles were directly captured - by Directive 70/220/EEC - and the first Directive to link the type approval procedure to fuel consumption and CO_2-emissions - initially for M1 vehicles - was 80/1268/EEC, which still constitutes the basis of later relevant legislation. The most recent amendment to 80/1268/EEC is 2004/3/EC, which extends type approval to N1 vehicles. Other important Directives are 88/77/EEC which establishes type approval for diesel engine emissions and fuel consumption as 'separate technical units' and Directive 92/53/EEC[1] - which amends Directive 70/156/EEC - regarding type approval of motor vehicles and their trailers built in one or more stages. Figure 2-1 indicates how these Directives are linked:

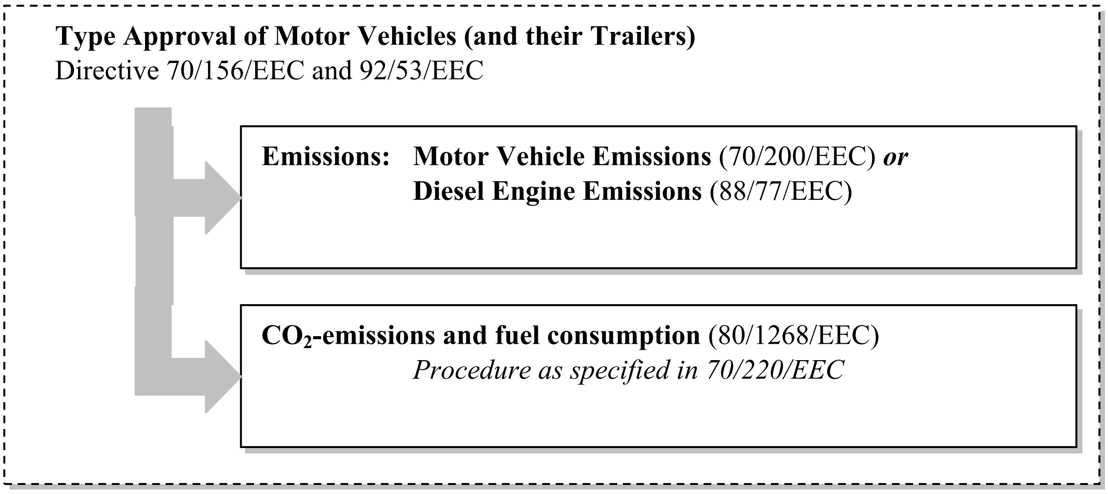

Figure 2-1: Links between Directives relevant for N1 vehicles

The Directives that are mentioned in Figure 2-1 have been amended several times. The amendments that are of interest for this study are indicated in Table 2-1. Column 'Remark' provides additional information about the reason for amending the original Directive (the colours group the Directives; the first one - in bold - is the original Directive, the ones that follow are the amendments to the initial Directive). Note that the Table is only covering the Directives and amendments that are of interest for N1 vehicles.

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[1] Annex IV of this Directive contains an overview Table in which the subjects (and corresponding Directive) that has to be type approved are indicated for each vehicle category.

Table 2-1: Relevant Directives for the N1 study

Directive number	**Title**	**Remark**
70/156/EEC	**Type Approval of Motor Vehicles**	**Initial Directive: General type approval Directive for Motor Vehicles**
92/53/EEC	Type Approval of Motor Vehicles and their Trailers	Updated version of 70/156/EEC: specifies type approval of Motor Vehicles including exhaust gas emissions, CO_2 and fuel consumption. Manufacturer can decide which emission type approval procedure (70/220/EEC or 88/77/EEC) is applied.
70/220/EEC	**Motor Vehicle Emissions**	**Initial Directive: Measures to be taken against air pollution by emissions from motor vehicles (Gasoline and Diesel engines, M1 and N1).**
98/69/EC	Motor Vehicle Emissions	Amendment to 70/220/EEC, abolishing 40 seconds idling in test procedure, setting Euro 3 and Euro 4 limits for class I, II, and III N1 vehicles, class division according to new definition
88/77/EEC	**Emissions Diesel Engines**	**Initial Directive: Emissions for Diesel engines**
1999/96/EC	Emissions Diesel Engines	Update of 88/77/EEC introducing an updated test procedure (ESC and ETC and limits for upcoming stages of legislation
80/1268/EEC	**CO_2-emissions and fuel consumption**	**Initial Directive on CO_2-emissions and fuel consumption (only for M1 category)**
2004/3/EC	CO_2-emissions and fuel consumption	Amendment to Directives 70/156/EEC and 80/1268/EEC to incorporate N1 vehicles as well. It also contains the definition of the family concept (CO_2-emission within 6%) and links family concept with 70/220/EEC

2.2 Incorporation of N1 vehicles in Directive 80/1268/EEC (by 2004/3/EC)

By adopting Directive 2004/3/EC, the scope of Directive 80/1268/EEC is extended to N1 vehicles. As a result of this, CO_2-emission and fuel consumption should be measured in order to grant type approval to N1 vehicles on the NEDC driving cycle (as in 70/220/EEC). Voluntary respectively compulsory dates are 1 January 2005 / 1 January 2006 (class I) and 1 January 2007 / 1 January 2008 (class II and III); an additional 12 months postponement applies to multi-stage vehicles. Hence, a data-set containing CO_2-emission and fuel consumption factors for all N1 vehicles will not be available before 2010.

Currently, the Directive exempts small volume manufacturers who buy engines from suppliers if the engine type fitted has received type-approval according to Directive 88/77/EEC **and** if the total annual world-wide production of N1 vehicles by the manufacturer is less than 2000 units.

Moreover, the Directive allows the extension of approval in cases of **vehicles of the same type**[2] or from a different type differing with regard to the following characteristics:

- Mass
- Maximum authorised mass
- Type of bodywork (lorry, van)
- Overall gear ratio's
- Engine equipment and accessories

To be considered as a vehicle of the same type, the manufacturer will also have to prove that the CO_2-emission will not exceed the value of the reference vehicle by more than 6%.

Apart from this extension possibility, the 80/1268/EEC Directive also introduces the **vehicle family concept** for N1 vehicles. A vehicle is observed as being member of a family when certain vehicle characteristics are identical while others are allowed to deviate within a certain range. These criteria are indicated in Table 2-2. A vehicle belonging to a vehicle family is excluded from the obligation to measure CO_2-emissions and fuel consumption, since these values are expected to be close to the 'parent' of the family.

Obviously, the possibilities to extend approval by either the concept of the vehicle family or the vehicle of the same type show certain similarities. The question that arises is the following:

> *How does the maximum allowed 6% CO_2 difference of the 'vehicle of the same type' concept relate to the maximum allowed difference in vehicle parameters of the 'vehicle family' concept?*

This is one of the key issues that will be addressed in this study (see section 4). The need to further look into this matter is also mentioned in Article 3 of the Directive - evaluation of the family concept.

Table 2-2: Criteria of vehicle families

2004/3/EC Section 12.1 vehicle family criteria	
Identical parameters	*Similar parameters*
Manufacturer and type	Transmission overall ratios (no more than 8 % higher than the lowest)
Engine capacity and type	Reference mass (no more than 220 kg lighter than the heaviest),
Emission control system type	Frontal area (no more than 15 % smaller than the largest)
Fuel system type	Engine power (no more than 10 % less than the highest value).

According to the Directive, N1 vehicles can be approved within a family as defined in Table 2-2 using two alternative methods described in paragraphs 12.2 and 12.3 of the Directive. The first alternative provides that a vehicle family can be approved with CO_2-emission and fuel consumption data that are common to all members of the family. The technical service must select for testing the member of the family, which the service considers to have the highest CO2-emissions, and the results are used as type approval values that are common to all members of the

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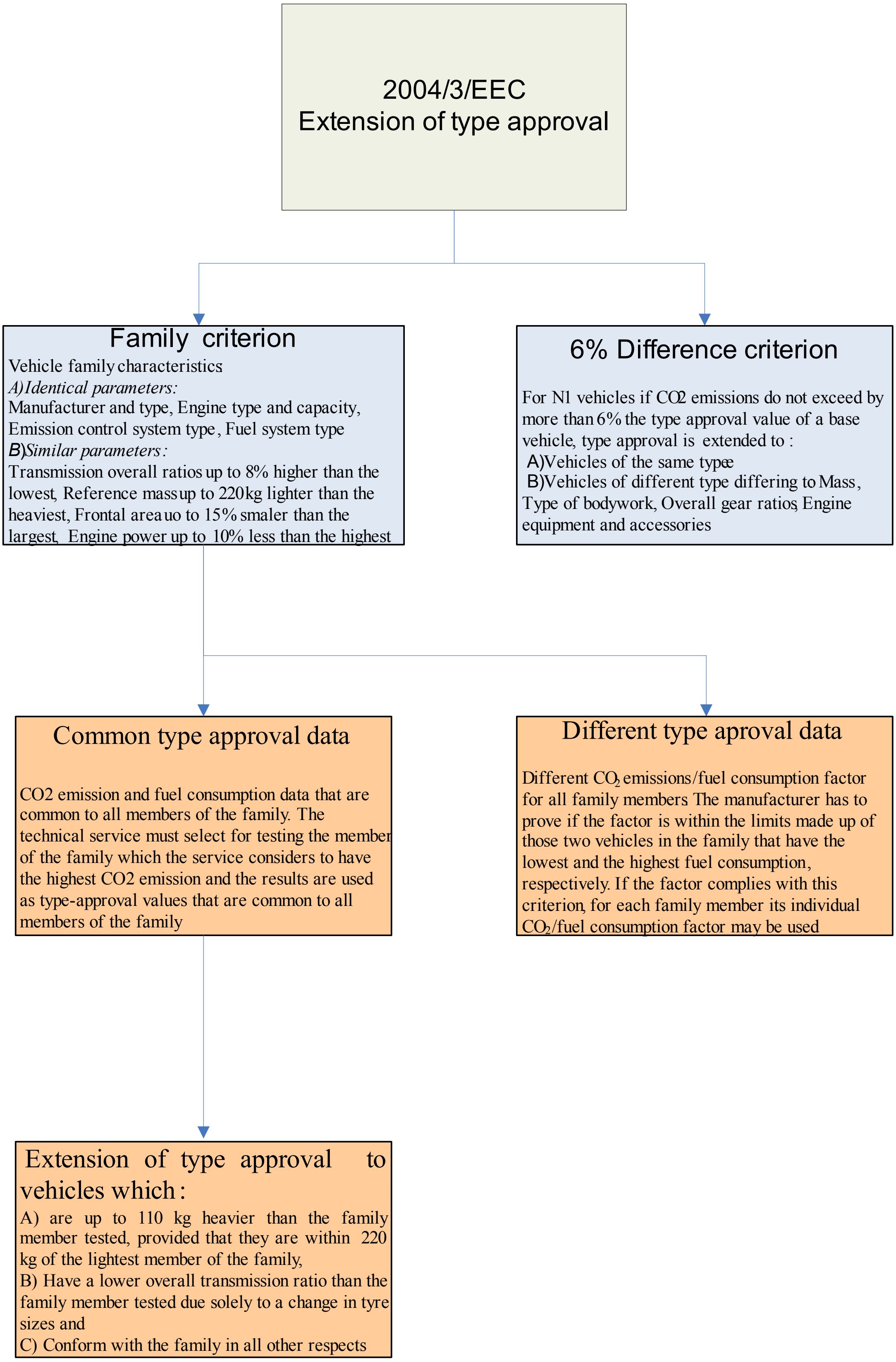
[2] This is specified in Annex II.B of 92/53/EEC (see Appendix B for further details).

family. The second alternative is to establish a different CO_2-emissions/fuel consumption factor for all family members. However, the manufacturer has to prove whether the factor is within the limits made up of those two vehicles in the family that have the lowest and the highest fuel consumption, respectively. If the factor complies with this criterion, for each family member its individual CO_2/fuel consumption factor may be used.

An interesting point in this new type approval procedure is that paragraph 11.2.1 allows extension of the type approval to other vehicles provided that they comply with certain criteria. In this case type approvals may also be extended to vehicles which:

- are up to 110 kg heavier than the family member tested, provided that they are within 220 kg of the lightest member of the family,
- have a lower overall transmission ratio than the family member tested due solely to a change in tyre sizes and
- conform with the family in all other respects

An overview of the extension of type approval provisions introduced by Directive 2004/3/EC is summarised in Figure 2-2.



2004/3/EEC
Extension of type approval

Family criterion

Vehicle family characteristics
A) Identical parameters:
Manufacturer and type, Engine type and capacity, Emission control system type, Fuel system type
B)*Similar parameters:*
Transmission overall ratios up to 8% higher than the lowest, Reference mass up to 220kg lighter than the heaviest, Frontal area uo to 15% smaler than the largest, Engine power up to 10% less than the highest

6% Difference criterion

For N1 vehicles if CO2 emissions do not exceed by more than 6% the type approval value of a base vehicle, type approval is extended to :
A)Vehicles of the same type
B)Vehicles of different type differing to Mass, Type of bodywork, Overall gear ratios, Engine equipment and accessories

Common type approval data

CO2 emission and fuel consumption data that are common to all members of the family. The technical service must select for testing the member of the family which the service considers to have the highest CO2 emission and the results are used as type-approval values that are common to all members of the family

Different type aproval data

Different CO_2 emissions/fuel consumption factor for all family members The manufacturer has to prove if the factor is within the limits made up of those two vehicles in the family that have the lowest and the highest fuel consumption, respectively. If the factor complies with this criterion, for each family member its individual CO_2/fuel consumption factor may be used

Extension of type approval to vehicles which:

A) are up to 110 kg heavier than the family member tested, provided that they are within 220 kg of the lightest member of the family,
B) Have a lower overall transmission ratio than the family member tested due solely to a change in tyre sizes and
C) Conform with the family in all other respects

Figure 2-2: Structure of extension of type approval procedure introduced by Directive 2004/3/EC

2.3 Diesel Engine emissions (Directive 88/77/EEC)

Directive 88/77/EEC as it was amended by 2001/27/EC and 1999/96/EC establishes type approval for diesel engines as separate technical units. Therefore, the engine is type approved rather than the vehicle in which it is installed. The test procedure consists of measurements of the engine's emissions and fuel consumption over 13 operational points - specified points in the engine's operational field. This procedure, also known as European Stationary Cycle (ESC), is presented in Appendix H. The ESC is a 13-mode, steady-state procedure that replaces the ECE R-49 test.

Moreover, Directive 1999/96/EC introduces the concept of engine families. Each engine family consists of a 'parent engine' and other engines that have several characteristics in common (amongst others: combustion cycle, cooling medium, cylinder displacement, fuel injection system, etc.). The 'parent engine' is selected using the primary criteria of the highest fuel delivery per stroke at the declared maximum torque speed.

This concept is almost similar to the one regarding vehicle families introduced in Directive 80/1268/EEC by Directive 2004/3/EC for N1 vehicles; the subject however is the engine, not the complete vehicle.

2.4 Completed multi-stage vehicles (Directive 92/53/EEC)

A large number of vehicles, also N1 type vehicles, are not produced straightforward by one manufacturer. Depending on the purpose that the vehicle is built for, in certain cases a vehicle might be assembled using parts of several different manufacturers. Granting type approval separately for these types of vehicles could increase their cost too much, knowing that these vehicles are produced in relatively small numbers. In order to simplify the type approval of these types of vehicles and to create a more flexible procedure, the EU has established the multi-stage type approval (introduced in Directive 92/53/EEC, see Appendix B). Multi-stage type approval means the procedure whereby one or more Member States certify that, depending on the state of completion, an incomplete or complete vehicle satisfies certain technical requirements.

While Directive 92/53/EEC does not define a multi-stage vehicle, it does define "base vehicles", "incomplete vehicles" and "completed vehicles". More specifically:

- **base vehicle** means any incomplete vehicle, the vehicle identification number is retained during subsequent stages of the multi-stage type-approval process;
- **incomplete vehicle** means any vehicle which still needs completion in at least one further stage in order to meet all the relevant requirements of the Directive;
- **completed vehicle** means a vehicle resulting from the process of multi-stage type-approval, which meets all the relevant requirements of the Directive.

In the specific case of N1 vehicles, the multi-stage procedure is applied for vehicles that contain an engine that is certified for emissions according to Directive 88/77/EEC. In most cases this deals with so-called chassis-cab vehicles: N1's that only consist of a driver cabin and an empty chassis that could be assumed as the base vehicle. These vehicles are completed by converter companies who install a body-work that fits to the needs of its final customer. The engine that is in the vehicle was already granted type approval; the other subjects (as indicated in the Table of Annex IV of Directive 92/53/EEC) still need to receive type approval in the different stages of completing the vehicle.

From the discussion in this section and the previous one on Directives 92/53/EEC and 88/77/EEC respectively it is clear that both Directives are strongly related to each other. Directive 88/77/EEC provides all the necessary background for the separate type approval of a vehicle's engine and 92/53/EEC establishes the legislative basis for the use of an approved engine in a multi-stage vehicle.

In this context, the following question arises:

> *Is granting a multi-stage vehicle type approval based solely on the type approval of the engine, technically acceptable?*

This question that is also mentioned in Article 3 of Directive 2004/3/EC, needs to be addressed in this study. One approach could be to employ a computer model for the calculation of CO_2-emissions by using the ESC engine map that will not be restricted by the vehicle itself but allow variations and experimentation with different vehicle parts and characteristics. As mentioned, Article 3 of Directive 2004/3/EC stresses that special attention should be given to obtain CO_2-emission and fuel consumption data for completed multi-stage vehicles and vehicles whose engine is type approved according to Directive 88/77/EEC since the cost-effectiveness of such a procedure could be rather worse. Therefore, the application of a computer model could most probably result in a rather cost-efficient solution.

3 CO_2-emission inventory

In order to determine the CO_2-emissions base line for new registrations and the fleet, statistical data on N1 vehicles is indispensable. Another purpose of this study is to calculate the average CO_2-emission factors not only according to N1 class, but also according to manufacturer association. Therefore, CO_2-emissions measured on the procedure as prescribed in Directive 80/1268/EEC (NEDC driving cycle) are needed for N1 vehicles.

For the objectives mentioned above, the data collected in the first study were evaluated to determine its applicability for the underlying study. The data analysis is discussed in the first paragraph of this section in which also the strong and weak points are addressed and lacking data is identified.

The second paragraph of this section deals with the data collection that has been carried out in the underlying study and starts with a detailed description of the N1 market. This presents an indication on the different definitions of N1 vehicles (or LCVs) that are applied by Member States, the differences that appear in national taxation and registration criteria, and addresses the issue of the grey area between M1 and N1 registrations. It ends with a detailed description of the market itself and its most important players. The same paragraph also discusses the procedure to determine the 30 most sold N1 vehicles of 2002 in the EU and the CO_2-emission factors that have been collected for these vehicles. Also the issue of completed multi-stage vehicles and N1 vehicles whose engine is type approved according to Directive 88/77/EEC will be addressed.

The section ends by discussing the calculation of the average CO_2-emissions per N1 class and manufacturer association, for the newly registered N1 vehicles in 2002.

3.1 Applicability of data from the first study

In the final report of the first study [Lu, 2003] - carried out by RAND Europe, Forschungsgesellschaft Kraftfahrtwesen Aachen (FKA) and Transport & Mobility Leuven (TML) - the topic of data collection have been addressed. The data retrieved for that study has been evaluated for applicability in the underlying study.

Historical trends in sales of new N1 vehicles
Information is obtained for Western Europe for the years 1995 to 2000, directly downloaded from the ACEA website [ACEA, 2002] or derived from data received from statistical offices of Member States. The following positive and negative aspects can be mentioned:

+ Detailed data is available for Hungary and Poland;
+ The share according to manufacturer association is derived from sales data published by L'Association Auxilaire de l'Automobile (AAA) in 1999 and 2001. This source is also used to determine the top 60 of most sold N1 vehicles in the EU;

– The share for the classes I, II and III is derived according to the class definition before Directive 98/69/EC had amended Directive 70/20/EEC;
– Division over fuel type is based on new registration data of Finland, Germany and UK.
– The number of vehicles for each class is estimated by using the linear relationship that was found between the parameters Gross Vehicle Weight (GVW) and load capacity; no actual data was used for this purpose.

Market driving forces

In the first study, the topics N1 vehicle variants, customer characteristics and consumer requirements are relatively shortly addressed. Information on the key market players is provided in different tables and figures. Future trends within the market are described based only on information supplied by ACEA during a workshop. Therefore, the description of the N1 vehicle market needs further detail in order to get an indication about the key market players and details about joint ventures, also taking into account future trends of the market. Furthermore, specific issues like multi-stage vehicles and the number of vehicles whose engine is type approved according to Directive 88/77/EEC are hardly mentioned and will need more attention.

N1 vehicle fleets 1995 - 2000

Data has been collected to get an indication on the N1 vehicle fleets by i) country ii) weight class iii) association and iv) age distribution. Lots of effort has been put in information collection of the N1 fleet by country; individual statistical offices for each Member State were approached to obtain detailed data. Since not all Member States did respond to the request, the missing data was obtained from ACEA. The report concluded that information on the N1 fleet could be achieved from different sources; in some cases data had to be purchased. However, the various data sources proved to be inconsistent in detail, provided data in many different formats and used different definitions or units. Data split up on N1 vehicle mass and manufacturer (association) was hardly available; only the information obtained from Austria, Germany, the Netherlands and Ireland and partially of Hungary contained a detailed breakdown. These data have been used to estimate the situation for the whole EU. Hence, repetition of this exercise will be a challenging task.

CO_2 base case calculations

Appropriate methodologies have been described to estimate the CO_2-emissions of the new registered vehicles and the N1 vehicle fleet. A methodology has been developed to predict CO_2-emissions for this class of vehicles in the future. Most of the input data - amongst others CO_2-emission factors, fleet composition, average vehicle age and vehicle kilometres - are provided by Transport & Mobility Leuven using the TREMOVE tool. In addition, CO_2-emission factors were collected from different sources, however these were in most cases based on real-world driving cycles (taken from 'Lastauto und Omnibus', a German magazine on vans, busses and trucks), and not on the NEDC type approval cycle that is prescribed by Directive 80/1268/EEC.

From the data collected, the annual CO_2 averages for new vehicles by class and associations were derived; these are summarised in Table 3-1. However, the CO_2 emissions used for the base case calculation seem to be rather high in case these are compared with the values mentioned in Table 3-1. In addition, the base case CO_2 factors are the same for the year 2005, 2010 and 2015 but the general trend shows that CO_2-emissions are getting lower over the years also for this category of vehicles.

Therefore, the CO_2-emission database that has been used in the previous study should be updated and contain values measured over the procedure specified by Directive 80/1268/EEC in order to update the N1 class and manufacturer association averages. These values can be either measured on a chassis dynamometer or be collected from type approval databases.

Table 3-1: Average CO_2-emissions per class and association for 2002 - source RAND study

Average CO_2 [g/km] for 2002	**Class I**	**Class II**	**Class III**	**Total**
ACEA	160	214	258	-
JAMA	-	202	-	-
KAMA	-	-	291	-
Total	-	-	-	-

From the evaluation described above and the objective of the underlying study following general conclusions and recommendations have been made for the purpose of data collection:

- The information that is obtained from the different sources in the previous study is - in most cases - up to the year 2000. The underlying study aims to derive the top 20 of most sold vehicles of 2002 and has to estimate the average CO_2-emissions of the complete EU fleet of 2002. These specific data lacks from the previous study however the sources that are contacted can probably provide updated figures.

- Member States apply different definitions for N1s and LCVs and show also a variety of detail and format in which the new registration and fleet data is delivered. Finding new registration and fleet data is a challenging task.

- Before the information is requested from the different sources, a detailed breakdown of the detail that is needed on information about N1 vehicles has to be defined. The level of detail is provided could comprehend:
  - Manufacturer
  - Model
  - Variant/Body
  - Number of new registrations
  - N1 class or reference mass
  - Fuel type
  - GVW (maximum 3500 kg)
  - Means of emission type approval (70/220/EEC or 88/77/EEC)
  - Engine swept volume
  - Maximum engine power
  - Number of gears
  - Fuel consumption (l/100 km)
  - CO_2-emissions (g/km)
  - Aerodynamic drag coefficient (C_w-value)
  - Frontal area (FA)

3.2 The N1 vehicle market in Europe

The project group acknowledges the efforts of the Centre of Automotive Industry Research (CAIR); Mr. Peter Wells who has kindly contributed to this section and Appendix C.

3.2.1 Definitions and market issues

In order to collect relevant and correct figures about the N1 vehicle fleet in Europe, a number of issues should be identified that deal with this topic. Therefore, this section provides background information to better understand the N1 and light commercial vehicles (LCV) market in the EU. The issues are:

- definitions of N1 vehicle category, applied in Member States;

- difference in national taxation and registration criteria;
- indication of the significance of the ’grey area’ that exist between M1’s and N1’s;
- description of the light commercial vehicle market in Europe.

The definition of an N1 vehicle, applied in Member States
Before seeking new registrations and fleet data on N1 vehicles, it is necessary to establish what is meant when talking about the N1 vehicle fleet in Europe. The terms ’N1 vehicle’ and ’light commercial vehicle’ are often used interchangeably by Member States to refer to those vehicles that are predominately (though not exclusively) bought by business and organisations for functional reasons rather than by individuals for private use. However, most Member States apply different definitions for light commercial vehicles, which in some cases also contain M1 vehicles. The key problem of this class of vehicles, for regulators and for those interested in the market for these vehicles, is one of definition or categorisation; i.e. properly defining those vehicles to be classed as light commercial vehicles. A related problem is that of data availability, as, clearly, different definitions yield different results in terms of production levels and market size. As a result of the lack of clarity on the definition, there is a grey area between passenger cars and light commercial vehicles, which potentially leads to inconsistency in data.

The terms N1 and M1 vehicle, the latter being the equivalent term for passenger cars, refer to the categories used in the common EU type approval process. In addition, N1 vehicles are split into three classes (based on reference mass) according to Article 5 of Directive 2004/3/EC. These definitions are also summarised in section Abbreviations and Definitions.

The M1/N1 categorisation, therefore, appears on the Certificate of Conformity (CoC) associated with a vehicle model. EU legislation, including that on emissions standards, also uses these categories to define their scope. For example, Directive 98/69/EC, which sets Euro III and IV standards, applies to all M and N1 (Classes I, II and III) vehicles. Similarly, Directive 2004/3/EC extends the scope of Directive 80/1268/EEC to include N1s in addition to M1s[3].

The key point, then, is that the definition is based on the intended purpose of the vehicle, not on objective criteria such the ratio of seating area to load-carrying area. More detailed definitions exist, for example in UNECE resolutions and in national regulation, but still there is scope for interpretation, particularly with vehicles, which, to one extent or another, fulfil both functions. (A more detailed discussion about the range of vehicles covered by the term ’light commercial vehicle’ can be found in Appendix C). In these cases, moreover, there is an incentive for manufacturers to seek an N1 classification because in a number of respects (such as, until 2004/3/EC, the absence of the requirements to measure and report on fuel economy and CO_2-emissions) the technical requirements for the latter are less stringent.

It appears that the manufacturer has the first initiative in deciding whether a vehicle is an M1 or an N1 when putting it forward for type approval, although the relevant approval agency may question. For N1 vehicles, a further complication arises at this point because N1s are still governed by national, not EU, type approval. This means that the criteria applied may differ slightly from country to country, as the national criteria reflect specific issues for the national fleet. Further, it is claimed that there is even the possibility of the same vehicle being treated as a passenger car in one country, and a light commercial vehicle in another. This problem may well be exacerbated by EU enlargement.

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[3] It does this by simply amending Row 39 of Part 1 of Annex IV in directive 70/156/EEC by putting a cross in the column headed ‘N1’ for the row (i.e. 39) that refers to directive 80/1268/EEC.

National taxation and registration criteria
Member States do not necessarily use the same categories as those used in EC legislation, e.g. for the purposes of taxation, at the national level. Indeed, the precise definition of light commercial vehicle used by Member States varies and is based on different characteristics, such as that they have sufficient rear load space. For example, some Member States classify some types of passenger car, i.e. vehicles that have been type approved as M1, as light commercial vehicles. In this case, as sales or circulation taxes for commercial vehicles tend to be lower than for passenger cars, there is an incentive to deem a vehicle to be N1 rather than M1 wherever possible, although the degree and nature of this incentive will vary from country to country. In addition, some Member States do not necessarily distinguish between the passenger cars and light commercial vehicles in their national registration categories.

Hence, there is a potential anomaly between manufacturers' and Member States' data, in that sales data and registration data are unlikely to match. The 'grey area' is one reason for this, although there are also others (such as grey imports, advance registration, etc). In addition, as each Member State could well use a different categorisation for the purposes of national registration, there is an issue of data comparability between individual Member States for M1 or N1 vehicles. This should be taken into account in case new registration and fleet data is collected.

For some pieces of legislation, e.g. Directive 98/69/EC, this classification issue is not a problem, as they apply equally to M1s and N1s. However, for others, e.g. Directive 80/1268/EEC before it was amended and the voluntary agreement with ACEA on reducing CO_2-emissions from passenger cars, it is an issue, as only vehicles registered, as M1s on their associated CoC would be subject to the provisions of such legislation.

Indication of the significance of the 'grey area' that exist between M1's and N1's
These issues have been recognised by those responsible for comparing and reporting on the Member State and manufacturer data submitted as part of the manufacturers' commitments to reduce CO_2 from passenger cars (i.e. under Decision 1753/2000/EC). A working paper related to the 2002 report suggested that vehicles classified under a number of categories - e.g. Sedan, Station Wagon, Combispace, Minispace, Monospace, Off road, Compact monospace - could fall within the grey area between M1s and N1s. The paper quoted AAA, who respect national 'vehicle type' parameters based on national fiscal rules, as estimating that the grey area amounts to around 3% of all makes (an average across makes) for 2000 and 2001. Figures for recent years suggest that for ACEA the grey area consist of around 2.2% of registrations or 270,000 vehicles for 2001. For JAMA the figures for 2000 and 2001 were 4.5% and 4.6% (i.e. around 70,500 vehicles); while for KAMA the figure was 6.3% for both years (around 25,000 vehicles), of which around 80% was due to three models sold in Spain, Portugal and Italy. Hence, the total number of new registrations possibly in the grey area for 2001 is 365,500. (In its earlier report on N1 vehicles [Lu, 2003], RAND quoted data that estimated that 408,560 vehicles occupied the grey area in 2000.)

The Annexes to the 2003 report [Mehlin, 2004] again underline the concerns of the associations in relation to the grey area between N1s and M1s. ACEA was reported to believe that some Member States might register vehicles in accordance with the fiscal regime (commercial or private vehicle), not in accordance with M1 and N1 category definitions and that this was a likely source of difference in need of more thorough investigation. It was noted that this was an issue particularly in relation to the number of M1 vehicles potentially registered (presumably by Member States) as a light commercial vehicle; a view that JAMA also shared. However, for both associations, it was claimed that the grey area issue was small, whereas for EU data 'it is an unknown volume'. For KAMA, there was no report on this issue.

It should be stressed; moreover, that the latter analysis in particular was from the perspective of M1 vehicles; in relation to N1s the potential distortionary effect is larger in percentage terms, as there are many fewer of them (total number of LCV's sold in 2000 according to [ACEA, 2000]: 1,908,180 (21% of the N1 vehicles sold could be in the grey area).

The market for light commercial vehicles

There are both significant suppliers and buyers in the light commercial vehicle sector - many of the bigger buyers being non-commercial organisations or government corporations. In terms of the basic vehicle platforms and engines (i.e. prior to customisation) there are three main categories of suppliers of light commercial vehicles:

- Car manufacturers who have an interest in light commercial vehicles but not heavy commercial vehicles e.g. Ford, PSA.
- Heavy commercial vehicle manufacturers that also have an interest in the light commercial vehicles sector e.g. Iveco, Mercedes.
- Independent producers of light commercial vehicles e.g. LDV of the UK.

Additionally, there are some imports. The largest flows of imports are probably those from Japan, such as the Daihatsu Extol. Some of these vehicles are based upon products designed to meet the Japanese Kei segment regulations. Other imports include those from Tata of India (pick up trucks) and various US-sourced products (chiefly pick-up trucks).

Panel vans are high cost items in terms of product development, because they involve pressed and welded steel bodies that require expensive press tooling. Given that production volumes are somewhat lower than cars (usually) it is not surprising that the light commercial vehicles sector features relatively long product cycles, with the same basic design remaining in production for many years. Moreover, the fundamental economics has prompted co-operative development and production in the sector exemplified by the Sevel joint venture between PSA and the Fiat group. Another example is the co-operation between Renault, Nissan and GM. Of course, in most instances it is possible to install more recent engine designs to meet contemporary requirements. Table 3-2 provides an example on the equivalent vehicle models that are sold by different manufacturers; in Table 3-3 vehicles are mentioned that carry an equivalent engine that has been type approved according to Directive 88/77/EEC; however the engine power of this engine can differ per manufacturer.

Table 3-2: Example of equivalent models sold by different manufacturers

	Sevel			**Renault/GM/Nissan**		
Class	**Citroën**	**Peugeot**	**Fiat**	**Renault**	**Opel**	**Nissan**
I	Berlingo	Partner		Kangoo		Kubistar
II	Jumpy	Expert	Scudo			
III	Jumper	Boxer	Ducato	Traffic	Vivaro	Primastar
III				Master	Movano	Interstar

Table 3-3: Example of equivalent engines applied in models of different manufacturers

Engine code	**Engine swept volume [ccm^3]**	**Vehicle 1**	**Vehicle 2**	**Vehicle 3**	**Vehicle 4**	**Vehicle 5**
F1AE0481X	2286	Iveco Daily	Fiat Ducato	-	-	-
8140.43X	2800	Iveco Daily	Fiat Ducato	Peugeot Boxer	Citroën Jumper	Renault VI Mascott

While the ubiquitous and undifferentiated product, the car-derived van and the standard panel van are the majority of the market, it remains the case that key buyers with specific applications are an important feature of the market. These large buyers include:
- Police, military and other government security organisations;
- Government postal services;
- Independent parcel delivery services;
- Telecommunications and other infrastructure services suppliers;
- Hauliers; and
- Large lease and contract hire companies.

As an illustration, the UK company British Telecom (BT) is the largest single purchaser of vehicles in the UK (and possibly in Europe), spending over £80m per annum on trucks, light commercial vehicles and cars. In particular, BT alone is almost sufficient to keep the Ford Transit plant in Southampton occupied. These big buyers are powerful enough to have vehicles built to their specification. In this context it is notable that the recent purchase by Deutsche Post of DHL and Securicor has resulted in a group with over 100,000 vehicles worldwide, giving huge purchasing power.

The large leasing companies are also significant, especially in the UK and Benelux. In the UK, for example, the largest vehicle leasing company is Lloyds TSB Autolease (owned by Lloyds TSB Bank) with 141,750 vehicles as of August 2003, and an annual turnover of about £400m. While much of the business for lease companies lies in cars and heavy commercial vehicles, some is connected to light commercial vehicles.

Alternatively, many other buyers are very small businesses, ranging across the spectrum of service supply from florists and farmers to cleaners and plumbers. These small businesses purchase light commercial vehicles ’off the shelf’ that match with their specific application needs. The manufacturers therefore developed different variants of one model. The main characterisations that are subject of change:
- body (car derived van, panel van, pick-up, etc.) and difference in height and length
- height and length (load volume - m^3)
- wheelbase (load capacity - kg)
- engine (power, fuel)
- gear box and final drive ratio

The combinations that can be made with these characterisations lead to a high amount of purchasable variants. For example: the Ford Transit has over 100 different variants.

Member State differences in vehicle categorisation and other factors result in different demand and market patterns. So, for example, the UK economy has a relatively highly concentrated corporate structure in key sectors such as retailing, and this in turn skews demand more towards the heavy commercial vehicle sector. In comparison, the French economy has a greater proportion of small businesses and these skews demand more towards the car-derived van sector.

In addition, in the past national purchasing preferences has tended to result in ’local’ manufacturers being significant in these markets: Renault and PSA in France; Iveco in Italy; Mercedes and Volkswagen in Germany for example. These patterns are breaking down, but probably not as fast as in the car market.

This brief overview of the N1 vehicle market shows that this market is not as straightforward as for ’normal’ passenger cars (M1 class). A vehicle model with the same name may appear in many different variants –even as an off the shelf product– while at the same time identical vehicles may have different manufacturers. In case of customers that buy many N1 vehicles, they can even be custom built according to specific demands. Between Member States the market can be subject to influences such as local suppliers and buyers, vehicle ownership (leasing), and the economic structure.

3.2.2 New registrations of N1 vehicles in 2002

New registration data of N1 vehicles has to be gathered in order to determine the 20 most sold N1 vehicles in the EU. Since the scope of the previous study was limited to the year 2000, no data on new registrations of N1 vehicles for the year 2002 was available. Hence, Member States registration bodies were requested to provide this information in as much detail as possible. Depending on the detail, the provided data can be analysed to determine the number of vehicles that carry an engine that is certified according to Directive 88/77/EEC and that are completed multi-stage N1 vehicles. The latter two items are discussed separately in section 3.2.3.

Supplementary to the collection of the data mentioned above, new registrations information for 2002 was downloaded from the ACEA website [ACEA, 2002], providing an overview in LCV sales per EU-15 country. Note that a grey area between M1 and N1 registrations exists; the LCV new registration numbers can therefore contain M1 vehicles as well and vice versa. However, the ACEA data provides an overview of which countries have a high contribution to total new registrations in the EU (see Figure 3-1). Unfortunately, data from the accession countries is lacking.

In relation to obtaining data from one source, other organisations that have previously worked with the Commission on aspects of the passenger car CO_2 strategy (e.g. Deutschen Zentrum für Luft- und Raumfahrt (DRL), l’Association Auxiliaire de l’Automobile (AAA) and Ökopol) have been contacted. These organisations have been consistently pointed in the direction of a German company ’RL Polk Marketing Systems GmbH’. Also the manufacturer’s associations were approached, but have not responded, although basic data are available on ACEA’s website, as mentioned above. In parallel, Marketing Systems was contacted and had opened up a dialogue. Marketing Systems has data on new registrations for light commercial vehicles for the EU-15, plus eight out of the ten countries that will be joining the EU from 1 May 2004. The data had to be purchased (costs 12,500 Euro) but the project group decided that these costs are too high for the objectives to determine the 20 most sold vehicles in Europe and information on the N1 market.

As it is stated in paragraph 3.2.1 and concluded in the report of the first study [Lu, 2003], Member States apply different definitions for this vehicle category causing inconsistency between data sets. However, following data was received from Member States and accession countries:

- By **model**: Czech Republic (Top 20), Finland, Greece, Italy, Latvia, Slovakia (Top 10)
- By **variant**: Denmark, Germany, Ireland, Spain, The Netherlands

Taking into account the total new registrations of LCVs in 2002 of ACEA, the collected data-set comprehends approximately 45% of the total EU-15 and Iceland, Norway and Switzerland. Hence, additional effort has been put in collecting new registrations data from France. Since the contacted persons did not respond to the request, CCFA (Le Comité des Constructeurs Français d'Automobiles) website has been visited. Data on the produced numbers of models of French manufacturers and new registrations of different manufacturers were found (remarkable detail: 71.6% of the models sold in France are from French manufacturers). These data has been combined and analysed in order to estimate the new registrations in France on a model basis.

Effort has been put in aggregating the data from variant to model level and to derive a model based sales list for all Member States for which data was available. The result of the exercise to derive the 20 most sold vehicles in Europe is given in Table 3-4. The Table summarises the 30 most sold vehicles and also the manufacturer association and subclass (I, II or III) for each model is indicated. The 20 most sold vehicles comprehend approximately 65% of the total N1 vehicles sold in the EU; the 30 most sold approximately 80%. The vehicles in this list are of ACEA or JAMA manufacturers; however in case the 150 most sold vehicles (~95% of the total sales) are identified, KAMA also comes into play (see Table 3-6). In addition to these figures, the division over the three defined subclasses is indicated in Table 3-6 as well. It should be noted that these figures do not follow the trends that have been identified in the previous study [Table 1-Lu, 2003]. Especially for class II and class III differences appear; the share of class II vehicles is 10% lower whereas the class III percentage is 10% higher. However, it is rather remarkable that the values mentioned in the summary and the list of 60 most sold vehicles of Appendix 6 of that report both tend to the class division mentioned in Table 3-6.

For the vehicles listed in Table 3-4, CO_2-emission and fuel consumption data on the type approval driving cycle is collected from databases or has been measured on the chassis dynamometer; this topic is discussed in paragraph 3.3.1.

Comparison of the new registration statistics collected in this study and the figures indicated on the ACEA website show that differences appear in total numbers. In fact, in most cases the ACEA numbers are higher most probably caused by the grey area in registrations between M1 and N1 vehicles (see Table 3-7).

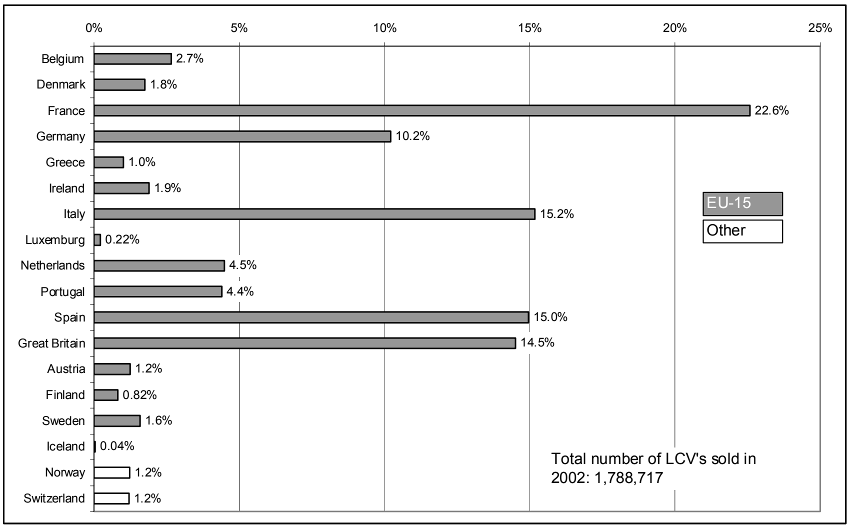

Figure 3-1: LCV new registrations in 2002, per country (source [ACEA,2002])

Table 3-4: Top 30 new registrations in the EU for 2002

Rank 2002	Rank 2000[4]	Manufacturer	Model	%share	%cumulative	Association	Class
1	1	Renault	Kangoo[5]	9.6%	9.6%	ACEA	I
2	2	Ford	Transit	5.6%	15.2%	ACEA	III
3	4	Citroen	Berlingo	5.1%	20.3%	ACEA	II
4	8	Renault	Master	4.8%	25.1%	ACEA	III
5	11	Peugeot	Partner	4.5%	29.6%	ACEA	II
6	6	Fiat	Ducato	4.4%	34.0%	ACEA	III
7	NA	Fiat	Doblo	3.8%	37.8%	ACEA	II
8	5	Volkswagen	Transporter	3.5%	41.3%	ACEA	III
9	7	Iveco	Daily	3.3%	44.6%	ACEA	III
10	9	Mercedes	Vito	2.6%	47.2%	ACEA	III
11	3	Mercedes	Sprinter 3-series	2.5%	49.7%	ACEA	III
12	10	Renault	Clio Van	2.4%	52.1%	ACEA	I
13	14	Peugeot	Boxer	2.2%	54.3%	ACEA	III
14	17	Citroen	Jumper	2.0%	56.4%	ACEA	III
15	12	Fiat	Scudo	1.9%	58.3%	ACEA	II
16	24	Opel	Combo	1.8%	60.1%	ACEA	I
17	13	Citroen	C 15 D	1.7%	61.8%	ACEA	I
18	26	Peugeot	Expert	1.7%	63.5%	ACEA	II
19	32	Citroen	Jumpy	1.5%	65.0%	ACEA	II
20	3	Mercedes	Sprinter 2-series	1.4%	66.4%	ACEA	III
21	21	Mitsubishi	L200	1.4%	67.7%	JAMA	II
22	NA	Opel	Vivaro	1.3%	69.1%	ACEA	III
23	20	Volkswagen	LT	1.3%	70.4%	ACEA	III
24	25	Fiat	Panda Van	1.3%	71.7%	ACEA	I

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[4] Rank from RAND study [Lu,2003], Appendix 6

[5] RAND assumed that the Renault Kangoo was a class II vehicle

Table 3-5 (cont.): Top 30 new registrations in the EU for 2002

25	NA	Peugeot	206 Van	1.3%	73.0%	ACEA	I
26	15	Volkswagen	Caddy	1.2%	74.3%	ACEA	I
27	50	Renault	Trafic	1.2%	75.5%	ACEA	III
28	36	Fiat	Punto Van	1.1%	76.6%	ACEA	I
29	27	Nissan	Cabstar	1.0%	77.6%	JAMA	III
30	3	Mercedes	Sprinter[6]	1.0%	78.6%	ACEA	III

Table 3-6: Share of manufacturer association and division over subclasses (based on 150 most sold vehicles in 2002)

	ACEA	JAMA	KAMA	Other	Total
Class I	25.6%	0.0%	0.0%	0.5%	**26.1%**
Class II	22.2%	2.7%	0.0%	0.0%	**24.9%**
Class III	43.2%	4.0%	1.6%	0.2%	**49.0%**
Total	**91.0%**	**6.7%**	**1.6%**	**0.6%**	**100.0%**

Table 3-7: Differences in new registrations per country: ACEA statistics versus statistics obtained from Member States

	Collected	ACEA	Difference
Czech	3827	n.a.	-
Germany	162373	182654	-12.5%
Denmark	31444	31442	0.0%
Spain	203346	267625	-31.6%
France	404919	404021	0.2%
Finland	12891	14614	-13.4%
Greece	18162	18157	0.0%
Italy	268357	271348	-1.1%
Ireland	34014	33792	0.7%
Latvia	848	n.a.	-
Netherlands	63487	80255	-26.4%
Slovakia	5621	n.a.	-
Total	**1209289**	**1303908**	**-7.8%**
% ACEA total	68%	73%	

3.2.3 Completed multi-stage vehicles

In order to get an indication on the number of vehicles that fall within the definition of multi-stage vehicles, three Dutch importers were contacted. The purpose of these contacts was to provide additional detail on the type approval procedure that is applied for this type of vehicles and the number of vehicles sold following this definition. With this information, the relevance of the issue can be argued.

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[6] For some Member States no differentiation was given on Sprinter 2- and 3-series

Type approval procedure

Basically, most manufacturers sell vehicles that are so-called base vehicles (definition: see paragraph 2.4). These vehicles consist of a chassis and a cabin on which converter companies can built customised bodies. In order to receive type approval on emissions for these types of vehicles, in practice, two different procedures can be followed:

1. gather the base vehicle under a family or as a vehicle of the same type: emission type approval values are taken from the 'parent' vehicle that have been tested according to Directive 70/220/EEC - in most cases an equivalent M1 variant of the vehicle that already has been granted type approval – the emissions are expressed in unit g/km.
2. get the emission type approval only on the engine by applying Directive 88/77/EEC.

Advantages of the latter procedure are to apply this engine in a lot of different variants without further type approval testing on emissions, and the possibility to sell these engines to other vehicle manufacturers that can apply the engine in their vehicles as well.

However, by applying the updated Directive 80/1268/EEC, the completed versions of these types of vehicles - i.e. after a body has been built on the chassis - should be tested on the driving cycle as well in order to measure CO_2-emissions for the type approval. This, however, will be a rather high-cost procedure since the number of vehicles that will be sold with that specific body will be low in most cases. To get an indication on the relevance of the problem, sales data is collected for this specific type of vehicle.

Sales of to be completed multi-stage vehicles

The previous study [Lu, 2003] quotes that approximately 30% of the N1 vehicles sold, are of the chassis-cab variant and are completed by converter companies. In fact it means that for only 70% of the vehicles, CO_2-emission factors will be available; to get these values for the other vehicles will be costly. Applying 80/1268/EEC is therefore rather cost-inefficient for these types of vehicles. However, the number of vehicles to be completed as mentioned in the RAND report was verified by contacting four Dutch importers of manufacturers that produce these specific variants; sales data was requested for 2002. For the Dutch situation the application of these values result, on average, in a number of 16%, based on data supplied by Iveco, Mercedes, Peugeot and Volkswagen (representing 44% of the total Dutch N1 market). Although the number is lower than the one mentioned in the previous study, it is still rather high. The study therefore aims to present a modelling approach in which the CO_2-emission of these types of vehicles can be predicted.

3.3 CO_2-emission and fuel consumption

3.3.1 *CO_2-emission factors of 30 most sold vehicles*

From the available databases [KBA, 2003], [VCA, 2003] and measurements that were conducted, CO_2-emission data measured on the type approval driving cycle (as specified by Directive 80/1268/EEC) was retrieved for the 30 most sold vehicles in the EU. In order to assure that the CO_2-emission data provided by the databases was valid, validation measurements have been conducted. The results of these measurements are summarised in Appendix E. Table 3-8 provides an overview of the CO_2-emission factors. The average CO_2-emission has been determined by weighing the CO_2-emission of the variants that are available. Classification to manufacturer association is based on the definition provided in the document COM (2004) 78 final.

These emission factors will be used to determine the 2002 new registrations average CO_2-emissions, which is discussed in paragraph 3.3.2.

Table 3-8: CO_2-emission factors for the 30 most sold vehicles in the EU in 2002; divided over Gasoline and Diesel

							CO_2 [g/km]			CO_2 [g/km] Diesel		
Rank 2002	Manufacturer	Model	%share	%cumulative	Association	Subclass	min	max	avg	min	max	avg
1	Renault	Kangoo	9.6%	9.6%	ACEA	I	163	205	179	139	196	163
2	Ford	Transit	5.6%	15.2%	ACEA	III	198	276	262	172	245	218
3	Citroen	Berlingo	5.1%	20.3%	ACEA	II	161	182	174	152	181	166
4	Renault	Master	4.8%	25.1%	ACEA	III	N.a.	N.a.	N.a.	213	246	233
5	Peugeot	Partner	4.5%	29.6%	ACEA	II	161	182	174	152	181	167
6	Fiat	Ducato	4.4%	34.0%	ACEA	III	301	311	307	208	307	256
7	Fiat	Doblo	3.8%	37.8%	ACEA	II	183	208	199	168	208	189
8	Volkswagen	Transporter	3.5%	41.3%	ACEA	III	293	324	305	203	275	228
9	Iveco	Daily	3.3%	44.6%	ACEA	III	N.a.	N.a.	N.a.	296	296	296
10	Mercedes	Vito	2.6%	47.2%	ACEA	III	N.a.	N.a.	N.a.	206	274	235
11	Mercedes	Sprinter 3-series	2.5%	49.7%	ACEA	III	N.a.	N.a.	N.a.	214	282	242
12	Renault	Clio Van	2.4%	52.1%	ACEA	I	137	194	166	110	139	125
13	Peugeot	Boxer	2.2%	54.3%	ACEA	III	301	311	307	226	307	258
14	Citroen	Jumper	2.0%	56.4%	ACEA	III	301	311	307	226	309	262
15	Fiat	Scudo	1.9%	58.3%	ACEA	II	216	232	224	186	211	199
16	Opel	Combo	1.8%	60.1%	ACEA	I	177	177	177	146	146	146
17	Citroen	C 15 D	1.7%	61.8%	ACEA	I	N.a.	N.a.	N.a.	N.a.	N.a.	N.a.
18	Peugeot	Expert	1.7%	63.5%	ACEA	II	216	232	224	186	211	199
19	Citroen	Jumpy	1.5%	65.0%	ACEA	II	216	232	224	186	211	199
20	Mercedes	Sprinter 2-series	1.4%	66.4%	ACEA	III	N.a.	N.a.	N.a.	214	282	242
21	Mitsubishi	L200	1.4%	67.7%	JAMA	II	N.a.	N.a.	N.a.	N.a.	N.a.	N.a.
22	Opel	Vivaro	1.3%	69.1%	ACEA	III	241	244	243	205	228	213
23	Volkswagen	LT	1.3%	70.4%	ACEA	III	N.a.	N.a.	N.a.	238	289	256
24	Fiat	Panda Van	1.3%	71.7%	ACEA	I	N.a.	N.a.	N.a.	N.a.	N.a.	N.a.
25	Peugeot	206 Van	1.3%	73.0%	ACEA	I	153	189	167	117	144	131
26	Volkswagen	Caddy	1.2%	74.3%	ACEA	I	187	192	190	151	159	155
27	Renault	Trafic	1.2%	75.5%	ACEA	III	241	244	242	205	228	212
28	Fiat	Punto Van	1.1%	76.6%	ACEA	I	136	197	151	119	140	131
29	Nissan	Cabstar	1.0%	77.6%	JAMA	III	N.a.	N.a.	N.a.	N.a.	N.a.	N.a.
30	Mercedes	Sprinter	1.0%	78.6%	ACEA	III	N.a.	N.a.	N.a.	214	282	242

3.3.2 Average specific CO_2-emissions of new vehicles

From the data provided in Table 3-8, the 2002 average specific CO_2 emissions can be derived for the manufacturer associations and classes I, II and III. In addition, averages of each class, manufacturer association and overall can be calculated as well. For this purpose however, additional data has to be found not only on the division over classes division but also on the division over manufacturer association. This data has been retrieved from the RAND's report [Lu, 2003] and the new registrations exercise that has been conducted in this study.

The first step towards calculating the average specific CO_2-emissions of new N1 vehicles is to obtain a view of the current N1 new registrations composition. As mentioned in paragraph 3.2.2, Table 3-4 shows the top 30 of most N1 vehicles sold in the EU in 2002. Through this listing of vehicles, 2002 new registrations can be classified in classes and groups. RAND's report contains similar classifications for previous years.

The data presented in Table 3-4 represents 78.6% of the total newly registered N1 vehicles in EU in 2002, a majority high enough to allow the application of any conclusions extracted by this grouping to all new registrations of 2002. Using this data, the new registrations of N1 vehicles were classified by class and manufacturer group and these results are presented in Table 3-9 and Table 3-10 together with similar information for previous years taken from RAND's report.

Table 3-9: Classification of new registrations of vehicles by class

Year	Class I	Class II	Class III
1995	**34.0%**	**31.4%**	**34.6%**
1996	**31.1%**	**32.8%**	**36.1%**
1997	**26.7%**	**34.9%**	**38.5%**
1998	**26.0%**	**35.2%**	**38.8%**
1999	**25.3%**	**35.5%**	**39.2%**
2000	**24.4%**	**35.9%**	**39.6%**
2002	**26.1%**	**24.9%**	**49.0%**
Average	27.6%	32.9%	39.4%

It should be noted that the data taken from RAND's report stood for EU-15 countries plus Iceland, Switzerland and Norway. Additionally the classification of N1s to subclasses in the underlying study was done in compliance to the subclasses I, II and III described in Directive 98/69/EC where the 'reference mass' instead of the 'empty vehicle mass' is used as the basis. Since the previous study used the old class definitions the inconsistency that appears in the trend between the years 2000 and 2002 could be explained by the different definition (the definitions of the classes are provided in section Abbreviations and Definitions). In order to find the reference mass for the models of Table 3-4 information was used which was taken from other sources such as KBA or various internet sites of the manufacturing companies. The historical evolution of the N1 subclasses as a ratio of the new registrations of N1s is graphically presented in Figure 3-2.

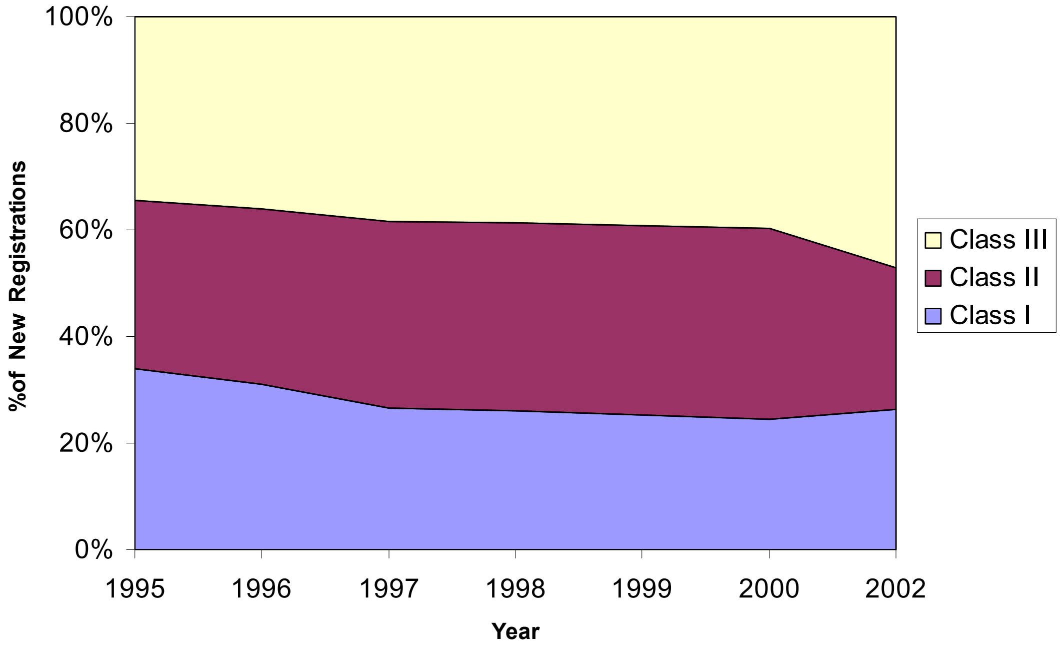

Figure 3-2: Evolution of N1 classes as a percentage of the total N1 new registrations

In further detail, the division by class appears to be changing smoothly with a trend towards stabilising – especially for class I –. From Figure 3-2, it is observed that in the past seven years the ratio of class I N1s seem to have balanced at approximately 25% of the new registrations. At the same time, class II appears to be slowly shrinking year by year contrary to class III which gains greater share in the market. Nevertheless, the needs for different kinds of commercial vehicles are not expected to change significantly in the next 10-20 years so it could be assumed that these percentages are going to stabilise somewhere around the average of the values of this time series.

The classification of the vehicles by manufacturer's group was conducted using again information taken from Table 3-4 and RAND's report (see Table 3-10).

Table 3-10: Classification of new registrations of N1 vehicles by manufacturer association

Association	1995	1996	1997	1998	1999	2000	2002	Average
ACEA	92.8	92.7	91.5	90.8	89.9	89.9	91.0	91.1
JAMA	6.7	5.8	6.3	6.7	8	8.1	6.7	7.0
KAMA	0.5	0.7	0.5	1.1	0.9	0.7	1.6	0.9
Other	0	0.7	1.7	1.5	1.2	1.3	0.6	1.0
Total market share (%)	100	100	100	100	100	100	100	100

Data of Table 3-10 are graphically presented in Figure 3-3. It appears that throughout the past seven years, the market share of the three major manufacturing groups did not change significantly, fluctuating periodically around an average value; note that the scale of the y-axis starts at 80%.

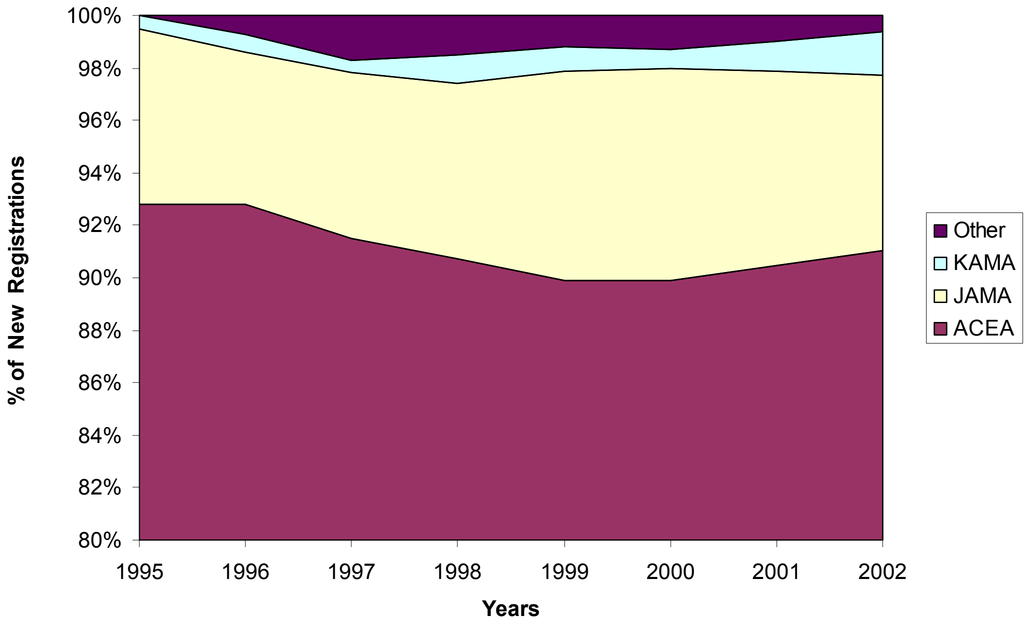

Figure 3-3: Division of the total N1 new registrations by group

Since more detailed data were not available to back up the estimations made about the shares of each class in the European N1 fleet and the shares of the manufacturing groups, the conclusions retrieved from this analysis were accepted as representative for the whole fleet and will be used for all the calculations to be carried out regarding estimating CO_2 emissions. Therefore, an average of the shares of the past seven years was adopted as being representative for the fleet and from now on for all calculations were such classification is necessary, the new registration and fleet will constitute of **27.5% Class I, 33% Class II and 39.5% Class III vehicles**. In the case of manufacturer's grouping the same approach is introduced. For the calculation of 2002 and future emissions, the vehicles are assumed to be divided in association classes with **91% belonging to ACEA, 7% to JAMA and 1% to KAMA.**

For the new registrations of N1 vehicles in 2002, CO_2-emission and fuel consumption data were retrieved from amongst others the KBA database and measurements. For a certain model, these values are the calculated average of the CO_2-emissions and fuel consumption measured on the NEDC driving cycle of all variants of each model and were also distinguished to gasoline and diesel.

The data were divided by vehicle class and manufacturing group. The weighted average value of CO_2-emissions and fuel consumption was calculated and CO_2-emissions were classified for 2002 according to manufacturer group and class (Table 3-11 and Table 3-12). This approach is based on the emissions under cold NEDC conditions and for empty vehicles (in the case that the vehicles where considered to be 50% loaded these emissions would be – as presented in paragraph 4.2.5.2 – about 5.6% higher.

Table 3-11: Average CO2 [g/km] for 2002 fleet (Gasoline) analysed by class and group

Average CO_2 [g/km] for 2002	Class I	Class II	Class III	Total
ACEA	179	181	283	222
JAMA	-	220	291	259
KAMA	-	-	261	261
Total	179	184	283	

Table 3-12: Average CO2 [g/km] for 2002 fleet (Diesel) analysed by class and group

Average CO2 [g/km] for 2002	Class I	Class II	Class III	Total
ACEA	160	176	226	192
JAMA	-	161	238	203
KAMA	-	-	236	236
Total	160	175	227	

From the tables above, the difference between emissions of diesel and gasoline vehicles is clear, with diesel engines having lower CO_2-emissions always. It is known that Diesel engines are more efficient than the Gasoline engines; this differentiation was expected. However, in the future new techniques will be applied in diesel engines in order to reduce their emissions, especially particles. This kind of equipment – particle traps – can reduce the efficiency of the engine particularly when the trap is not well maintained. Therefore the gap between these two types of propulsion (Table 3-13) may be reduced. The influence of this on the total CO_2-emissions from N1 vehicles will be significant as more than 65% of the N1 fleet consists of Diesel vehicles.

Table 3-13: Average emissions with respect to the engine and their difference

	Gasoline	Diesel	Difference
Class I	179	160	10.1%
Class II	184	175	4.8%
Class III	283	227	19.8%

Finally, the average emission factors for new gasoline and diesel N1 vehicles for 2002 are calculated by combining the total values of Table 3-11 and Table 3-12 and the average percentage of the market for each N1 class as presented in Table 3-9. The result is summarised in Table 3-14.

Table 3-14: Emission factors for N1 vehicles (weighted average from 2002 data)

Engine	CO2 (g/km)
Gasoline	222
Diesel	192

In order to get an indication whether the average emission factors provided in Table 3-11 and Table 3-12 are representative, a validation with the averages provided in the RAND report has been conducted. For this purpose Table 3-15 is introduced.

Table 3-15: Comparison between the emission factors (gCO$_2$/km) from RAND and this study

Type	Class	RAND	This study	Difference
Gasoline	**I**	**193**	**179**	**7%**
	II	**258**	**184**	**29%**
	III	**312**	**283**	**9%**
Diesel	**I**	**212**	**160**	**25%**
	II	**283**	**175**	**38%**
	III	**341**	**227**	**33%**

However, it is worth noting that the factors calculated in the RAND study are based on real-world measurements and CO$_2$-emission factors provided by TREMOVE. The CO$_2$-emissions collected in the current study are measured on the type approval driving cycle according to the procedure that is prescribed in Directive 80/1268/EEC. In addition, the source of that data-set is clear and has proven to be reliable. Therefore, the emission factors presented in Table 3-11 and Table 3-12 will be used in all further evaluations on present and future CO$_2$-emission estimations (in fact, they are used for Euro 3 and Euro 4 CO$_2$ emission factors).

4 CO_2-emission calculations and evaluation

By extending the scope of the CO_2 and fuel consumption Directive 80/1268/EEC to N1 vehicles, specific concerns were addressed on the cost-efficiency of the procedure especially for completed multi-stage vehicles and vehicles whose engines are type approved according to Directive 88/77/EEC. To improve cost-efficiency, the potential of a model that is able to predict CO_2-emissions for these types of vehicles should be assessed. The underlying section deals with this topic and introduces a model that could probably be used for this purpose. In addition, the calculations that have been carried out are discussed and are split up to the topics:

- predict emissions for a N1 vehicle that contains an engine that granted emission type approval according to Directive 88/77/EEC;
- predict emissions for completed multi-stage vehicles (influence of mass, C_w and FA);
- evaluate the family concept (link 6% derogation to vehicle characteristic differences);
- predict CO_2-emissions and fuel consumption from N1 vehicles in laden real use conditions.

4.1 Adopting a modelling approach

For the purposes of this study two different approaches were investigated for simulating and predicting fuel consumption and CO_2-emissions from N1 vehicles. The first approach was to use an existing commercial vehicle modelling software (Advisor 2002) and the second was to use a simple method based on the fundamental equations of vehicle resistances in a predefined driving cycle. The scope behind this second attempt was to come up with a simple and easy to use method for predicting fuel consumption of N1s driven over the NEDC driving cycles when engine maps and efficiency data are not available. Unfortunately the lack of sufficient data and detail regarding the publicised type approval values of the vehicles limited the accuracy of this modelling approach.

Advanced Vehicle Simulator (Advisor) on the other hand was found accurate enough for analysing the issues addressed in this study. More detailed information on the models that have been developed for carrying out the simulations mentioned in this section is provided in Appendix D together with a thorough validation of their results.

Provided that vehicle mass, C_w, FA[7] and engine map are supplied together with some other technical characteristics such as gear ratios, wheel diameter and engine power, Advisor can calculate the engine operating points throughout a driving cycle and therefore efficiency and fuel consumption. Through this procedure Advisor produces fuel consumption results that are very close to experimental measurements. The general performance of Advisor as a modelling tool for fuel consumption has been thoroughly tested and proven reliable, (see Appendix D and [Fontaras, 2004]). Hence, Advisor can be employed to examine how the vehicle's performance is affected by the variation of certain parameters such as mass, aerodynamic drag or gearbox ratios.

It should be noted that the assumption that CO_2-emissions are directly proportional to the fuel consumption of the vehicle was adopted. The ratio of $mCO_2/mfuel$ is equal to 3.17 for ideal combustion of a hydrocarbon of the form $(CH_{1.86})_x$ - according to 70/220/EEC -, which is an average value for diesel fuel - 86% b.w. C, 14% b.w. H2 -. This value was used for transforming the consumed fuel mass data to CO_2 mass throughout the analysis presented in this study. This value doesn't take into account CO and HC generation inside the engine, which in the case of

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[7] Frontal area (FA) and design (factor C_w) have always a combined result on fuel consumption thus from now on we will refer to the product C_w*FA as aerodynamic factor

diesel engines is not significant. Considering that N1s are equipped mostly with diesel engines the deviation of the calculated CO_2-emissions is estimated to be in the range of 1%.

4.2 CO_2-emission predictions using the model

As it will be shown in the following paragraphs, several vehicles were simulated with Advisor. Some of them were also measured on a chassis dyno in order to create a baseline of comparison between modelled and measured fuel consumption. The N1 market share of these N1 vehicle models (all variants) represents the 29.8% of the total 2002 new registrations, indicating that an adequately representative part of the fleet was studied. Table 4-1 shows a short outline of the vehicles that were tested and simulated for this study.

Table 4-1: Measured - simulated vehicles and their N1 market share in 2002

Vehicle	Measured	Simulated	Market Share
VW Golf	Yes	Yes	0.05%
Citroen Berlingo	Yes	Yes[8]	5.1%
Iveco Daily	Yes	Yes	3.3%
Peugeot Boxer	Yes	Yes	2.2%
Ford Transit	Yes	No	5.6%
VW Transporter	No	Yes	3.5%
VW Caddy	No	Yes	1.2%
Peugeot Partner	No	Yes	4.5%
Fiat Ducato	No	Yes	4.4%

More specifically, engine maps were acquired of a Volkswagen 1.9 TDi engine which is used in some versions of VW Transporter, a PSA 2.2 HDi engine scaled down to match the 2.0 HDi of the same engine family used in Peugeot Boxer variants and an Iveco 2.8 8140 Common Rail engine used in Iveco Daily variants as well as in some variants of Peugeot Boxer, Citroen Jumper and Fiat Ducato. These maps were imported in Advisor and used for simulating several different vehicles. Initially, vehicles carrying those engines were measured in the framework of this project and then were simulated in order to obtain a picture of the model's operation and accuracy. Then KBA data regarding the fuel consumption of certain vehicles equipped with these engines were used to run additional simulations in order to validate the modelling procedure.

4.2.1 Vehicles containing engines type approved according to 88/77/EEC

Council Directive 88/77/EEC as it was amended by 2001/27/EC and 1999/96/EC establishes type approval for diesel engines as separate technical units. This test procedure consists of measurements of engine emissions and fuel consumption in specified points in the engine operational field. This procedure, also known as ESC test cycle, is presented in Appendix H.

Through this procedure, a specific fuel consumption engine map can be obtained and be used by Advisor or other similar software for modelling the vehicle performance over a driving cycle and predicting its fuel consumption and CO_2-emissions. However the engine maps derived on 13 points are not detailed and therefore affect the accuracy of the model's predictions.

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[8] Citroen Berlingo was simulated equipped with a different engine than the one used in the measurement therefore no direct comparison between the two results could be made

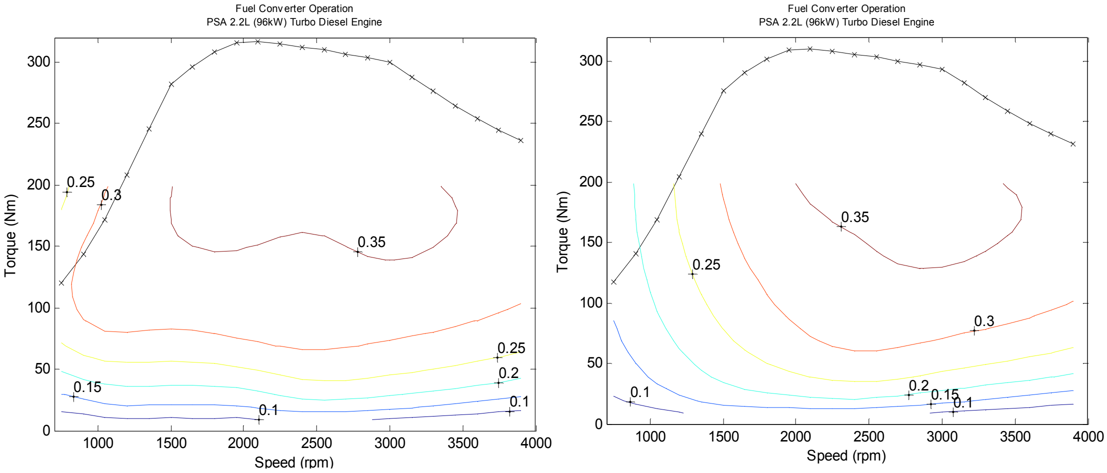

Figure 4-1: Full engine map (left) and 13 point map according to 88/77/EEC (right)

Figure 4-1 gives a first picture of how a 13 point based engine map (right) differs from a full engine map (left). These engine maps were created by measurements conducted in LAT on a PSA 2.2HDi engine following the 88/77/ECE for acquiring 13 point and measuring 8 more points at lower engine speeds for creating a full map. It is clear that the 13 point based map is the same as the full map at engine speeds over 2200 rpm, while at lower speeds it is rather inaccurate. This is because the 13-ESC modes were established considering engines of larger capacity used in Heavy-Duty vehicles under real driving conditions. These engines tend to operate at higher engine speed and torque values (middle and right side of the maps). However, in the NEDC – especially in the UDC part – the engine operation is concentrated at the middle and left part of the maps (lower engine speeds), where the resolution of 88/77/EEC is not sufficient. This is more clearly depicted in Figure 4-2 where the operational points of a Peugeot Boxer are shown for UDC and Artemis Road (CADC-Road) cycles. In both cases the main field of operation of the engine is located in the area which is not covered by 13 mode test with the CADC-Road cycle points covering a much larger area of the map. This driving cycle was chosen in this case as a representative cycle for the operation of an N1 vehicle.

From these observations it is concluded that ESC data points can be used for evaluating the fuel consumption of a vehicle – through modelling procedures – but less accuracy should be expected especially for low speed driving cycles.

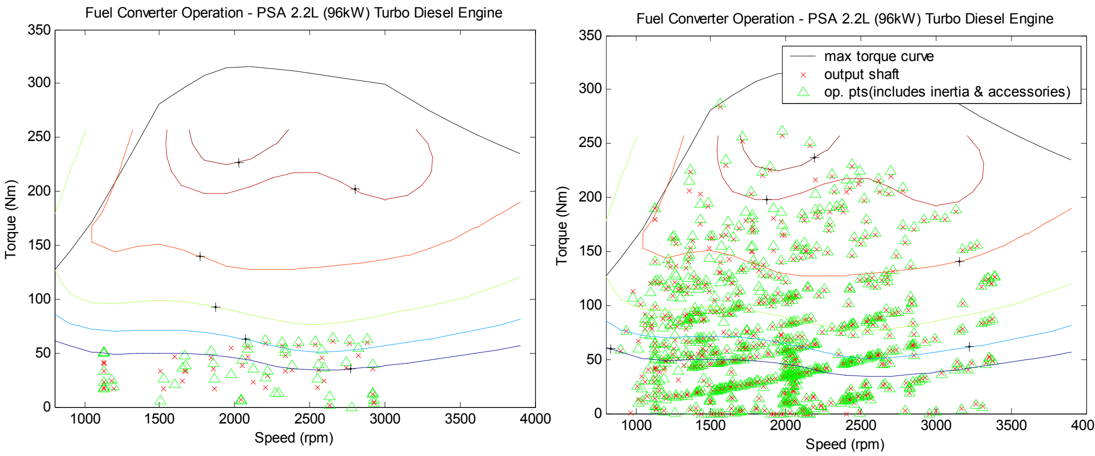

Figure 4-2: Engine operation points over UDC (left) and the Artemis Road cycle (right)

The analysis presented above was validated using real engine data and Advisor. Three different engine maps were available for this study, the maps of a VW 1.9 TDi and of a PSA 2.2 HDi measured by LAT and a map of an Iveco 8140.43 2.8 engine provided by Iveco.

All these engines are installed in N1 vehicles that were measured within this project. The full engine maps were created using more than 13 points. In order to evaluate the performance of a model when using a 13 point map according to 88/77/EEC; new maps were created using only the legislated 13 points. These 13-point based maps were then used by Advisor for running the same simulations as with the full maps. The results of these simulations are presented in Figure 4-3 to Figure 4-5. On the x axis of these figures the driving cycle is mentioned together with two different numbers; the first stands for the inertia class value of the vehicle and the second for the equivalent inertia class air drag values that were used. Note that the deviation from the measured values for the two modelling approaches is always greater in the case of the UDC part. This observation confirms the fact mentioned before that the ESC maps are less accurate when simulating low velocity cycles than when simulating high velocity cycles.

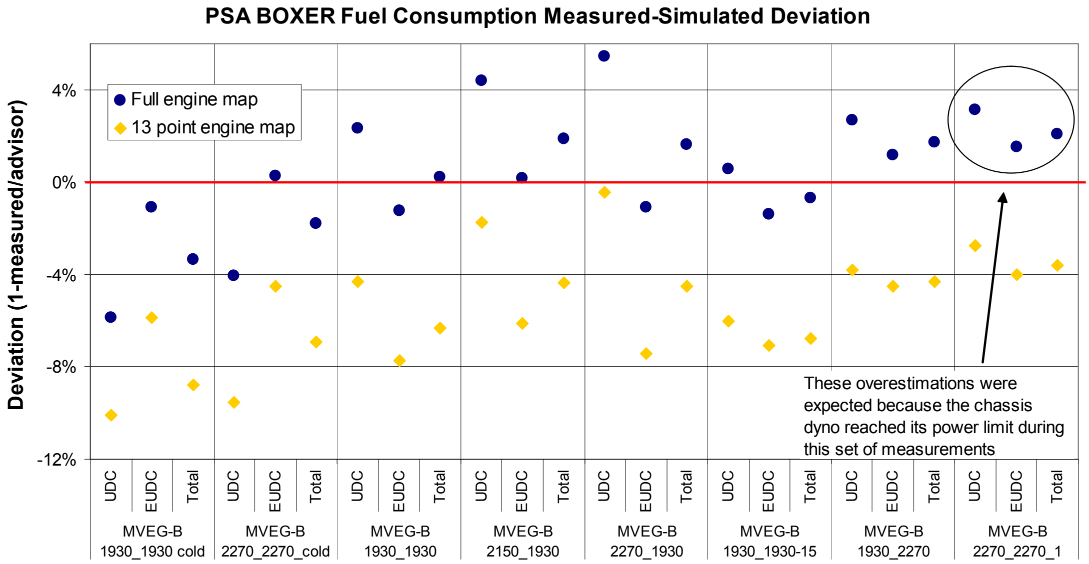

Figure 4-3: Peugeot Boxer simulations deviation from measurements

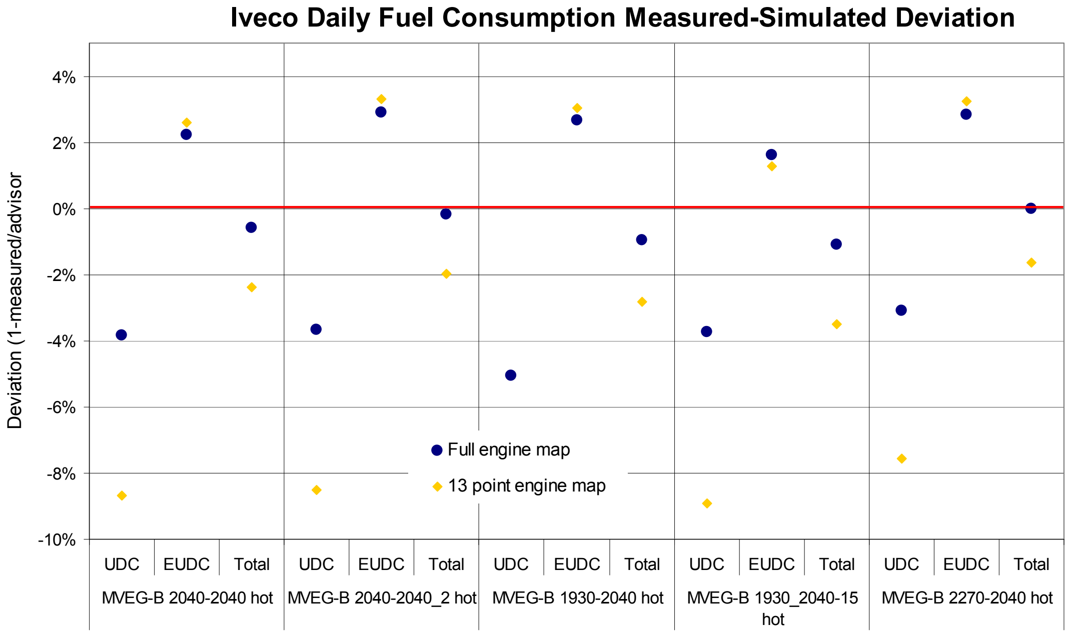

Figure 4-4: Iveco Daily simulations deviation from measurements

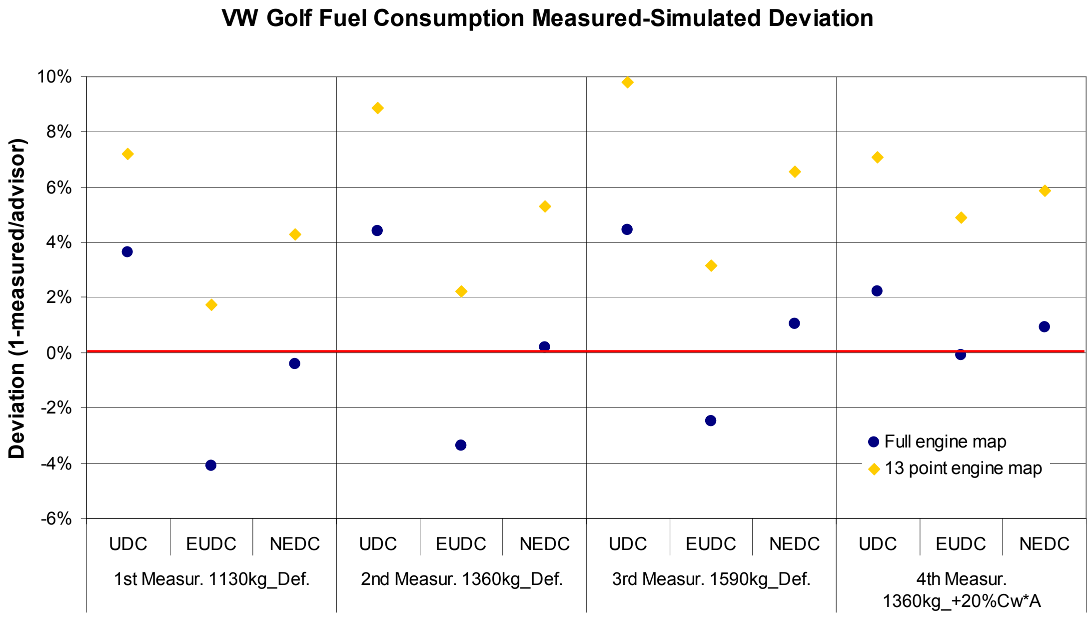

Figure 4-5: VW Golf simulations deviation from measurements

From the figures it becomes clear that the results of the 13-point based engine maps simulations follow the same patterns as the full engine map simulations but with lower accuracy compared to the measured fuel consumption. The maximum deviation of the full map model is ±4% for all parts of the NEDC while in the case of the reduced points map goes up to ±8%. Regarding only NEDC, the simulations made with the complete engine map have a deviation less than ±2% while those made with the reduced points maps are show a deviation of ±6%. Provided that this 6% deviation is accepted a type approval procedure could be established on this basis.

In addition to the above, the following point should be emphasised. Directive 1999/96/EC introduces the concept of engine families. Each engine family consists of a so-called parent engine and other engines that have several characteristics in common. This concept is very similar to the one of vehicle families introduced in Directive 2004/3/EC for N1 vehicles. In the case of Peugeot Boxer the engine installed in the vehicle was a 2.0 PSA HDi while the engine map used for modelling was a 2.2 PSA HDi that belongs to the same engine family. In order to meet the power output criteria of the vehicle's engine; the used engine map was suitably scaled down before running the simulations. It appears that this procedure can be applied with good accuracy. Thus for modelling vehicles with engines of the same family with Advisor, only one engine map that belongs to a certain vehicle family is necessary.

4.2.2 *Completed multi-stage vehicles*

As mentioned in paragraph 2.4, one of the questions investigated in this study is whether granting a multi-stage vehicle type approval based solely on the type approval of the engine is technically acceptable. The answer to this question is also related to the analysis presented in the previous section regarding type approving based on data retrieved from ESC engine tests.

Currently, vehicle fuel consumption is being measured according to the procedure established in Directive 80/1268/EEC by using the procedure described in Directive 70/220/EEC (as amended by Directive 96/44/EC). The latter Directive allows two options to choose from on how the chassis dynamometer will simulate the vehicle driving resistances. The first option is to use specific data for rolling and aerodynamic resistances provided by the manufacturer – coast down data. The second option is to use predefined values for the resistances of the vehicle from a table introduced in section 3.2.2 of the Directive (see Appendix F). This table provides the necessary values for simulating vehicle resistances as function of vehicle's equivalent inertia. The latter type approval option is rather common for N1 vehicles especially for vehicles belonging to classes II and III. It is obvious that with this second option, type approval is only linked to vehicle's engine, transmission ratios and mass regardless of all other characteristics. This procedure is based on the assumption that two substantially different vehicles equipped with the same engine, having the same gear ratios and belonging to the same inertia class should have more or less the same fuel consumption and CO_2- emissions.

In order to make this conclusion more comprehensible; a simple example will be used. Let's assume that a manufacturer produces a certain vehicle chassis equipped with a specific engine and gearbox. This incomplete chassis (base vehicle) can be used by the manufacturer or other assemblers in order to build vehicles of different load carrying capacity, mass and aerodynamic drag. If it was possible to measure the fuel consumption of all completed variants of this parent chassis using the table values provided in Directive 96/44/EC, all the vehicles belonging to the same inertia class would have almost the same fuel consumption. In other words: a complete multistage vehicle is expected to have fuel consumption and CO_2-emissions similar to those of any other regular vehicle of the same inertia class which carries the same engine and has the same gear ratios when table values of 96/44/EC are used for the measurement.

It becomes evident that it is technically acceptable to grant type approval to a certain chassis-engine-gearbox combination by estimating accurately the weight of the complete vehicle. This can be done by adopting the fuel consumption and CO_2-emissions of another vehicle that is equipped with the same engine and gearbox, has the same inertia class and was type approved using 96/44/EC table values. If such an approach for granting type approval is adopted, a small deviation between the predicted and the real value of the weight of the final vehicle may be allowed.

Table 4-2 shows the deviation of fuel consumption for simulated vehicles when their inertia class changes. A mass shift of 340 kg (three inertia classes) towards heavier inertia results in an average increase of fuel consumption by 4.6%. In case the exact estimation of the inertia class of the complete vehicle is not possible, this factor can be taken into account for adjusting the final type approval fuel consumption value. Since this relation is linear (will be presented analytically in section 4.2.3) a 1.5% increase in fuel consumption could be assumed for each inertia class shift.

Table 4-2: Effect of inertia class change in fuel consumption of simulated vehicles

Vehicle	Cycle	Inertia (kg)	Air Drag	FC (lt/100km)	Dev. FC
Boxer	MVEG-B cold	1930	1930 equiv.	9.67	4.3%
		2270	2270 equiv.	10.10	
	MVEG-B Hot	1930	1930 equiv.	9.38	4.5%
		2270	2270 equiv.	9.82	
Daily	MVEG-B cold	1930	1930 equiv.	9.74	4.4%
		2270	2270 equiv.	10.19	
	MVEG-B Hot	1930	1930 equiv.	9.24	4.6%
		2270	2270 equiv.	9.69	
Ducato	MVEG-B cold	1930	1930 equiv.	10.04	4.7%
		2270	2270 equiv.	10.54	
	MVEG-B Hot	1930	1930 equiv.	9.61	4.9%
		2270	2270 equiv.	10.11	
Transporter	MVEG-B cold	1930	1930 equiv.	7.44	4.9%
		2270	2270 equiv.	7.82	
	MVEG-B Hot	1930	1930 equiv.	7.14	5.0%
		2270	2270 equiv.	7.52	

Finally, it is important to remember that the factor that affects the fuel consumption is transmission ratios and not only the gearbox. This means that the overall transmission ratios including the gearbox ratios, wheel diameters and the final drive should be within a rather tight range. Additionally, in cases of differentiation of the mass or transmission ratios it is possible to use modelling tools for estimating the fuel consumption that a completed multi-stage vehicle will have. The issue of whether ESC type approval emissions values can be used for accurately predicting fuel consumption of a vehicle and granting type approval has been addressed in section 4.2.1.

4.2.3 *Family concept*

A detailed description of the family concept and the type approval extension procedure that has been introduced for N1 vehicles in Directive 2004/3/EC, is given in paragraph 2.2; the overview of the extension of type approval that applies to N1s is visualised in Figure 2-2.

From this Figure, it is clear that in the way family concept is currently established, it groups the member vehicles in comparison to the members that are heaviest and have the greatest frontal area (FA). This means that all other family members with the same gear ratios have by definition lower fuel consumption. But since they have lower fuel consumption and emissions the logical question arises: *why a limit of 220 kg and 15% air drag has been set to define the family members?* Furthermore it is not possible to compare the two alternative type approval extensions (6% limit and the family concept). The only factor that raises fuel consumption and that can be compared to the 6% rule is the change of the gear ratios but at the same time changes in mass and frontal area may act as reduction factors. It is therefore difficult to evaluate the correlation between the vehicle families and the 6% derogation approach as well as the criteria established in 11.2.1 of Directive 2004/3/EC. In order to address these issues, an analysis based on a different approach was carried out and is presented in this section. More specifically, the path followed for this analysis is as follows:

- Initially each factor (mass, air drag and gear ratios) was separately examined in order to acquire a clear view on how changes in these factors affect the fuel consumption. For this purpose experimental and simulation data were used.
- The effect of the combination of these factors was studied in order to investigate their combined result.
- The family concept was evaluated using the results of the analysis.

In the framework of this study, the fuel consumption and CO_2-emissions of certain vehicles were measured not only under their basic characteristics but also for different mass and aerodynamic drag values. This experimental data were used for estimating the effect of the change of the vehicle mass to the fuel consumption. Figure 4-6 indicates the link between mass and fuel consumption.

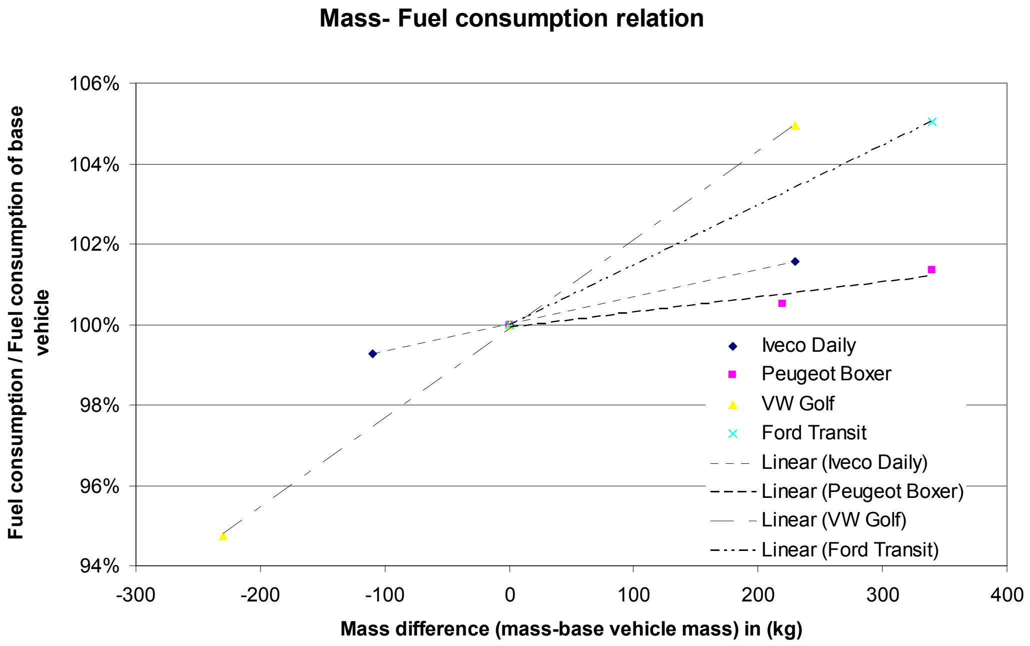

Figure 4-6: Effect of mass change on the fuel consumption of tested vehicles

The figure shows that the relation between the changes of the vehicle's mass and those of the fuel consumption of the vehicle are described with a linear equation quite accurately in the ± 220 kg interval introduced by the family concept.

Figure 4-7 is quite similar to Figure 4-6. This time the effect of aerodynamic drag is being analysed. Because of limitations in the number of measurements that could be conducted and technical restrictions imposed by the chassis dynamometer's output limit, fewer points were acquired in this analysis (2 per vehicle)[9]. The assumption that for the ± 15 % interval introduced by the family concept the relation between fuel consumption and aerodynamic drag is linear, was adopted.

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[9] Actually for Peugeot Boxer measurements with three different air-drag values were conducted but the one was excluded from this analysis because of the fact that the chassis dyno reached its power output limit throughout the measurement.

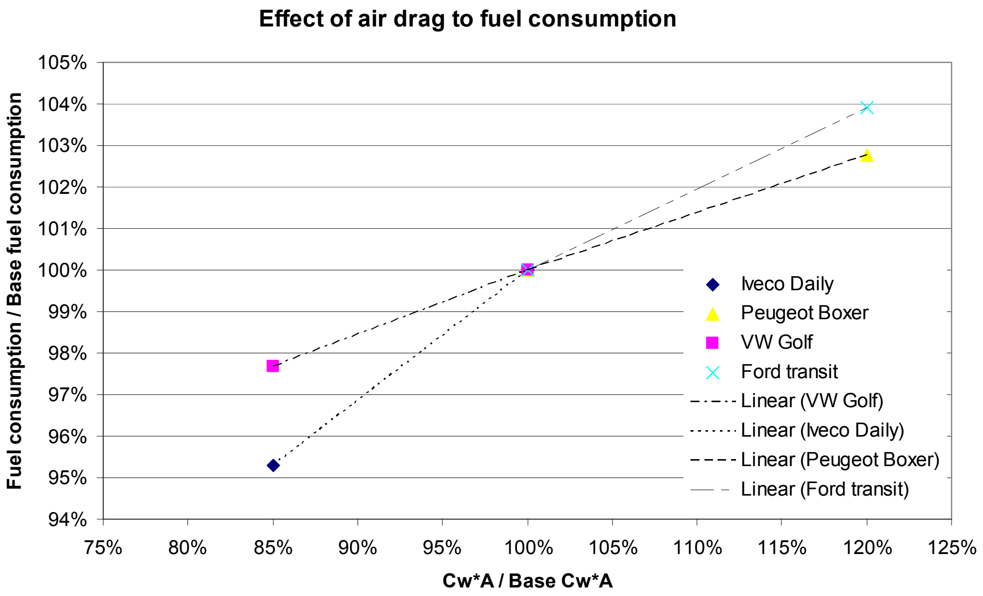

*Figure 4-7: Effect of air drag change (C_w*A) on the fuel consumption of the measured vehicles*

Summarising the results of the experimental data presented above, it is concluded that in the case of heavier vehicles (class III) the 220 kg increase mentioned in the Directive causes a rise in the fuel consumption not more than 2% from that of the base vehicle. For the case of class I vehicles the rise is higher reaching 5%. Similarly a 15% increase in a vehicle's aerodynamic drag appears to cause a rise in the fuel consumption between 2.5% and 4.5% irrespective of the class of the vehicle. It appears that based on the above, the 6% limit is equivalent to the family concept for heavy vehicles (class III) and stricter in the case of lighter vehicles (class I).

Advisor was used to simulate vehicles with different loads and aerodynamic drags. In these virtual experiments, the influence of mass and aerodynamic drag factors was studied. Figure 4-8 and Figure 4-9 show the results of these simulations. In both cases it is clear that within the mass and air drag intervals specified in the Directive – the area between the red lines – the linearity's discussed above are verified. Additionally, in this case is also shown that the heavier a vehicle is the less its fuel consumption is affected by changes in its mass (e.g. by comparing the trendline of the Iveco Daily (heavy) with the trendline of the VW Golf).

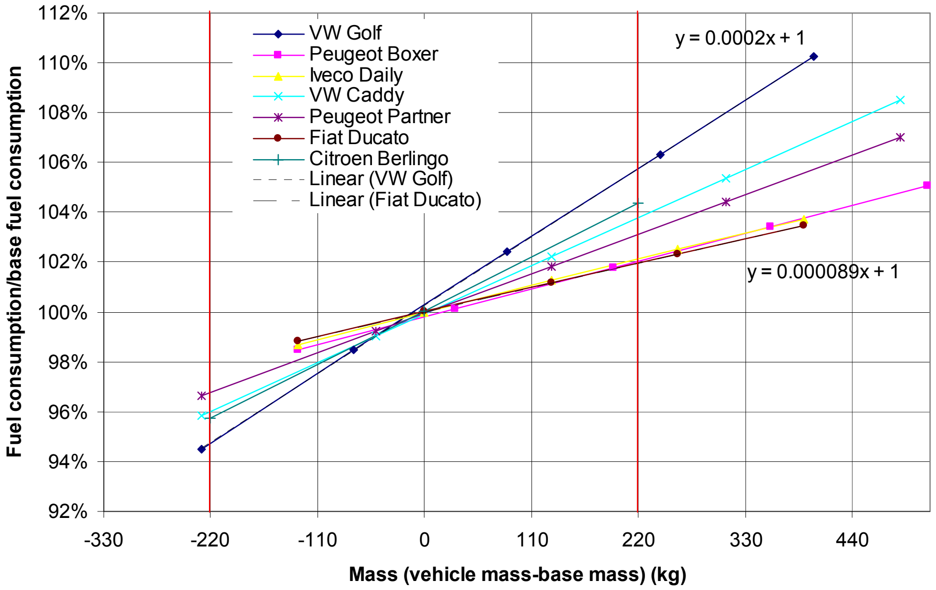

Figure 4-8: Calculated fuel consumption for different masses of simulated vehicles

Evaluating Figure 4-9 shows another interesting observation. Apart from the linear relation between the two factors, it seems that in the area of interest all vehicles respond to an air drag change with the same proportional change of fuel consumption. This fact is also implied in Figure 4-7 by the trend lines of VW Golf and Peugeot Boxer. Therefore, it is assumed that a single linear equation can link the change of C_w*FA product of all vehicles to the change in their fuel consumption. Derived from Advisor's data this equation is:

$$Cf = 0.228 \cdot x + 0.772$$

Where *Cf* is the change in a vehicle's fuel consumption in % when C_w*FA is changed by x%. This assumption means that a rise of 15% in a vehicle's frontal area causes an increase of approximately 3.5% in the fuel consumption of the vehicle (0.228*1.15+0.772=1.035).

It should be kept in mind that this analysis is based solely on the NEDC driving cycle. This means that the conclusions presented above are valid only under these conditions and cannot be extrapolated to other driving conditions.

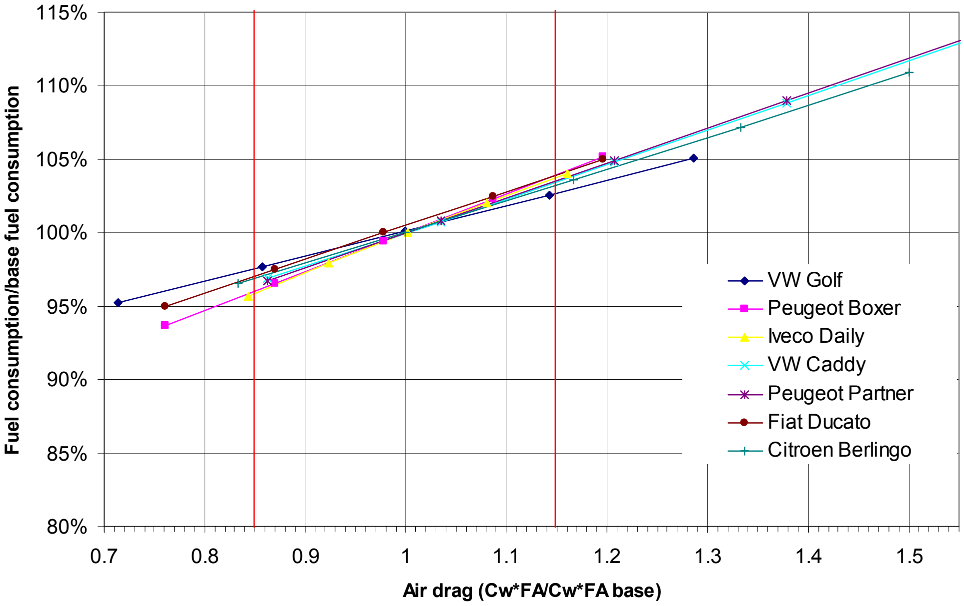

Figure 4-9: Calculated fuel consumption for different air drag values of simulated vehicles

The analysis discussed above was also carried out for the differentiation in the gear ratios. Since experimental data is lacking, the problem was approached through simulations by using Advisor. Keeping mass and aerodynamic drag constant, three simulations were run for each vehicle, one with normal gear ratios, one with overall gear ratios 8% higher and one with 8% lower. The results are shown in Figure 4-10

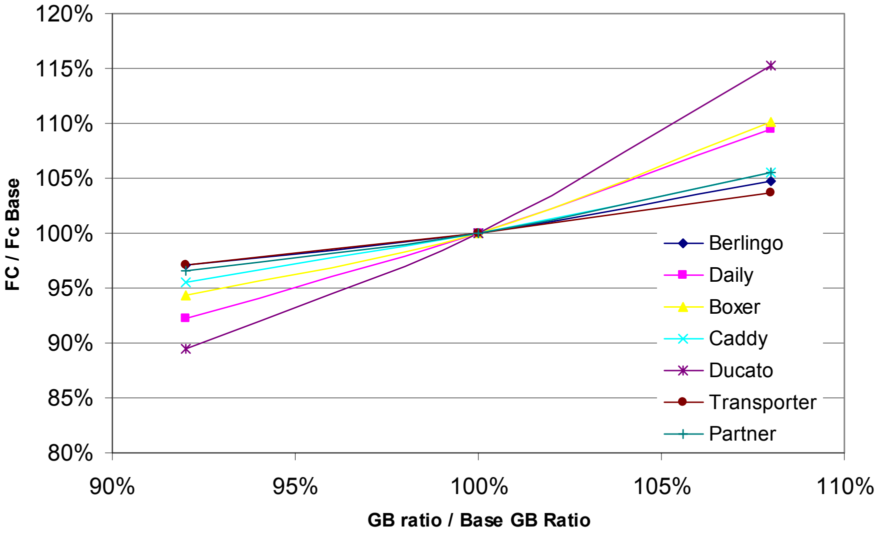

Figure 4-10: Effect of gearbox ratios change in fuel consumption

From the above data it becomes clear that an 8% increase in the overall gear ratios will result in a 6.8% increase of fuel consumption on average. On the other hand, an equal decrease results in a 5.2% decrease in fuel consumption. It is clear that such changes of the gearbox can affect the fuel consumption more than the changes in mass or air drag, however changes are limited by driveability issues. The relation between fuel consumption and the ratios does not appear to be linear; these values are indicative for the NEDC driving cycle.

As presented in the detailed discussion above, simulations were conducted in order to examine how each family criterion affects fuel consumption separately. Additionally, several runs were performed in order to find out their combined result. The simulation data produced from these runs are summarised in Table 4-3. In this Table, vehicles are divided according to their gear ratios into two groups and then the effect of the other family criteria is presented. Combined results are produced by simulations and are **not** the sum of the effect of the all factors.

Table 4-3: Mass, air drag and gear ratios criteria and their effect on fuel consumption

Model	**Base gear ratios**				**Gear ratios *108%**			
	FC base vehicle (l/100km)	mass +220kg	Air drag 115%	Combined	108% Base (Deviation from base)	mass +220kg	Air drag 115%	Total Combined
Golf	4.82	5.4%	2.6%	8.1%	4.6%	5.4%	2.5%	12.6%
Berlingo	5.87	4.4%	3.5%	8.0%	5.9%	4.4%	3.5%	13.8%
Caddy	5.62	3.3%	3.3%	6.6%	5.0%	3.3%	3.1%	11.4%
Daily	9.38	2.1%	3.7%	5.7%	9.4%	2.2%	4.0%	15.5%
Ducato	9.82	2.1%	3.6%	5.6%	8.5%	2.2%	3.9%	14.4%
Partner	5.90	3.0%	3.4%	6.4%	5.5%	3.0%	3.3%	11.9%
Boxer (2200cc)	9.27	2.6%	4.4%	6.9%	8.6%	2.5%	3.8%	14.8%
Transporter	7.44	2.4%	3.7%	6.3%	3.9%	2.7%	3.9%	10.3%
Boxer (2800cc)	9.49	1.9%	3.4%	5.4%	10.1%	2.0%	3.4%	15.5%
Average	-	3.0%	3.5%	6.5%	6.8%	3.1%	3.5%	13.4%

From the above analysis it is concluded that the family criteria introduced for N1s in 2004/3/EC result in fuel consumption changes that are below 6% for all cases. Furthermore regarding the family concept criteria, it seems that the effect of the gearbox was underestimated and needs to be adjusted (see Table 4-3 for more detail). The effect of the 10% engine power variation was found not to affect the final result especially in the cases of engines of the same engine family. For a summary of the impact of each family criterion as well as their combined result see Table 4-4.

Table 4-4: Effect on fuel consumption of the family criteria as defined in 2004/3/EC

Similar parameters	Class I	Class II	Class III
Transmission overall ratios (no more than 8 % higher than the lowest)	**5%**	**6%**	**8%**
Reference mass (no more than 220 kg lighter than the heaviest)	**-4%**	**-3.%**	**-2.2%**
Frontal area (no more than 15 % smaller than the largest)	**-3.5%**	**-3.5%**	**-3.5%**
Engine power (no more than 10 % less than the highest value)	**0%**	**0%**	**0%**
Overall	**-3%**	**-2%**	**2%**

Before closing the issue of the vehicle family concept, it is necessary to make some useful comments about the way 2004/3/EC establish the families. As it can be seen in Table 4-4 the current definition of vehicle families creates a stricter boundary than the 6% approach. Furthermore, the way it is defined it operates as a lower and not a higher limit in fuel consumption deviations – compared to the ones of the parent vehicle –. In order to make the 6% and family concept equivalent; the comparison of the CO_2-emissions should be done with respect to the less polluting member of the family (mass up to 220 kg **higher** than the lightest and frontal area up to 15% **larger** than the smallest). In that case the effect of each family criterion and their result is presented in Table 4-5.

Table 4-5: Increase of fuel consumption by criterion with respect to the "cleanest" member

	Class I	Class II	Class III
Mass +220kg	4.0%	3.0%	2.2%
Air Drag +15%	3.5%	3.5%	3.5%
Mass+Drag Effect	7.5%	6.5%	5.7%
Transmission Ratios +8%	5.0%	6.0%	8.0%
Overall	12.5%	12.5%	13.7%

From Table 4-5 it is clear that the 8% change limit of transmission ratios should not be applied as it causes significant increase of the fuel consumption. In order to limit the fuel consumption deviation close to 6%, no change in overall transmission ratios should be allowed. It is therefore concluded that in order to make the vehicle family concept more efficient and applicable, its criteria should be redefined. A possible definition could be that members are vehicles which:

- are up to 110 kg for class I and up to 220 kg for classes II and III heavier than the family member tested;
- have up to 15% greater frontal area than the vehicle tested;
- have a different overall transmission ratio than the family member tested due solely to a change in tyre sizes, and
- conform to the identical parameters as already defined in 2004/3/EC.

With this definition, vehicle family is equal to the 6% approach. If the lower limit concept has to be preserved for vehicle families, the same limits should be established but with respect to the most fuel consuming member. Finally in the case of vehicle families as for completed multi-stage ones, modelling tools can provide fast, accurate and reliable solutions.

4.2.4 *Improvements for current type approval legislation*

Evaluation of the 70/220/EEC type approval table values

As discussed, legislation provides the possibility of type approval using table values, which depend only on the mass of the vehicle. The research made on multi-stage vehicles indicated that there are possible inconveniences in this type approval procedure. With the following analysis it will be attempted to evaluate the efficiency of this type approval method and figure out if the legislation needs to be revised.

Each N1 model might have several different variants that can be significantly different with respect to their size and carrying capacity. However, it is possible that two variants with different size can belong to the same inertia class. For example, let's examine the case of Peugeot boxer [Peugeot,2004]. Peugeot Boxer panel van is sold in 3 different wheelbase sizes and each one of them has different variants; the medium wheelbase version vehicles are divided into standard roof and high roof vehicles. The 330 standard roof and the 330 high roof variants carrying a 2.0l or 2.2l HDi engine all appear to belong to the same inertia class (1930kg estimated). All variants appear to have the same "width between wheel arches" according to the manufacturer (1388mm). The high roof version is 320mm higher than the standard one, which means that it also has 0.416 m2 larger frontal area (16-20% increase). Such a differentiation in the frontal area is expected to increase fuel consumption by approximately 5% (see section 4.2.3). In case these two vehicles are granted type approval under the same inertia class then this increase in frontal area would not affect the fuel consumption of the high roof variants. There are many similar examples amongst N1 vehicles.

Additionally it should be mentioned that the table values as mentioned in Directive 96/44/EC were found being “beneficial” for the vehicle in terms of fuel consumption and CO_2-emissions. A clear example of this is presented in Figure 4-11 chassis dyno power curves from coast down times are compared with those produced by the relevant table values.

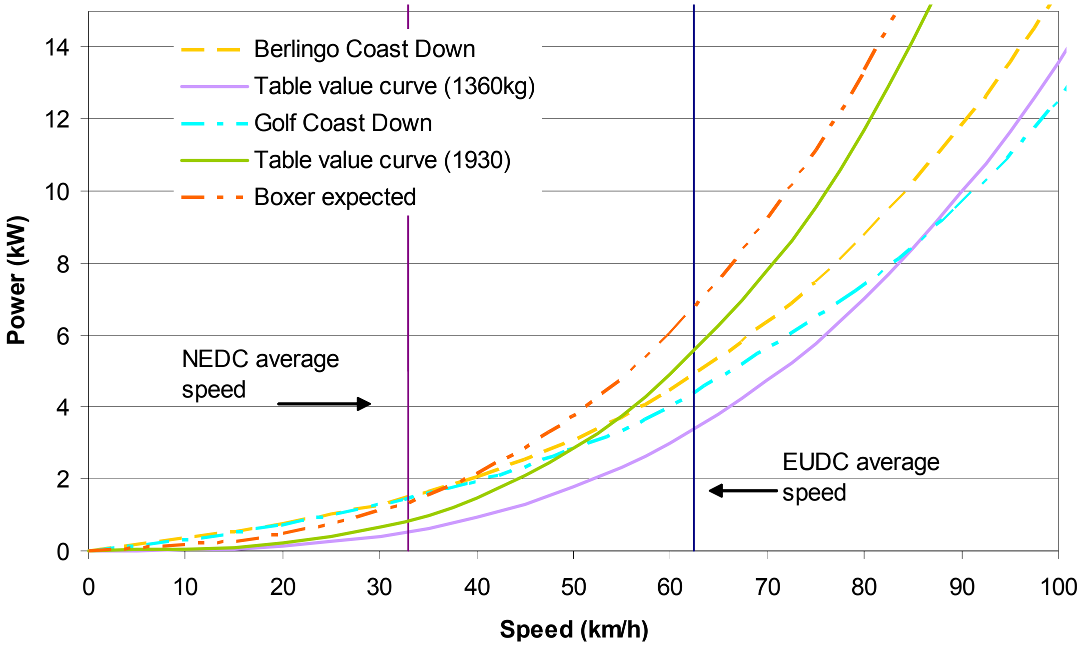

Figure 4-11: Chassis-dyno power curves comparison

Among the vehicles tested for this study was a VW Golf (not an N1) and a Citroën Berlingo (N1 version). Manufacturers have provided coast down times for both vehicles, which result in the corresponding power curves provided in Figure 4-11. Both Berlingo and Golf belong to the same inertia class (1360 kg) for which the power curve - created with the table values of 96/44/EC - is also presented. It is evident that the table value curve has lower resistances than those derived from the coast down times.

In addition two curves representing the resistances of a Peugeot Boxer are presented. The first one is based on the table values of 96/44/EE and the second one is the curve that occurs if the aerodynamic drag of the vehicle is increased by 15% (C_w*FA=1.85) compared to the table value (C_w*FA=1.62) and its rolling resistances are taken as half of those of Citroen Berlingo. This second curve is indicative and represents an expected curve, as it would occur if more realistic values of C_w, FA and rolling resistance coefficients were used. In absolute numbers, a quantification of the results of this analysis is shown in Table 4-6. According to this data, the deviation between a measurement based on coast down data and one based on the Directive predefined values can be 8% or higher.

Table 4-6: Comparison of simulations using coast down - table values characteristics

	FC UDC (l/100km)	**FC EUDC (l/100km)**	**FC NEDC (l/100km)**
Golf Coast Down	6.10	4.09	4.82
Golf Table values	5.83	4.00	4.67
Deviation	**4.5%**	**2.1%**	**3.2%**
Berlingo Coast Down	6.93	5.27	5.89
Berlingo Table values.	6.42	4.84	5.42
Deviation	**7.3%**	**8.1%**	**7.8%**
Boxer estimate	10.92	9.37	9.93
Boxer Table values	10.60	8.51	9.27
Deviation	**2.9%**	**9.2%**	**6.7%**

As presented above, granting type approval by using predefined values of Directive 96/44/EC can allow miscalculations of the fuel consumption and CO_2-emissions of a significant number of N1 vehicles. This is an important fact that should be taken into account by the officials for two reasons:

- The CO_2-emissions and fuel consumption data of N1 vehicles are retrieved from type approval certificates and thus will provide an inaccurate picture with regard to what happens in reality, in fact which can lead to false estimations of CO_2-emissions
- This distorted picture of the vehicle performance does not allow the consumer to make an unbiased choice of vehicle and cancels the competitive advantage that certain more efficient and better designed models of N1 vehicles might have

Because of these reasons it is recommended to revise the table value based type approval procedure introduced by 96/44/EC.

4.2.5 *Real-world CO_2-emissions*

All the results presented above refer to legislative driving cycles (NEDC) and empty vehicles. However, real driving conditions are different from the ones used for type approving. The main differences are the driving patterns and the weight carried by the vehicle. In the following paragraphs an attempt is made to compare these two influences and estimate how they affect the fuel consumption of the vehicles.

4.2.5.1 *Measurements on real-world driving cycles*

The CO_2-emissions used for the calculations are measured according to the type approval procedure (empty vehicle and artificial driving cycle). Furthermore, the distribution on parts that are representative for Urban, Rural and Motorway driving is fixed. When applying these emission factors in studies to estimate total CO_2-emissions from the N1 fleet, the actual situation that appears in real-life could be under- or overestimated.

To address the issue of CO_2-emissions representative for real-world usage, the measurement programme was extended in order to measure CO_2-emissions on real-world driving cycles. The objective to add these measurements is to verify whether average factors can be derived to convert CO_2-emissions measured on the type approval cycle to real-world representative CO_2-emissions, and – if that is feasible – to give an indication of these factors.

Representative driving cycles for N1 vehicles have been developed by Inrets [Joumard,2001]. From the comprehensive set of available driving cycles – which have been developed for Class I to Class III, different loads and road types – a selection based on the average speed of the driving cycles and additional load to be carried was made. Four driving cycles representative for Urban driving were selected based on the requirement that the average speed is of an equivalent level as the average speed of the UDC. In addition, two Rural driving cycles are selected that have an average speed close to the one of the EUDC.

The measurements were conducted on the Iveco Daily and the Ford Transit Connect on 6 real-world driving cycles. In addition, results from 4 other N1 vehicles were collected from measurements conducted within the Artemis project. The results are expressed relative to the emissions produced on the cold NEDC driving cycle and plotted against the average speed of the driving cycle. The results are visualised in Figure 4-12.

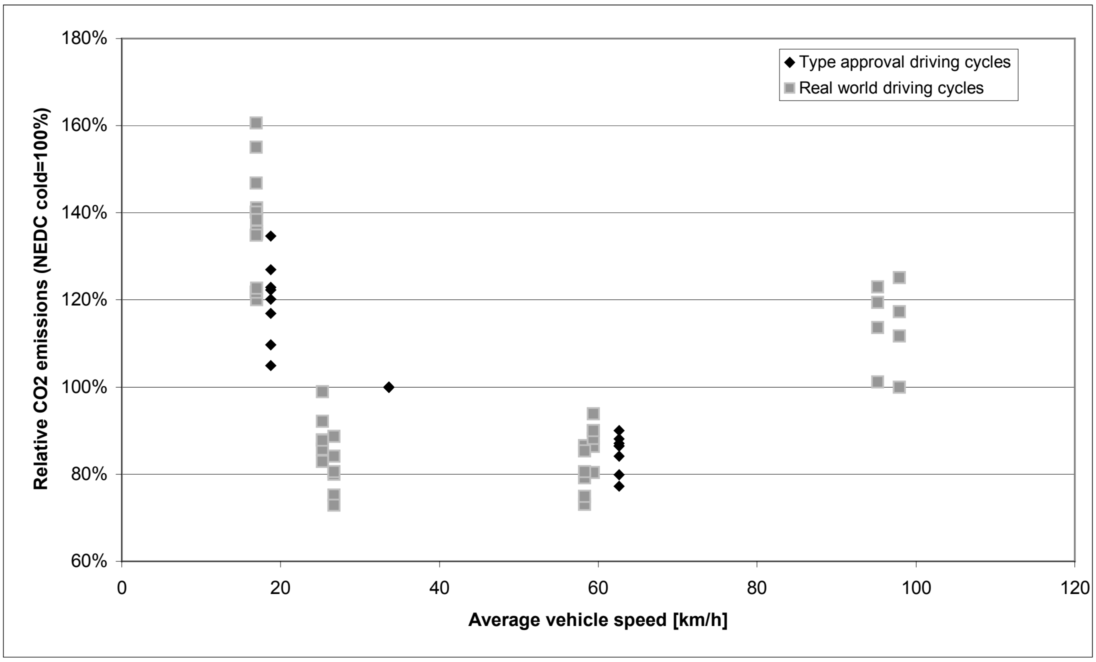

Figure 4-12: Relative emission results on real-world and type approval driving cycles

The results show that rather high differences can occur, especially on the driving cycles that have a low average speed where the CO_2 emissions can be up to 60% higher than the one on the NEDC driving cycle. For the driving cycles that are representative for Rural conditions, the CO_2-emissions are lower than the one on the NEDC driving cycle and the relative differences are also much lower (up to 75%). The CO_2 emissions on the Motorway driving cycles are again higher going up to a factor of 125%.

However, one should take into account that the CO_2-emissions are expressed in unit g/km. The number of kilometres driven in an Urban area may be much lower than the kilometres driven in Rural and Motorway conditions resulting in an average value that could be the same or even lower than measured on the NEDC.

Before this assumption makes sense, additional insight is required about the kilometres that are driven on different road types. At the moment that data on this issue is available, more relevant conclusions about the probably under- or overestimation by using type approval values on estimating the CO_2 emissions that occur while driving in real-life, can be derived.

4.2.5.2 Laden N1 vehicles in real-use

In the paragraph regarding the family concept (4.2.3), experimental and simulated data were presented showing that the mass of the vehicle affects its fuel consumption and thus the CO_2-emissions. As discussed, there appears to be a linear relation between the change in vehicle's mass and the change in its fuel consumption. For passenger cars, it is easy to assign a given mass of load for each vehicle – e.g. about 2-4 passengers of approximately 75 kg – whereas in N1 it is difficult to determine additional payload as these cars are predominately used for carrying various types of goods. Moreover, N1s include a large range of vehicles with different carrying capacities used for different purposes. In order to provide a simple method for estimating the effect of the vehicle's load to its fuel consumption, an analysis based on the load percentage under which these vehicles are operated was performed.

In emissions calculation tools like COPERT it is common to assume a single percentage of load during the operation of a vehicle [Ntziachristos, 2000]. In the case of COPERT, the CO_2-emission and fuel consumption factors used for Heavy Duty vehicles are representative only for a partially loaded vehicle, which means that a load factor of 50 % is taken into account. Due to this, a formula is introduced for calculating emissions under different loading conditions. The approach is applied only for Heavy Duty vehicles, since in this vehicle category a high load fluctuation is expected, depending on the different vehicle use. For smaller vehicles, a load factor of 50 % seems to be in accordance with the actual fleet average. This factor of 50% load for the operating conditions was adopted for the case of N1 vehicles.

Having the loading conditions of the vehicles, it is necessary to examine how load affects fuel consumption. As presented in the vehicle family paragraph (4.2.3), a linear relation between mass and fuel consumption was observed in experimental and simulated data. A similar linear relation is also expected between the load percentage of each vehicle and its fuel consumption. Figure 4-13 shows the effect of the load of the vehicle as it was recorded in the measurements conducted for this project. These results show that not only the relation is linear but also that different vehicles have similar behaviour under the same loading conditions.

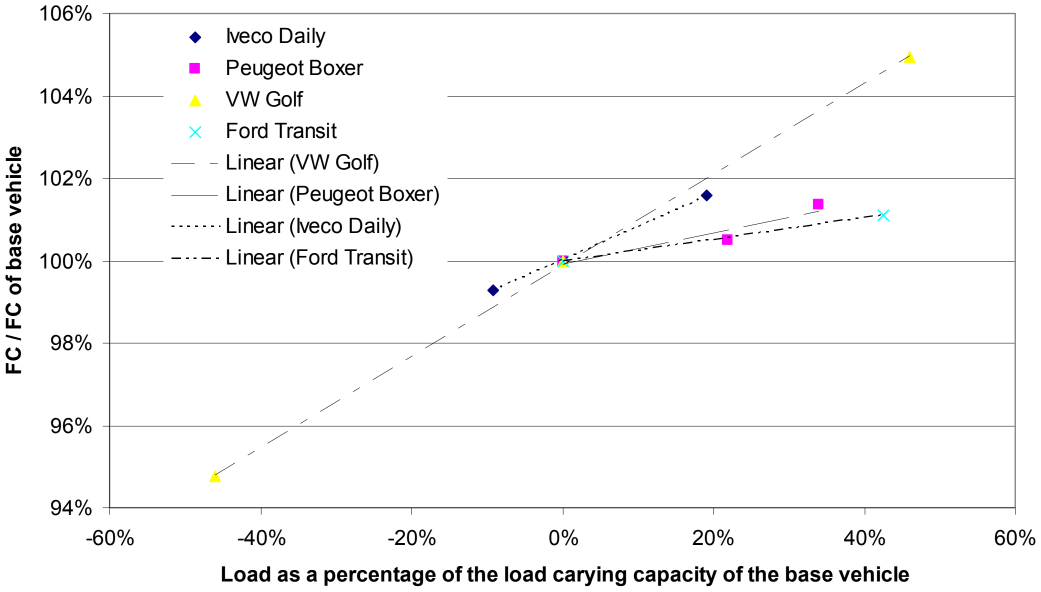

Figure 4-13: Effect of mass change as a fraction of the load capacity to the fuel consumption

Advisor has shown that it is able to predict fuel consumption for different vehicle masses with good accuracy. Therefore, it can be used to predict fuel consumption for different load factors. A number of runs were performed for the simulated vehicles each time with different load factor. The vehicles represent all three N1 classes and the results can be derived from Figure 4-14.

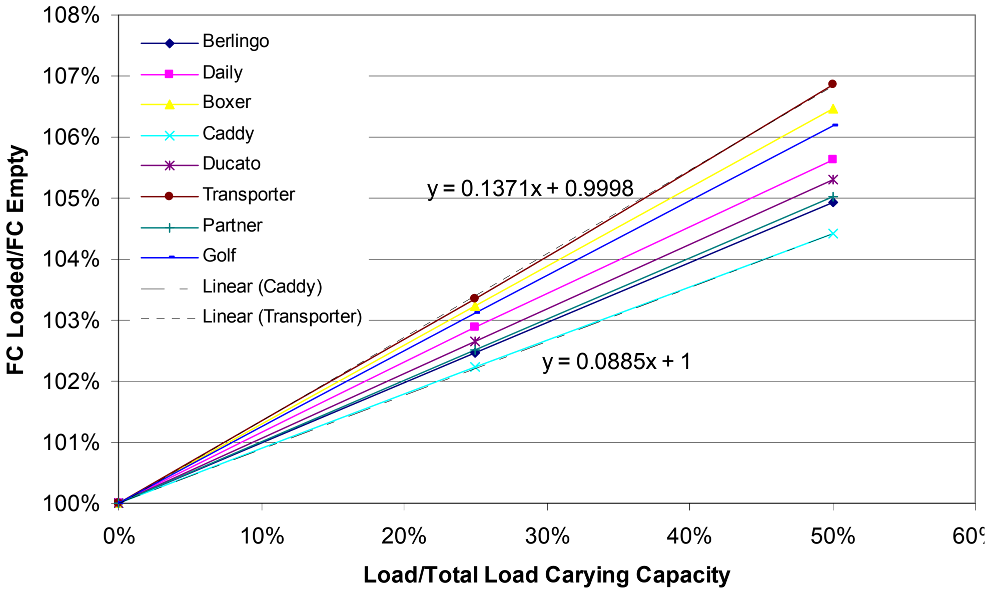

Figure 4-14: Change in the fuel consumption as a function of load change (Advisor)

Figure 4-14 shows that an increase of the vehicle's mass equal to 50% of its load carrying capacity results in an average increase of the fuel consumption of about 5.6% with a scatter not greater than ± 1.2%. Since this 50% load condition is adopted for this study, we could also adopt this 5.6% increase in the fuel consumption and CO_2-emissions.

5 Technological options to reduce CO_2-emissions of N1 vehicles

In this section, a brief survey of technologies for CO_2-emission reduction for N1 vehicles has been undertaken. As the RAND study has already given an extensive overview of individual technology options, the focus here will be on CO_2 reduction potentials and costs of various technologies and technology packages. The basic approach has been adopted from the M1 CO_2 study [Ten Brink et al, 2004]. This section will focus on both gasoline and diesel N1 vehicles.

It is clear that certain technologies and measures will in reality be applied together. There are certain complementary technologies and certain cases where the choice of one technology will lead to the immediate exclusion of the potential use of another technology.

The first stage of the work is to identify the technology baseline of the three classes of N1 vehicles. In other words three typical 2002 models are identified to which technology packages, the main building blocks for the development of the retail price-curves, can be applied. The 2002 baseline technologies for the baseline N1 vehicles have been identified are as follows:

Table 5-1: 2002 baseline technologies

	Class I, Gasoline	**Class II, Gasoline**	**Class III, Gasoline**	**Class I, Diesel**	**Class II, Diesel**	**Class III, Diesel**
Engine layout:	4 cylinder in-line	4 cylinder in-line	4/6 cylinder in-line	4 cylinder in-line	4 cylinder in-line	4/6 cylinder in-line
Fuel system:	Multi-point indirect fuel injection	Multi-point indirect fuel injection	Multi-point indirect fuel injection	Common rail direct injection, turbo	Common rail direct injection, turbo	Common rail direct injection, turbo
Gearbox:	5 speed manual	5 speed manual	5 speed manual	5 speed manual	5 speed manual	5 speed manual

Technology options

Basically N1 technology will closely follow the developments of the M1 segment. Therefore the same technologies that have been identified in the M1 study also apply here. However, for reasons of robustness and durability it is expected that some technologies will not enter the N1 segment, such as piezo-injectors and a continuous variable transmission. The same applies for concepts such as strong downsizing and strong weight reduction.

It must be noted that the technology options listed in Table 5-2 and Table 5-3 are all feasible in 2012. This is likely to be more the case for Class II and Class III vehicles. It will depend on the manufacturer strategy and the stringency of legislation to be introduced whether these technologies will be applied.

Table 5-2: Technology options for N1 gasoline engines

		Class I	Class II	Class III
	Description			
Engine	Optimised engine efficiency	✓	✓	✓
	Direct injection (stoichiometric)	✓	✓	✓
	Mild downsizing	✓	✓	✓
	Medium downsizing	✓		
	Variable valve timing	✓	✓	✓
Transmission	6-speed manual/(automatic) gearbox	✓	✓	✓
	Piloted gearbox	✓	✓	✓
Hybrid	Start-stop function	✓	✓	✓
	Regenerative braking	✓	✓	✓
	Mild hybrid (motor assist)	✓	✓	✓
	Full hybrid (electric drive)	✓	✓	✓
Body	Improved aerodynamic efficiency	✓	✓	✓
	Mild weight reduction	✓	✓	✓
	Medium weight reduction	✓		
Other	Low friction tires	✓	✓	✓

Table 5-3: Technology options for N1 diesel engines

		Class I	Class II	Class III
	Description			
Engine	Optimised engine efficiency	✓	✓	✓
	Mild downsizing	✓	✓	✓
	Medium downsizing	✓		
Transmission	6-speed manual/(automatic) gearbox	✓	✓	✓
	Piloted gearbox	✓	✓	✓
Hybrid	Start-stop function	✓	✓	✓
	Regenerative braking	✓	✓	✓
	Mild hybrid (motor assist)	✓	✓	✓
	Full hybrid (electric drive)	✓	✓	✓
Body	Improved aerodynamic efficiency	✓	✓	✓
	Mild weight reduction	✓	✓	✓
	Medium weight reduction	✓		
Other	Low friction tires	✓	✓	✓
	Particulate trap	✓	✓	✓

Retail prices of technologies

Because it is out of the scope of this study to do an extensive CO_2 versus associated retail prices exercise, the basic approach of the M1 study has been adopted. Therefore, also the basic retail price data of the various technology options from the M1 study have been used. However, where it seemed appropriate or where additional retail price data was available the retail prices have been adjusted. Basically, the following assumptions have been made:

- Retail price and reduction potential for Class I technology options are equal to the M1 Medium diesel data.
- Retail price and reduction potential for Class II technology options are equal to the average of M1 Medium and Large diesel data.
- Retail price and reduction potential for Class III technology options are equal to the M1 Large diesel data.

These assumptions result in the retail price data as displayed the Table 5-4 (gasoline) and Table 5-5 (diesel).

Technology packages

From the 2002 technology baseline N1 vehicles will develop to a 2012 technology level. This level will be determined by external factors, such as consumer preferences, fuel price and legislation. In this paragraph, some typical technical pathways for short to medium term CO_2-emission reduction are described for each N1 class in the form of technology packages. The basic assumption here is that the technology packages are considered feasible in 2012. The outcome of this exercise in terms of cost increase and CO_2-emission reduction will indicate to which extent CO_2-emissions can be reduced and the costs (in retail price) per vehicle that are involved.

Because of the limited availability of retail price data and the limited N1 vehicle future outlooks, the number of technology packages has been limited to four. This does not mean that other possible combinations are excluded, or are considered less feasible. A 'Business As Usual' package has been added as well, to indicate the CO_2 reduction potential of N1 vehicles under the circumstance that no external factors are present to initiate a further reduction of CO_2-emissions.

The technology packages that have been used in this study are summarised in Table 5-6 and Table 5-7 for respectively gasoline and diesel engines.

CO_2-emission reduction

For each N1 subclass and the above mentioned technology packages, the retail price versus CO_2-emission reduction have been calculated. The 2002 reference CO_2-emissions used in these calculations were taken from paragraph 3.3.2. For gasoline Class I: 179 g/km, Class II: 184 g/km and Class III: 283 g/km; for diesel Class I: 160 g/km, Class II: 175 g/km and Class III: 227 g/km. Figure 5-1 and Figure 5-2 provide an impression of the CO_2-emission reductions that are achievable at a certain retail price.

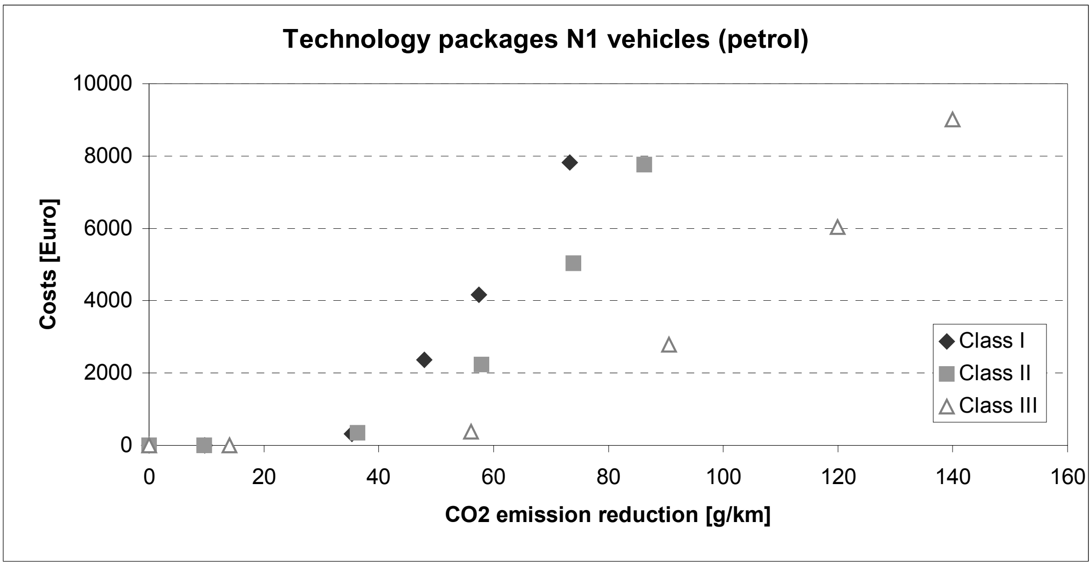

Figure 5-1: Retail prices versus CO_2-emission reduction for N1 class I, II and III gasoline vehicle technology packages

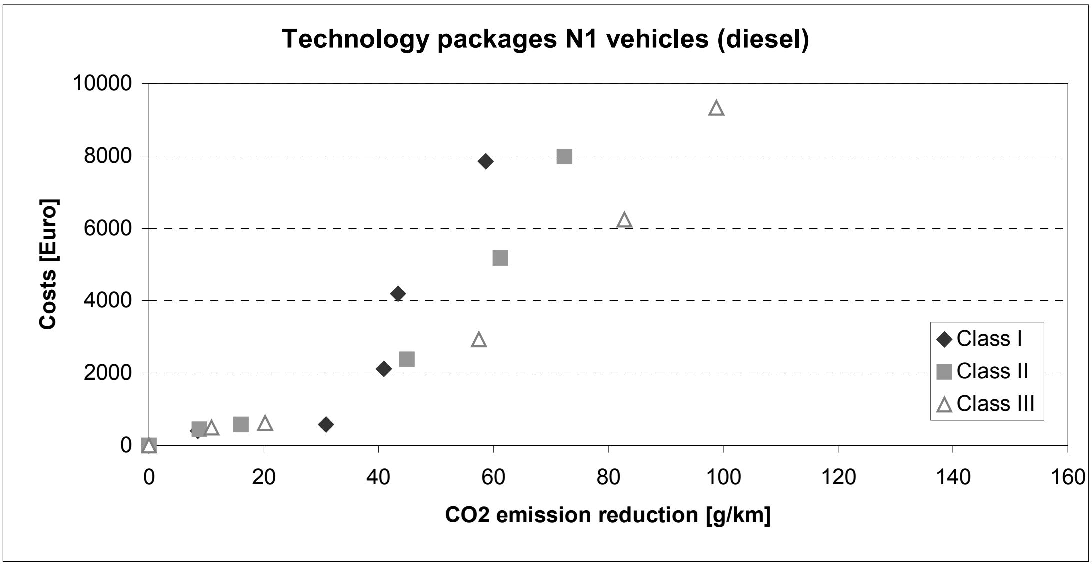

Figure 5-2: Retail prices versus CO_2-emission reduction for N1 class I, II and III diesel vehicle technology packages

Table 5-4: Indication of retail prices for technological options - gasoline

	Class I			**Class II**			**Class III**		
	FE benefit [%]	Costs [Euro]	Weight [kg]	FE benefit [%]	Costs [Euro]	Weight [kg]	FE benefit [%]	Costs [Euro]	Weight [kg]
Optimised engine efficiency	4	0	0	4	0	0	4	0	0
Direct injection (stoichiometric)	5	100	0	5	100	0	5	100	0
Mild downsizing	10	100	-40	10	125	-48	10	151	-57
Medium downsizing	15	250	-80	-	-	-	-	-	-
Variable valve timing	6	150	0	7	181	0	8	212	0
6-speed manual/automatic gearbox	3	125	5.5	3	125	6	3	125	5.5
Piloted gearbox	5	1000	10	5	1500	10	5	2000	10
Start-stop function	4	200	0	3	200	0	3	200	0
Regenerative braking	7	800	0	8	876	0	8	952	0
Mild hybrid (motor assist)	11	2000	0	12	2190	0	13	2379	0
Full hybrid (electric drive)	20	4500	0	22	4927	0	24	5353	0
Improved aerodynamic efficiency	1.5	0	0	1	0	0	1.0	0	0
Mild weight reduction	3	545	-121	4	811	-180	5	1077	-239
Medium weight reduction	6	1695	-242	-	-	-	-	-	-
Low friction tires	2	0	0	2	0	0	2	0	0

Table 5-5: Indication of retail prices for technological options - diesel

	Class I			**Class II**			**Class III**		
	FE benefit [%]	Costs [Euro]	Weight [kg]	FE benefit [%]	Costs [Euro]	Weight [kg]	FE benefit [%]	Costs [Euro]	Weight [kg]
Optimised engine efficiency	4	0	0	4	0	0	4	0	0
Mild downsizing	10	50	-40	10	56	-44	10	62	-48
Medium downsizing	15	125	-80	-	-	-	-	-	-
6-speed manual/automatic gearbox	3	125	5.5	3	125	6	3	125	5.5
Piloted gearbox	5	1000	10	5	1500	10	5	2000	10
Start-stop function	4	250	8	4	250	8	3	250	8
Regenerative braking	7	800	7	8	895	8	9	990	9
Mild hybrid (motor assist)	11	2000	19	12	2237	21	14	2475	24
Full hybrid (electric drive)	20	4500	84	22	5034	94	25	5568	104
Improved aerodynamic efficiency	1.5	0	0	1	0	0	1.0	0	0
Mild weight reduction	3	545	-121	4	811	-180	5	1077	-239
Medium weight reduction	6	1695	-242	-	-	-	-	-	-
Low friction tires	2	0	0	2	0	0	2	0	0
Particulate trap	-2	400	6	-2	450	7	-2	500	7

Table 5-6: Technology packages for N1 gasoline vehicles

			Class I				Class II				Class III			
		Business As Usual	P1	P2	P3	P4	P1	P2	P3	P4	P1	P2	P3	P4
	Description													
Engine	Optimised engine efficiency	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Direct injection (stoichiometric)		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Mild downsizing		✓	✓				✓	✓	✓		✓	✓	✓
	Medium downsizing				✓	✓								
	Variable valve timing			✓	✓	✓		✓	✓	✓			✓	✓
Transmission	6-speed manual/(automatic) gearbox		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Piloted gearbox			✓	✓	✓		✓	✓	✓		✓	✓	✓
Hybrid	Start-stop function			✓				✓				✓		
	Regenerative braking													
	Mild hybrid (motor assist)				✓				✓				✓	
	Full hybrid (electric drive)					✓				✓				✓
Body	Improved aerodynamic efficiency	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Mild weight reduction			✓	✓				✓	✓			✓	✓
	Medium weight reduction					✓								
Other	Low friction tires		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Reduction rate		5%	20%	27%	32%	41%	20%	31%	40%	47%	20%	32%	42%	49%

Table 5-7: Technology packages for N1 diesel vehicles

			Class I				Class II				Class III			
		Business As Usual	P1	P2	P3	P4	P1	P2	P3	P4	P1	P2	P3	P4
	Description													
Engine	Optimised engine efficiency	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Mild downsizing		✓	✓				✓	✓	✓		✓	✓	✓
	Medium downsizing				✓	✓								
Transmission	6-speed manual/(automatic) gearbox		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Piloted gearbox			✓	✓	✓		✓	✓	✓		✓	✓	✓
Hybrid	Start-stop function			✓				✓				✓		
	Regenerative braking													
	Mild hybrid (motor assist)				✓				✓				✓	
	Full hybrid (electric drive)					✓				✓				✓
Body	Improved aerodynamic efficiency	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Mild weight reduction			✓	✓				✓	✓			✓	✓
	Medium weight reduction					✓								
Other	Low friction tires		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Particulate trap	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Reduction rate		**5%**	**19%**	**26%**	**27%**	**37%**	**9%**	**26%**	**35%**	**41%**	**9%**	**25%**	**36%**	**44%**

6 Current status and policy options for CO_2 reduction

Within the previous study, the issue of policy options for the purpose to reduce CO_2-emissions from N1 vehicles was hardly addressed. Only for a few countries (The Netherlands, Switzerland, USA and Japan) the policy options that are currently applied have been summarised. Data from other countries and Member States as well as manufacturers and NGO's were lacking. The underlying study aims to retrieve more detailed information regarding the policy options that could be applied. In addition, the pros and cons of the different instruments will be evaluated in great detail addressing its potential for probable application.

6.1 Current activities by Members States, NGO's and manufacturers

IEEP sent questionnaires out to all Member States requesting details of any measures (e.g. on taxation, subsidies) either a) currently in place, or, b) planned in the future. Additionally a number of other sources were identified to gain a wider perspective of measures implemented in the Member States, these include:

- OECD tax database[10]
- International Energy Agency: Climate Change- Policies and Measures Database[11]
- ACEA Tax Guide[12]
- DLR Report for the European Commission[13]

There is no concerted information available from manufacturers, but this does not mean that no action has been taken. Since N1 vehicles are used in commercial operation, there will be some cost pressure for good fuel economy. Also, for car-based vans, technical innovations in the M1 sector (required in response to the Voluntary Agreement) may also be applied to the N1 equivalents. More generally, new technology developed for M1s may also be applied to N1s.

Column 1 in Table G-1 (see Appendix G) provides details of the current policies for N1 vehicles in all Member States. The questionnaires received from Member States highlighted that very few measures were in place dealing with N1s. The majority of measures that could be seen as having an impact on CO_2-emissions were related to annual vehicle taxes. The majority of Member States have implemented systems that are based on weight/mass. Accordingly, as heavier vehicles have to pay higher rates this could possibly have an impact on influencing purchasing behaviour in favour of lighter N1s – although within obvious limits imposed by operational requirements of the vehicle. A number of Member States have also implemented measures to encourage the use of alternative fuels in N1s. These are provided through tax breaks, exemptions and the use of grants. For instance in Sweden, N1s that operate on electricity or electric hybrid vans, are exempt from annual vehicles taxation for the first five years after the first registration.

As the research developed it was clear that relatively few policies were directed at reducing CO_2-emissions *per se* from N1 vehicles, and consultation with the other sources listed above reinforces the apparent lack of measures. However, some measures do have an indirect linkage to CO_2.

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[10] http://www.oecd.org/document/60/0,2340,en_2649_37427_1942460_1_1_1_37427,00.html

[11] http://www.iea.org/dbtw-wpd/textbase/envissu/pamsdb/index.html

[12] European Automobile Manufacturers Association (ACEA), Tax Guide: Motor Vehicle Taxation in European – 2004 edition, Brussels

[13] DLR (German Aerospace Centre, Institute of Transport Research), Preparation of the 2003 review of the commitment of car manufacturers to reduce CO2 emissions from M1, Report to the European Commission's DG Environment, March 2004

Nonetheless a second column was added to the table detailing policies on other vehicles, these were predominately for reducing CO_2-emissions for M1s. The inclusion of these measures was to help provide a useful comparison of the measures currently in place for M1 vehicles to see if extending the scope of such measure to N1s was possible.

As expected, in line with Directive 1999/94/EC on labelling CO_2 from passenger cars, the EU-15 Member States all have labelling (although Germany have not yet transposed the Directive) in place which aims to provide buyers with information on the fuel economy and CO_2-emissions of new cars at the point of sale. Similarly, the promotion of the use of alternative fuels for cars was again apparent, with tax breaks, exemptions and grants available for their use. For instance in Italy, persons ordering the installation of a CNG or LPG system on private cars are given a discount of 650 Euros, and in Portugal a 50 per cent reduction of the tax on the purchase of vehicles using CNG or LPG is given. However, a number of more innovative measures designed to reduce CO_2-emissions were also present in some Member States. In Sweden, free car parking or special parking for cars that run on alternative fuels is available. In the UK, a vehicle's CO_2 figure has been used as the basis for applying Vehicle Excise Duty (VED – i.e. circulation tax) rates for new passenger cars, with a graduated system with six categories ranging from AAA – D.

IEEP contacted Member States and NGOs; currently there is no information from manufacturers. IEEP provided a table for each country; general conclusions:

- Tax in most Member States based on vehicle weight and/or engine capacity and/or engine power
- Tax reduction for alternative fuels/powertrains (GTL, LPG, CNG, Electric, Hybrid)
- CO_2 / Fuel consumption labelling exists in most Member States

6.2 Study on potential policy options

The methodology for this section began by building a list of policy measures that might be applied to CO_2 reductions for N1 vehicles, developing work begun by RAND and adding in an inventory of measures already in use at EU or MS level, and material from previous studies on M1 measures.

6.2.1 Available Policy Measures

Reflecting this, Table 6-1 addresses the main measures already in play or under consideration for passenger cars, and indicates how these might be applied or extended to cover N1 vehicles. The measures listed focus on vehicle technology-oriented measures, as this is consistent with the coverage of this study. Other, more broad-based measures such as improved driver behaviour, demand management or modal shift can also have an influence on actual CO_2-emissions on the road, but are outside the scope of this study.

Columns 2-5 of Table 6-1 briefly characterise how or where these measures are currently utilised, while the last column indicates how, how easily, and over what possible time-scale, such measures might be extended to N1 vehicles. The latter column is in effect a preliminary assessment of the potential relevance of the instrument to being utilised at the European level for the purposes of reducing CO_2-emissions from N1 vehicles. However, it will not, at this stage, lead to an assessment of which instrument would be most appropriate, overall, as this is left to Section 6.3, after the instruments have all been assessed against a broader range of criteria in Section 6.2.

The principal conclusions to be drawn from Table 6-1 are:

- most measures presuppose the availability of the CO_2 data for each model under Directive 2004/3/EC;
- most measures are potentially as applicable to N1s as to M1s;
- some could be based on the equivalent, existing M1 legislation, e.g. monitoring and labelling;
- for some instruments, it is unlikely, for reasons of sophistication and complexity, that the instrument would be developed solely for N1s, e.g. a bubble concept or trading, but an instrument covering N1s and M1s could be developed;
- conversely, there would be clear benefits in many cases from combining M1s and N1s under a single regime;
- it would be difficult to reach an agreement at the European level for some measures, e.g. taxation, so national applications might be more appropriate;

On this basis, it was determined to focus on measures where there is (a) a greater possibility of Community action and (b) there may be a possibility at some stage to harmonise the measure with one, which is already in place, or under consideration for M1 vehicles.

Table 6-1: Use of instruments to reduce CO_2 from passenger cars/vans

Type of Instrument	**Level of where applied or applicable – EU, national, local, company etc.**				**Comment on transfer from M1 to N1**
	EU	**National**	**Regional/Local**	**Manufacturers**	
Technology Standards, i.e. setting a maximum emission limit value(s) for new N1 vehicles that requires these to emit no more than a certain level of CO_2	None but could be considered	None – and not appropriate given internal market	None – and not appropriate given internal market		Perhaps more applicable to N1 due to the nature of the N1 market, as fuel efficiency already an issue. Would have to be implemented at the EU level, so as not to adversely impact on the internal market. Would need a significant amount of time to agree on standards and for these to be translated into EU legislation.
Bubble concepts – averaging, i.e. requiring that the average CO_2-emissions of a subset of all new N1 vehicles, e.g. those produced by each manufacturer, do not exceed a pre-determined level	Yes – within the car mfrs' self-commit-ments	No in Europe, yes in US (CAFE)	None – and not appropriate given internal market		Equally applicable, but not yet applied in Europe. Would have to be introduced at the European level and would take time to develop concept and introduce the legislation. Unlikely that such a sophisticated instrument would be applied to N1s if it is not already used for M1s, which might be possible post-2009.
Voluntary Agreement, i.e. an agreement between the relevant authorities and manufacturers for the latter to voluntarily reduce CO_2-emissions of new N1 vehicles	Yes – car mfrs' self-commit-ments	In principle possible	Not practicable	Have been involved at EU and national levels	Could piggy back on current cars self commitment for manufacturers. Unlikely for the current agreement period, but could be included in a follow-up agreement post-2009. Besides, it would take time to negotiate with industry and develop necessary monitoring and reporting mechanism.
Emissions Trading, e.g. a trading system under which emission allowances are allocated to manufacturers, which can then trade these if they exceed their allotted allocation	In principle possible	In principle possible	Not practicable		As with a bubble concept, equally applicable but would take time to develop and would probably not be introduced for N1s without being also applied to M1s. NB: this would probably need to be a free-standing system for vehicles – i.e. not linked to ETS, at least initially.

Type of Instrument	**Level of where applied or applicable – EU, national, local, company etc.**				**Comment on transfer from M1 to N1**
	EU	**National**	**Regional/Local**	**Manufacturers**	
Taxes – fuel, i.e. the tax that motorists pay that is added to the price of fuel	Minimum tax rates set – but these do not generally impact on current duty levels	Key domain – levels and differentials	Can occur in federal countries		The same fuels are used by N1 and M1s, and fuel duties have been used as an instrument to influence CO_2-emissions in the past and could do so again, but only at the national level. European application would need unanimity among Member States, which is very unlikely given existing voting rules.
Taxes – Registration/ purchase, i.e. the tax that is paid when a vehicle is purchased or first registered with the relevant authorities	No – unlikely that an agreement could agreed at European level	Yes – e.g. new French proposal	Can occur in federal countries		Could be extended to cover N1s once CO_2 data are available as a result of Directive 2004/3/EC. However, very unlikely an agreement could be reached at European level, so measures would need to be national.
Taxes – Circulation, i.e. the tax that motorists pay to allow them to use their cars on public roads	No – unlikely that an agreement could agreed at European level	Limited differentiation in some countries	Can occur in federal countries?		As with purchase taxes, national measures could be introduced once the CO_2 data are available. Commission has already argued for some approximation on basis of CO_2.
Subsidies for low emissions vehicles, e.g. a government grant to contribute to the additional purchase costs of a cleaner vehicle	Not an area of EU competence	Yes – e.g. UK PowerShift, new French proposals	Can occur in federal countries?	Manufacturers selling cars below cost – e.g. Toyota Prius	Yes – could be attractive, but only relevant to the national level.
Vehicle conversion incentives (e.g. to LPG), e.g. a government grant to enable vehicles to be converted to use a cleaner fuel	Not an area of EU competence	Yes – e.g. UK, Italy, Luxembourg	Can occur in federal countries?	Yes – improved OEM offers	Limited potential in terms of CO_2 savings. OEM models offer better performance.

Type of Instrument	Level of where applied or applicable – EU, national, local, company etc.				Comment on transfer from M1 to N1
	EU	**National**	**Regional/Local**	**Manufacturers**	
Scrappage incentives, e.g. a benefit paid to an owner to encourage the scrappage of an older, more polluting vehicle	No – ELV Directive makes limited prov.	Some past experience in US, little in Europe	Unlikely	Possible	Difficult to apply, but would need to be a national measure all the same.
Monitoring, i.e. the collation of data to ascertain accurately the emissions of new vehicles and therefore of the entire fleet	1753/2000	National application	N.a.	Yes – monitoring originally based on manufacturer data	Very valuable to help get information currently not available and could be undertaken at a national level, but to enable it to support another piece of EU level legislation, would need to be standardised at the European level along the lines of Decision 1753/2000 for M1s. Mechanism could be based closely on 1753/2000, but would need a number of years to pass through the legislative process.
Labelling, i.e. the provision of information on fuel economy and CO_2-emissions to potential purchasers of new vehicles	EU Directive	National practice	Unlikely	Voluntary labels possible	Potentially not as relevant for N1s, as fuel efficiency more of a factor in determining some N1 purchases than it is for M1s, but would make the figures transparent and comparable. Could be applied, either nationally or at the European level, along the lines of Directive 1999/94/EC for M1s, once fuel consumption and CO_2 are available. Could be based on Directive 1999/94/EC, but would need some time to pass through the legislative process.
Public procurement, i.e. the setting of requirements for the public purchase (e.g. municipal buses, local authority vans) of vehicles, e.g. requiring these not to exceed a certain pre-determined level of CO_2	Governed by state aid rules, etc	Possible – examples? UK has some	Possible	Manufacturers may tender for supply	Benchmarks could be developed once CO_2 data are available and could be more applicable to N1 than to M1s, although the potential effectiveness reduced as result of privatisations.

6.2.2 *Utility Parameters to apply a CO_2 measure*

The aim of this section is to summarise the range of technical characteristics or combinations of technical characteristics that could be used as a basis for emissions reduction legislation for vans. The first part summarises the 'long list' of options, while the second part discusses in greater detail a short list of options. The aim is to decide which of these characteristics offers the greatest potential to act as a base for CO_2-emissions reductions legislation, and where necessary, to define further work needed. These final technical characteristics can then be explored under different instrument options – outlined above e.g. straight technical requirements, or linkage to emissions trading.

The key problem of establishing a CO_2 regime for vans based on a single limit value is the substantial variation between the most and least economical vans – reflecting in large part the significant variation between the size classes. As there is no simple abatement technology, which can bring emissions down to a low level across the board, it is probably impractical to set a single limit value, as this would bear very heavily on some large vans, and not at all on most others. Therefore some sort of ratio or classification is probably needed for practical purposes to set environmental limit values – and possibly also for the other types of more flexible arrangements discussed elsewhere in this section.

Ideally the criteria used to achieve this would be some measure of the utility of the vehicle, as this might justify extra CO_2-emissions; while attributes which actively contribute to increased CO_2 should be avoided. As the purpose of a van is fairly clearly to carry (some) people and (more) goods, a measure of carrying capacity is arguably the most desirable metric. This is complex in practice, however, as engine power in particular can be argued to fall into both categories. These issues are set out in the table below.

Possible criteria on which to base technology standards (e.g. emission limit values (ELVs)) fall into two basic types – continuous (e.g. a measurable attribute such as mass) or discontinuous (e.g. vehicle class). The latter type can be used only to establish a set of vehicle classes for which separate CO_2 limit values or 'bubbles' can be set – i.e. they *classify* the N1 fleet. Continuous variables can also be used in this way – by banding – but can also be used to set a CO_2 ratio (i.e. they *normalise* CO_2-emissions), which may be better. In particular, banding would be in danger of causing serious boundary effects, which could distort the market. In this respect, continuous variables are often more valuable in establishing robust ELVs where single or discrete limit values are not feasible.

Table 6-2 below summarises the main options available, and indicates the main arguments for or against considering them in greater detail.

Table 6-2: Criteria, Pros and Cons, fit characteristics and decision re shortlist

Criteria	**Specific format**	**Pros**	**Cons**	**Decision regarding whether to maintain on the Shortlist**
Discontinuous				
N1 subclasses	I to III	Comprehensible in terms of consumer perception – these are recognisable size classes and reflect purchasing behaviour. Seen to be 'fair'. Easy to operate.	Some boundary effects – i.e. might distort sizes and designs of future N1s to move into a higher classification. Further investigation may be needed to set a 'fair' emission limit for each class.	Yes – initial results suggest the variation within class is limited.
Number of Seats	Number	Simple. Comprehensible.	Little differentiation for most van types. Arguably not helpful as does not address the primary purpose of a van.	No – cons outweigh pros.
Vehicle category	Category, e.g. box van, car-derived van	Comprehensible in terms of consumer perception – reflects utility to some degree	Problems of definition? Likely boundary effects depending on emission levels	No – due to definitional problems
Continuous				
Price	€	Presumably some measure of utility on a 'willingness to pay' basis.	Could impose high additional costs on lowest-cost and lowest-value vehicles. Prices vary (notably across Member States) and are hard to define precisely. Probably no good relationship between CO_2 and price – e.g. the latter may reflect specialist requirements and add-ons which have little bearing on CO_2.	No – likely to create incentives for novel price structures to manipulate the 'list price', and create perverse effects such as lower price and higher cost of add-ons.
Vehicle Mass	Kg (gross or net)	Readily available. reasonable proxy for vehicle size.	Weight contributes adversely to CO_2 emissions so should not be encouraged. There could be perverse effects.	Yes: Possible – Easy to use. Need to investigate how real or how great are the possibilities of perverse effects (reducing mass to get into other CO_2 weight band, with lesser mass compromising safety). Conversely, reduced body weight might allow greater payload.

Criteria	**Specific format**	**Pros**	**Cons**	**Decision regarding whether to maintain on the Shortlist**
Max Payload	kg	A good proxy for utility. Reasonably available.	Possibility of artificially manipulating? With advent of ‘smart’ air suspensions, it may become possible to offer artificially high payloads.	Yes: good, simple and available
Engine Capacity or cylinder volume	cc	Readily available. Easily understood.	Capacity is not necessarily a good guide to power or utility. i.e. Not a good proxy.	No – especially with advent of hybrids and other new technologies, engine capacity will be ever less meaningful.
Power	kW, kW/kg	Readily available. Easily understood. Specific power is a key design parameter for driveability.	Potentially controversial; an element of utility, but not to be encouraged?	No – ever-increasing power in danger of increasing the divergence of real world emissions from test cycle emissions (as the test cycle only uses a very small part of the power range) – i.e. growing potential for perverse outcomes.
Vehicle Pan Area	m^2 length * width	Some measure of utility Relatively easy to derive[14]	Favours some classes (e.g. high sided vans) over others (e.g. open-backed pickups).	No.
Footprint	L*w*kg	Some measure of utility Relatively easy to derive and good base for CO_2 efficiency	Length and width can be manipulated – though question as to whether significant. Lack of definition of size limit; difficulty in EU of defining such a limit.	Yes – can probably correct for specific vehicle body types, but need to consider how far the other drawbacks can be overcome.
Internal capacity/ volume	m^3 goods compartment	Good measure of utility (similar to payload?)	Problems of definition and measurement. Compartment height could be manipulated. Problem of calculating for pickups and flatbeds.	No – An agreed measure of compartment size is too complex; even if one could be agreed in principle, there would be major new data requirements.

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[14] NB should be defined as *minimum* or average width and length to avoid manipulation.

Criteria	**Specific format**	**Pros**	**Cons**	**Decision regarding whether to maintain on the Shortlist**
External Capacity	m^3 l * w * h	Relatively easy to derive. Data availability? Moderately good index of utility (though less good than internal).	Problem of calculating for pickups and flatbeds.	Yes – need to consider availability of dimensional data and how weaknesses may be overcome.
Frontal area	m^2	Key factor in determining fuel consumption at high speeds – good indicator for real life fuel efficiency for cars.	Inappropriate for urban circulation; less relevant for vans.	No.
Other options				
Composite of payload and volume		Could mitigate weaknesses of either one singly, and give optimum utility function.	More difficult to derive, and less easy to understand.	Yes – but needs further data and analysis.

From this table, the following are shortlisted:
(a) N1 subclasses
(b) Vehicle Mass
(c) Max payload
(d) Footprint
(e) External capacity
(f) Composite of payload/volume

This shortlist gives a good range of options, including one discontinuous and five continuous variables. Together these offer strong possibilities of finding a viable and realistic utility function.

Having reached the shortlist of possible parameters, we now need to investigate the relationship between the specific parameter and test cycle CO_2-emissions, to see how closely it can 'explain' the emissions level, and how the parameter might be refined to improve its utility (this has been done for a broader range already in Table 6-2, to underline characteristic validity issues). Note however that the closeness of the fit between CO_2-emissions and a given parameter is not automatically an indication of its suitability in establishing an ELV. For example, power is closely correlated with fuel use and emissions, but it may still be unsuitable for use in deriving an ELV for the reasons set out above. Initial indications of correlation are set out in Figure 6-1 to Figure 6-3.

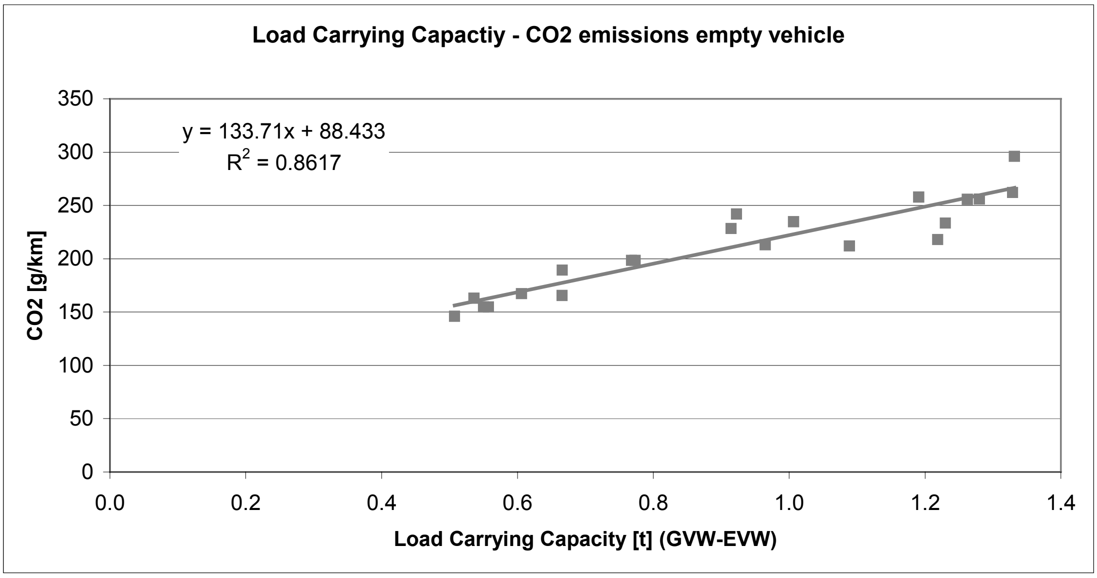

Figure 6-1: Relation between load carrying capacity and CO_2-emission (source [KBA ,2003] and [Lastauto und Omnibus,2004]

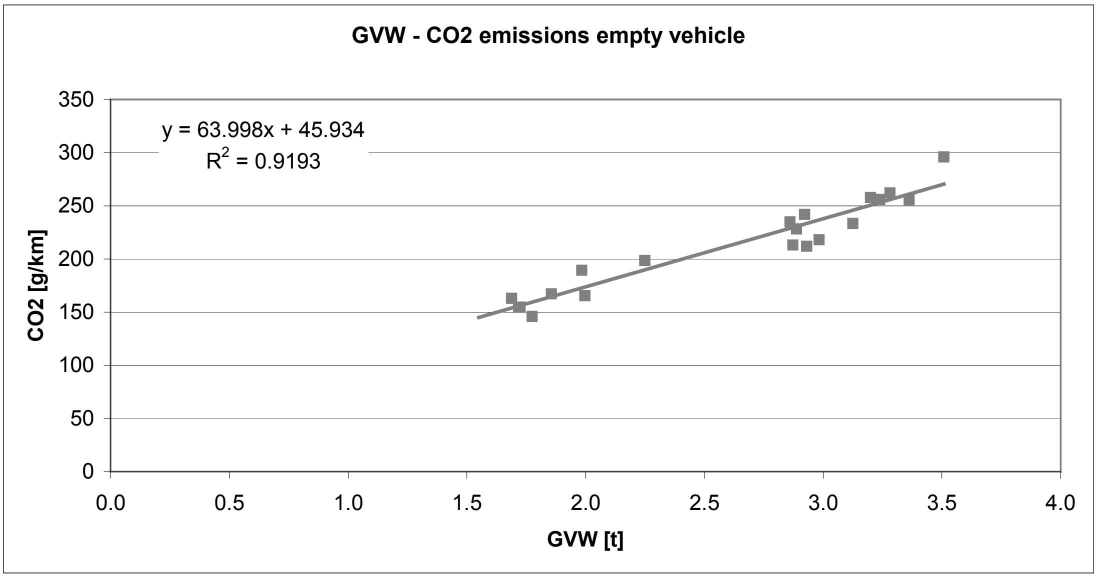

Figure 6-2: Relation between Gross Vehicle Weigth and CO_2-emission (source [KBA ,2003] and [Lastauto und Omnibus,2004]

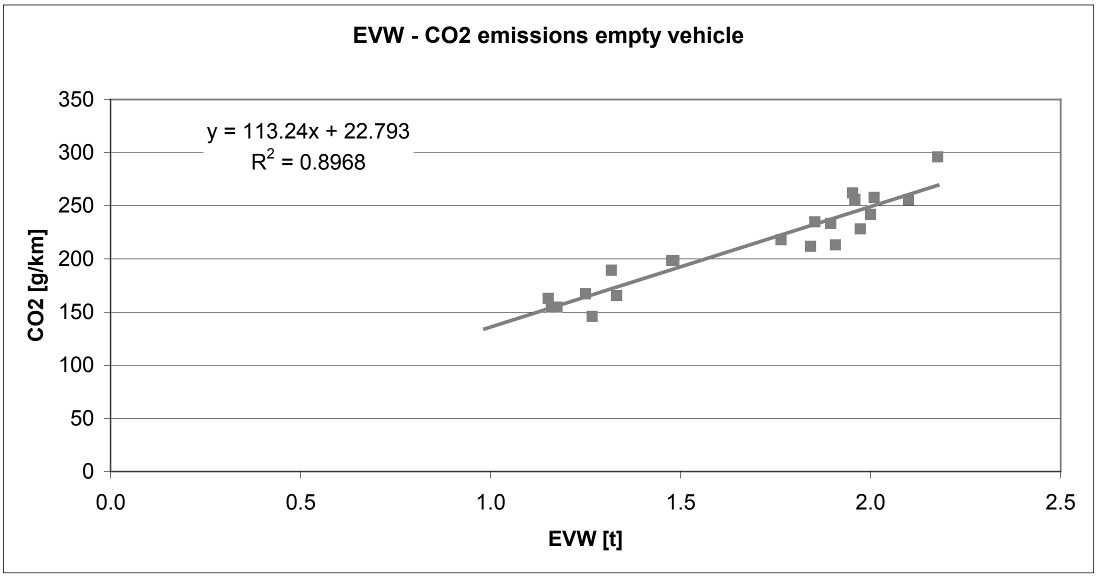

Figure 6-3: Relation between load carrying capacity and CO_2-emission (source [KBA ,2003] and [Lastauto und Omnibus,2004]

As yet this analysis is incomplete, but illustrates that each of these three measures of weight gives a good explanation of the CO_2-emissions – and a distinctly closer fit than is available for cars. Given that the payload is by far the best option in terms of utility function, and that the closest fit is not necessarily the best criterion, this suggests that the payload criterion is the best parameter of those investigated in detail so far.

6.3 Feasibility of introducing various policy options

The methodology for this section was to take the policy measures identified in the previous section and assess each against a number of criteria in order to assess the potential application of each to N1 vehicles. The criteria were based on an internal brainstorm and knowledge of the application of such instruments for similar purposes. The evaluation, the results of which are presented in Table 6-3, was undertaken through internal brainstorms, discussions and consultation within IEEP reflecting existing knowledge and experience of instruments in the sector.
The principal conclusions to be drawn from this Table are:

- The highest evaluation scores apply to monitoring, labelling, voluntary agreements and subsidies for new vehicles.
- Technical standards score much better for N1s than M1s, as a result of their relatively limited impact on the market and consumer choice. They could in the end prove the simplest choice. Further investigation is needed, however, to assess carefully the feasibility of class-based standards, and/or the value of the shortlisted utility parameter options.
- Taxes on fuel and purchases/registrations receive marginally positive scores as they could be effective, are practical to introduce and need few additional data requirements, but suffer from their political unacceptability to be used as a mechanism for reducing CO_2-emissions, especially at EU level.
- Bubble concepts and emissions trading also receive a marginally positive scores, as they are potentially effective in terms of emissions reductions, as well as being cost-effective, but suffer from high data requirements and the need to develop more sophisticated monitoring systems and would therefore require time to bring into action.
- Public procurement also scored marginally positively, as potentially a significant impact on the vehicle parcs concerned, but suffers as only a small proportion of the total new vehicle fleet would be covered. Could be useful in stimulating early demand for innovative technologies, however.
- Vehicle conversions, scrappage incentives and circulation taxes were considered to be relatively inconsequential instruments when it comes to CO_2 reduction from new vehicles.

Table 6-3: Instruments characterisation against different criteria

Type of Instrument	N1 possible application	Utility parameter needed	Performance against criteria – quantitative and qualitative. Quantitative: from –3 to +3; 0: no effect, +3 very good								Summary (not an average)
			Effectiveness - potential CO_2 reduction	Cost and efficiency	Impact on market	Impact on technological development	Impact on consumer choice	Data requirements	Practicality	Political acceptability	
Technology Standards	EU: CO_2-emissions for each class	N1 class may be adequate, or full utility function	+3: if set at a demanding level	-3: as no flexibility	-1: some might lose - either off the market or fined	+2: significant for some, but static for those that met the requirement	-1; some vehicles possibly off the market at least in the short term	+2: low requirements, but need emissions test data to set the standards	+3: easy linked to certificates of conformity	-1: as some costs and market impacts	+1: good on balance if suitable utility function agreed
Bubble concepts – averaging	EU: For each mfr.	N1 class may be adequate, or full utility function	+3: if set at a demanding level	-2: reduces costs	-2: still winners and losers	+2: impact where gains are easiest	-1: should be limited impact	+1: need fleet performance data for each mfr	+1: relatively straightforward	-1: effective, and impacts reduced	+2: limited risk
VA	EU: For each mfr or association	N1 class may be adequate, or full utility function	+3: if set at a demanding level, and effectively enforced	-1: should reduce costs further	-1: esp at assoc level, low market effects	+2: would stimulate cost-effective measures	-1: should be limited impact	+1: need fleet performance data for each mfr	+2: easy, but monitoring needed	+2: relatively acceptable	+2: in place for M1, but possible limit to effectiveness

Type of Instrument	N1 possible application	Utility parameter needed	Performance against criteria – quantitative and qualitative. Quantitative: from –3 to +3; 0: no effect, +3 very good								Summary (not an average)
			Effectiveness - potential CO_2 reduction	Cost and efficiency	Impact on market	Impact on technological development	Impact on consumer choice	Data requirements	Practicality	Political acceptability	
ET	EU: For each manufacturer	Not needed?	+2: likely positive effect if capped	-1: should reduce costs further	-1: should minimise market effects	+2: would stimulate cost-effective measures	-1: should be limited impact	-2: quite demanding data and control requirements	-2: demanding new arrangements needed	+1: positive aspects, but also risks	+1: positive aspects, but also risks
Taxes – fuel	Nat: differentiate according to CO_2	N.a.	+1: only indirect effect on purchase decisions	0: little or no effect on mfr costs	-1: limited effect on purchasing	+1: some value added	0: does not limit choice	+3: very limited new data requirements	+3: very few changes needed	-2: very unpopular	+1: useful contributor, but limited effect
Taxes – Registration/ purchase	Nat: make CO_2 related	Based directly on CO_2?	+2: if strongly differentiated	0: little or no effect on mfr costs	-2: some effect on purchasing if strongly differentiated	+2: should incentivise new technologies	0: does not limit choice	+2: low requirements, but need emissions test data to set the tax level	+2: quite straightforward if there is existing system	0: feebate schemes could be acceptable	+1: useful contribution?
Taxes – Circulation	Nat: make CO_2 related	Based directly on CO_2?	+1: only limited effect on purchase decisions	0: little or no effect on mfr costs	-1: limited effect on purchasing	+1: some value added	0: does not limit choice	+2: low requirements, but need emissions test data to set the tax level	+2: quite straightforward	+1: some differentiation is accepted	0: limited effect?

Type of Instrument	N1 possible application	Utility parameter needed	Performance against criteria – quantitative and qualitative. Quantitative: from –3 to +3; 0: no effect, +3 very good								Summary (not an average)
			Effectiveness - potential CO_2 reduction	Cost and efficiency	Impact on market	Impact on technological development	Impact on consumer choice	Data requirements	Practicality	Political acceptability	
Subsidies for low emissions vehicles	Nat: e.g. for less than 120g/km	Based on class or utility function	+1: if strongly differentiated; limited effect on total sales	+1: could ease mfr costs for low CO2 vehicles	+1: would benefit market leaders	+2: should incentivise new technologies	+1: could improve choice in new technologies	+2: low requirements, but need emissions test data to set the subsidy level	+1: quite straightforward once benchmarks established	+1: popular, but potentially costly	+2: positive effects
Vehicle conversion incentives (e.g. to LPG)	Nat: subsidies for approved models Mfr: set benchmarks ?	N/A	0: limited effect on total sales	+1: could ease mfr costs for low CO2 vehicles	0: little effect on mfrs	+1: incentive to limited range of technologies	0: little effect on choice	+2: low requirements, except benchmark levels	+1: quite straightforward once benchmarks established	+1: low profile, limited cost	0: limited benefit overall
Scrappage incentives	Nat:	N/A	0: little effect on purchase decisions	+1: could stimulate demand and reduce mfr costs	+1: could stimulate market?	0: little or no effect	0: no effect	+2: low requirements, but need emissions test data to set the scrappage level	+1: quite straightforward once benchmarks established	-1: potential costs, and some risks	0: very little impact

Type of Instrument	N1 possible application	Utility parameter needed	Performance against criteria – quantitative and qualitative. Quantitative: from –3 to +3; 0: no effect, +3 very good								Summary (not an average)
			Effectiveness - potential CO_2 reduction	Cost and efficiency	Impact on market	Impact on technological development	Impact on consumer choice	Data requirements	Practicality	Political acceptability	
Monitoring	EU Dir + Nat application	Based on class	0: little effect on purchase decisions	-1: imposes small extra cost	0: very little effect on market	0: no direct impact	0: no direct impact	-1: likely to set additional data require-ments	+2: fairly straight-forward, as a model exists for cars	+1: necessary and not controversial	+2: important element of most policies
Labelling	EU Dir + Nat application	Class or utility function	+1: some positive effect on purchasing decisions?	-1: imposes small extra cost	+1: could benefit market leaders	+1: should give some incentive for new technologies	+1: could improve choices available	+2: low require-ments, but need emissions test data to set the label band	+2: fairly straight-forward, as a model being developed for cars	+1: has visibility, but low cost	+2: low cost, uncertain benefit
Public procurement	Nat or local: set benchmarks for procurement	Class or utility function	+1: small effect over total parc, but could help take up of advanced technology	+1: could stimulate demand and reduce mfr costs	+1: would benefit market leaders	+2: should incentivise new technologies	+1: could improve choice available	+2: low require-ments, except benchmark levels	+1: quite straight-forward once bench-marks esta-blished	+2: effective, but potentially costly	+1: could make positive contribution

6.4 Proposals for monitoring and evaluation of progress

The discussions and analysis of the previous two sections are brought together in Table 6-4.

Table 6-4: A summary of measures and next steps

Measure	Decision	Rationale	Development perspective
Technology Standards	Retain	Simple, and attractive subject to suitable utility parameter	Further investigation of feasibility of class-based or continuous utility functions
Bubble concepts – averaging	Retain for potential later application	Reduces pressure on individual models in range	Could be developed at a later date and combined with other measures, e.g. trading. Could be applied to both N1s and M1s, together?
VA	Retain	Scores well on balance	Existing M1 VA could be extended progressively. NB possibility of initial voluntary self-commitments?
ET	Retain for potential later application	Positive score; could add flexibility	Not ready yet – a possible later addition to be applied to cover N1s and M1s? Not yet a route to fungibility with EU ETS.
Taxes – fuel	Exclude	Potential impact, but little EU relevance or likelihood of use.	N.a.
Taxes – Registration/purchase	Exclude	Potential impact, but politically difficult at national and EU level	N.a.
Taxes – Circulation	Exclude	Limited impact and not really applicable at EU level	N.a.
Subsidies for low emissions vehicles	Exclude	Positive effects, but limited EU dimension	N.a.
Vehicle conversion incentives (e.g. to LPG)	Exclude	Limited benefit; limited EU dimension	N.a.
Scrappage incentives	Exclude	Little or no CO_2 benefit; limited EU dimension	N.a.
Monitoring	Retain	High score – Vital component of various other measures	Extend existing M1 mechanism. NB option of initial mfr-based voluntary scheme
Labelling	Retain to await developments in M1 system	High score and low cost supporting measure for various other measures	Extend existing M1 mechanism after review. NB option of initial mfr-based voluntary scheme
Public procurement	Retain for later development	Positive effects, but limited EU dimension	Develop EU benchmarks for procurement programmes?

The table suggests that emissions trading and/or the bubble concept/averaging could be retained for possible implementation at a later date. It is unlikely that such schemes would be applied to N1s without also being applied to M1s, so could not happen before the end of the current M1 commitment period, i.e. 2008/9. Alternatively, a voluntary self-commitment could be introduced post-2009 to cover M1 or N1s, either in one combined instrument or with two separate instruments along the lines of the current agreements. Once CO_2 data are available, the existing regime could be incorporated into the existing passenger car agreement and associated instruments. This may prove more appropriate for the car-style vans in N1 Class I, but less effective for Classes II or III, as they are less similar to the vehicles under the current regime.

Technical standards remain a far stronger possibility for N1s than M1s, however, owing to the relative homogeneity of technologies within classes.

Whichever of these options might be chosen in the future, it is important to obtain information on the CO_2 emissions of new N1s in order that the instruments can be designed properly. With the recent agreement on Directive 2004/3/EC, the fuel efficiency and CO_2-emissions of N1 vehicles will be measured, so it would be relatively straightforward to set up a monitoring mechanism to enable these data to be collected centrally and assessed in order that a better understanding of the existing emissions profile of the new N1 vehicle fleet is achieved. This could then inform future policy decisions.

As with M1 vehicles, the introduction of labelling arrangements in line with those of Directive 1999/94/EC might also prove to be a useful tool to better inform purchasers of the fuel consumption of the various vehicles and might be more important and therefore effective in relation to N1s, as good fuel efficiency is likely to be, on average, a higher priority for N1 users than M1 users. This could be introduced at the same time as the monitoring proposal and be based on Directive 1999/94/EC and any subsequent recommendations.

7 Scenario study

In section 5 different technology packages including their reduction potential and associated retail prices are provided for both gasoline and diesel N1 vehicles. To get an indication of the effect on total CO_2 reduction because of technology packages being applied in connection with certain policy options, several different scenarios have been developed. The methodology that has been used to conduct this exercise is given in Figure 7-1.

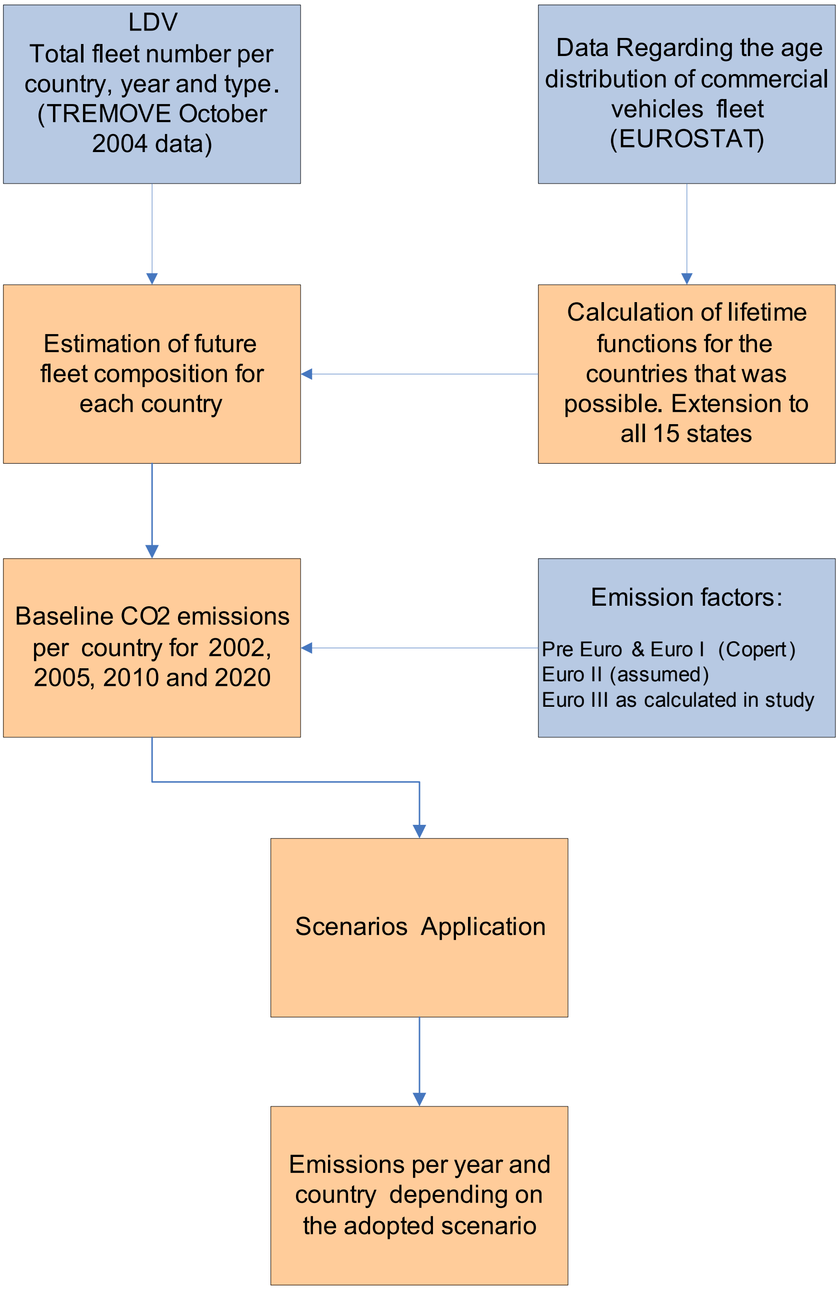

Figure 7-1: Methodology for the CO_2 emission and costs evaluation of applying different scenarios

7.1 Scenario description

As mentioned in section 5, the CO_2 emission reduction percentages are valid for 2012 and the application of these technological options is expected to be feasible from 2012 and onwards. Depending on the stringency of policy options that are applied different technological options could enter the market. This

However, to get an indication on the CO_2 reductions that can be achieved by applying technological options in different years and under different measures, a rather straightforward approach has been followed. To conduct the exercise, three packages have been selected from Table 5-4and Table 5-5. These are the 'Business As Usual' -case, a low cost technological option (in fact technology package I) and a high cost option (technology package II). In fact this means that in case the high cost option is applied, the 'target' value is more stringent compared to the low cost package. The reduction rates and associated costs have been taken from Figure 5-1 and Figure 5-2; for each category (Gasoline/Diesel, Class I/ II / III) third order polynomial cost curves have been derived to link reduction rates with costs.

In addition to the difference in technological options, the implementation dates from which a certain measure comes into force - which requires one of the two selected technological options - are 2012 and 2015.

Furthermore, two different penetration trends have been used in order to get an indication on the effect over the years. The first trend is expected to be linearly increasing from the year of introducing a certain measure – in this case it is assumed as 2005 – up to the date that the measure will become effective. Such a trend could be expected dealing with a voluntary agreement and monitoring mechanism. The other trend assumes that the CO_2 emissions of newly sold vehicles will only be reduced at the date at which all vehicles have to comply with the measure (in one step). This could be the case when setting fixed emission limit values. Over the years, these scenarios will result in different overall CO_2 emission reductions and different overall costs. By comparing the results of both trends, the effectiveness and necessity of a monitoring instrument - that currently applies to M1s - can be addressed. Table 7-1 summarises the different scenarios that are assessed (9 in total).

Table 7-1: Scenario description

Policy option	**Linear Trend**		**Step Trend**	
	Year of introduction		**Year of introduction**	
Technology option	2012	2015	2012	2015
Business as usual	√	√	√	√
Low cost package	√	√	√	√
High cost package	√	√	√	√

It must be noted that the approach followed is rather theoretical and based on a high number of assumptions. The results of this assessment can only be used to provide an indication on the effect of applying the measures in different years.

7.2 Cost effectiveness evaluation

Based on the selected scenarios that have been discussed in the previous paragraph, CO_2 emissions and associated costs for the complete N1 fleet for EU-15 are estimated for the years 2002 to 2020 to estimate the possible effect of different technology packages application in different years with different trends.

The following should be kept in mind:

Fleet data
The N1 fleet data provided by TREMOVE were compared with the fleet data from the previous study [Lu,2003] and those taken from ANFAC (see Appendix J). The TREMOVE data is valid for EU-15 (fleet data of individual Member States have been summed up) while the data from the other two sources refer to EU-15 and 2 additional countries. The totals from the different data sources are different, however in case of the two latter within 10%. The data provided by TREMOVE; are on average approximately 10% lower than the numbers provided by the other two sources. It was decided to use TREMOVE N1 fleet data in order to exclude the effect of discrepancies between data provided by different data sources but also in an attempt to introduce comparability with CAFE.

In order to make any future estimations regarding the fleet composition of N1s in Europe and the CO_2-emissions produced, data about the change of the fleet's population as well as data regarding the ageing of the fleet are necessary. Data concerning the evolution of N1 fleet were retrieved from TREMOVE (based on TRENDS [Trends,2002]) for each European country individually. The TRENDS program can also provide information about the ageing of the vehicles. However a different approach was decided for estimating survival rates of the N1 vehicles for the countries for which enough statistical data were available. A detailed background on the ageing of the vehicle fleet is given in Appendix H.

The only additional data necessary for computing this distribution is the total number of N1 vehicles for each year. In order to obtain data about the total number of N1 vehicles in each European country, the TRENDS program was used. TRENDS can provide the predicted total number of light duty vehicles per country also categorising these into Diesel and Gasoline vehicles. As the total number of the vehicles for each year and the base age distribution for the first year are known, life time functions can be applied in order to calculate the age distribution at any future year. The fleet age distribution per year is given in the age ranges 0 - 1, 2 - 5, 6 - 10, 11 - 20 and 21 years and older. The difference between the sum of the vehicles older than 1 year and the total number of vehicles provides the new registrations. In addition, the percentages of vehicles that comply with a specific Euro class were estimated for each year as well.

Gasoline and Diesel
The TREMOVE fleet composition is based on the TRENDS model that predicts fleets on forecast years based on information gathered before 1996. Based on this data, TREMOVE expects that in the future a rather high percentage of the N1 fleet will be gasoline fuelled. This starts at 34.1% in 2002 and ends with 36.9% in 2020. As there are Member States that are really 'Diesel' minded (amongst others France and Germany), other Member States (like UK) and the countries that acceded the EU in May 2004 are more 'Gasoline' minded; a shift to diesel - like the one that occurred in the M1 category - can be expected for these countries as well in case taxes will change

or more emphasis will be given to reduce CO_2-emissions of the vehicle fleet but this shift is not taken into account in the current assessment.

Division over classes

As mentioned in paragraph 3.3.2, the distribution over the N1 classes is assumed to be constant; these constants are also applied in the evaluation of the scenarios. The division that is applied is summarised in Table 7-2.

Table 7-2: Distribution over classes

Class distribution [%]	
Class I	27.5
Class II	33
Class III	39.5

Mileage

The average mileage was taken from TREMOVE; mileage values are different for gasoline and diesel. Since TREMOVE does not provide detailed data on mileage for the N1 classes I, II and III, the averages are only different for gasoline and diesel. The mileage values that have been used are summarised in Table 7-3.

Table 7-3: Mileage for different vehicle classes and years (source TREMOVE)

Mileage [km]		**2002**	**2005**	**2010**	**2015**	**2020**
Class I	Petrol	19336	19336	19336	19336	19336
Class II	Petrol	19336	19336	19336	19336	19336
Class III	Petrol	19336	19336	19336	19336	19336
Class I	Diesel	23579	23579	23579	23579	23579
Class II	Diesel	23579	23579	23579	23579	23579
Class III	Diesel	23579	23579	23579	23579	23579

CO_2-emission factors

For pre-Euro and Euro 1 vehicles emission factors from Copert III [Ntziachristos,2000] were used; for Euro 3 and onwards, emission factors calculated in the underlying study were used and the scenario improvements were applied on these factors. For Euro 2 vehicles the average emission factor of Euro 1 and Euro 3 was used in order to avoid anomalies in the evolution of the CO_2-emissions. In case of the gasoline vehicles, Euro 1 factors are higher than pre-Euro CO_2 emissions factors due to weight increase and the application of exhaust gas after-treatment. The emission factors are all based on the type approval driving cycle (NEDC) that has an average speed of 33 km/h and are valid for empty vehicles. As explained in paragraph 4.2.5, the real-world CO_2-emissions could be higher and therefore the totals shown here could be not representative for the situation on the road. The CO_2 emission factors that have been used are summarised in Table 7-4.

Table 7-4: CO2 emission factors

CO_2 [g/km]		pre-Euro	Euro 1	Euro 2	Euro 3	Euro 4
Class I	Gasoline	235	275	227	179	179
Class II	Gasoline	242	283	234	184	184
Class III	Gasoline	371	435	359	283	283
Class I	Diesel	223	201	181	160	160
Class II	Diesel	243	220	198	175	175
Class III	Diesel	316	285	257	227	227

Fuel price

The fuel price is assumed to be constant over the years - based on the prices of 2002 - since this would give another variable that has to be taken into account when looking at the figures. Most probably fuel prices will increase over the years, which means that the actual fuel cost savings will - most probably - be higher as well; the current savings are therefore representing a worse case situation. The fuel prices excluding and including tax that are used are presented in Table 7-5; these have been taken from the M1 study.

Table 7-5: Fuel prices in Euro/litre

	Prices excl. tax	Prices incl. tax
Petrol	0.30	1.00
Diesel	0.30	0.82

Costs and addressing fuel savings

'Costs' for implementing the technological options are calculated by using the retail prices that are provided in Table 5-4 (gasoline) and Table 5-5 (diesel). However, not only the prices the customer has to pay for the technology that is needed to reduce CO_2 emissions is taken into account. Reduction of CO_2 is equivalent to fuel economy improvement and therefore these savings have to be taken into account as well. Conversion factors are applied to calculate the fuel saving in litre from the CO_2 emissions in kg/km. For gasoline vehicles a conversion factor of 1/2.365 is used; for diesel vehicles the conversion factor is 1/2.609 [Ten Brink et al,2004].

Societal costs or costs to the consumer

The cost-effectiveness calculation is based on two different levels:

1. **the societal costs**: this cost effectiveness calculation is based on the actual technology costs of the manufacturer (retail prices for the technological options divided by 2 as converting the retail price to actual additional costs for the technologies - also used in the M1 study [Ten Brink et al.,2004]) and the fuel prices *excluding* taxes.
2. **the costs to the consumer**: cost effectiveness is based on retail prices for technological options and fuel prices *including* taxes. This exercise provides information on what are the benefits or drawbacks for the customer who buys the vehicle.

7.2.1 *Estimating the CO_2-emissions on different scenarios*

For each of the forecast years, the total CO_2 emissions from the N1 fleet are calculated by summing the result of the multiplication of fleet, mileage and CO_2 emission for each scenario. Figure 7-2 and Figure 7-3 show the results of that exercise. Figure 7-2 shows the effects for different scenarios in which low cost technological options are introduced; Figure 7-3 contains the results for scenarios in which the target requires that high cost technological options have to be applied. Note that the total CO_2 emission is expressed in ktonnes.

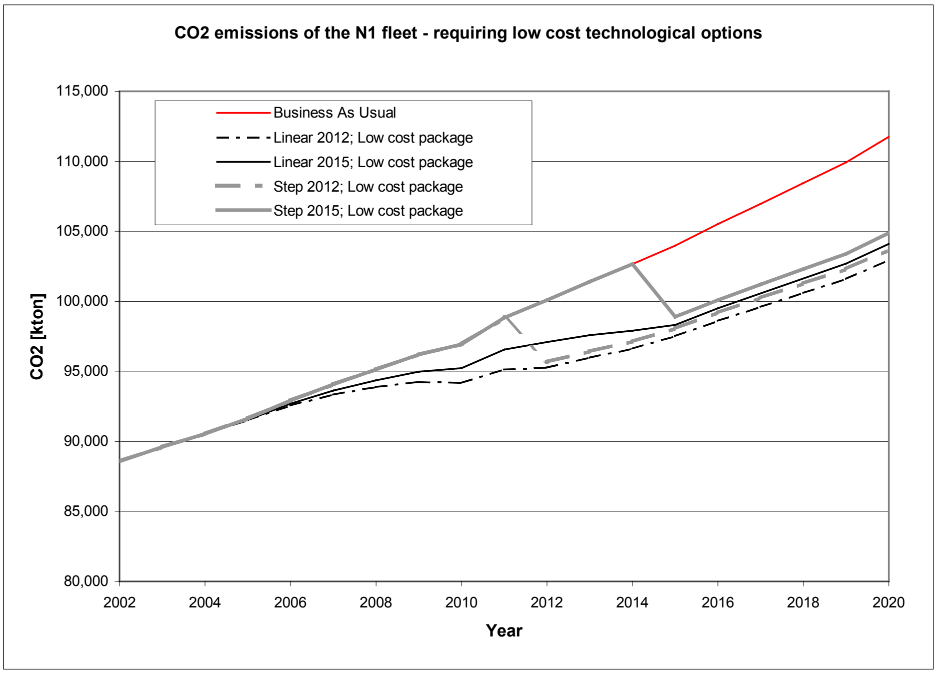

Figure 7-2: Total effect on CO_2 of the linear and step-trend associated with low cost technological options

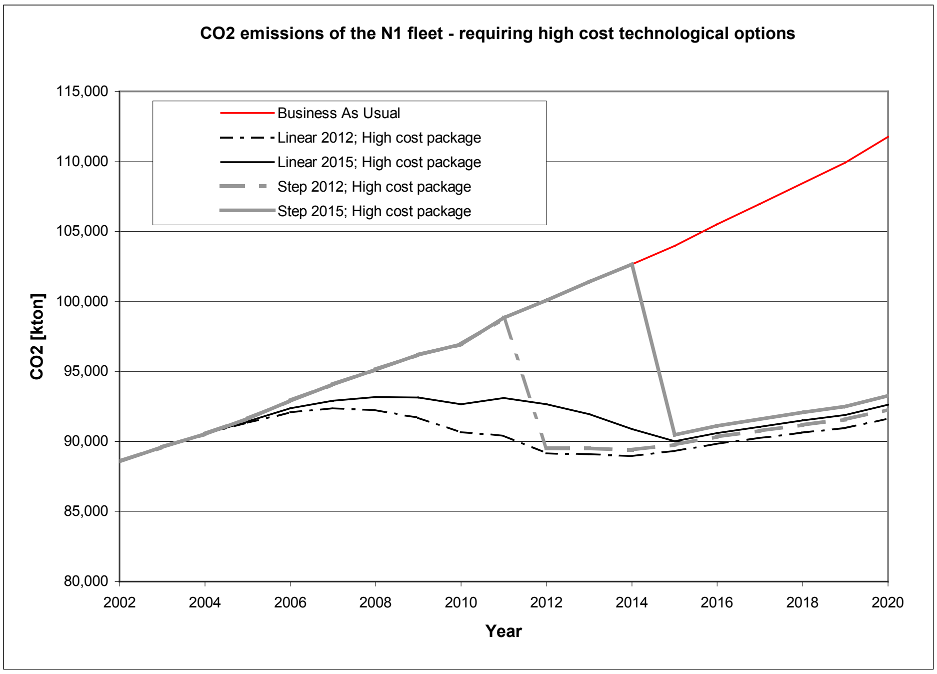

Figure 7-3: Total effect on CO_2 of the linear and step-trend associated with high cost technological option

By summing the CO_2 emissions of each scenario, the total cumulative CO_2 that is emitted by N1 vehicles over the period to 2020 are calculated. These results provide detail about the reductions that could be achieved when applying different scenarios that have different reduction rates in different years. In Table 7-6 to Table 7-9, the cumulative CO_2 emissions that are emitted by N1 vehicles from 2002 on are summarised for the years 2002, 2005, 2010, 2015 and 2020, for different technological packages, trends (linear or step) and introduction dates (2012 or 2015).

Figure 7-2 and Figure 7-3 and Table 7-6 to Table 7-9 show that the date of introduction, the trend and the level of reduction may all affect total CO_2 emissions of the N1 fleet. In 2020, the achieved yearly reductions compared to the "Business As Usual scenario' range from 6.2% up to 18.0%. The effect of different introduction scenarios is limited on the yearly basis (maximum difference between the scenarios applied in year 2020 is 0.7%); the effect of the introduction date is higher and for both options (maximum 1.1%). However, when the cumulative results in 2020 are compared, absolute differences appear to be significant (ranging from 35,790 to 165,824 ktonnes CO_2-emissions savings) whereas the effect is lower in relative terms (range 1.9% to 8.0%). When comparing the trends, the estimated CO_2 reduction is higher for the linear trend instead than for the step trend: difference in reductions achieved between the trends range from 0.9% (2012 - low cost option) to 2.6% (2015 - high cost option).

Table 7-6: Cumulative CO_2-emissions when expecting a linear trend; measure effective from 2012

kTonnes CO_2	2002	2005	2010	2015	2020
BAU	88593	360371	835663	1342623	1885234
Low cost	88593	360248	828412	1308924	1812272
High cost	88593	360088	819140	1266110	1719410

Table 7-7: Cumulative CO_2-emissions when expecting a linear trend; measure effective from 2015

kTonnes CO_2	2002	2005	2010	2015	2020
BAU	88593	360371	835663	1342623	1885234
Low cost	88593	360295	831180	1318675	1827168
High cost	88593	360179	824437	1283066	1740740

Table 7-8: Cumulative CO_2-emissions when expecting a step-trend; measure effective from 2012

kTonnes CO_2	2002	2005	2010	2015	2020
BAU	88593	360371	835663	1342623	1885234
Low cost	88593	360371	835663	1321808	1828514
High cost	88593	360371	835663	1292686	1748841

Table 7-9: Cumulative CO_2-emissions when expecting a step-trend; measure effective from 2015

kTonnes CO_2	2002	2005	2010	2015	2020
BAU	88593	360371	835663	1342623	1885234
Low cost	88593	360371	835663	1337541	1849444
High cost	88593	360371	835663	1329137	1789710

7.2.2 *Estimating the costs*

For each forecast year, the total cumulative costs of the N1 fleet are calculated. These costs consist of two parts: additional costs of implementing technological options (compared to 'Business As

Usual') and the expenses that are made for fuel. The latter is calculated by multiplying the total estimated CO_2 emissions with the conversion factor m_{CO2}/m_{fuel} and the price of the fuel.
The total **societal** costs per year of implementing technological options are provided in Figure 7-4 to Figure 7-5. Figure 7-4 contains the results for scenarios in which the target requires low technological options; Figure 7-5 refers to the different scenarios in which high cost technological options are required. Note that the additional costs are expressed in kEuro.

The total cumulative **societal** costs (both technological and fuel) are provided in Table 7-10 to Table 7-13 for the years 2002, 2005, 2010, 2015 and 2020. As mentioned above, different technological packages, different trends (linear or step) and introduction dates (2012 or 2015) were applied. An equivalent procedure is followed in order to calculate the **costs to the consumer**.

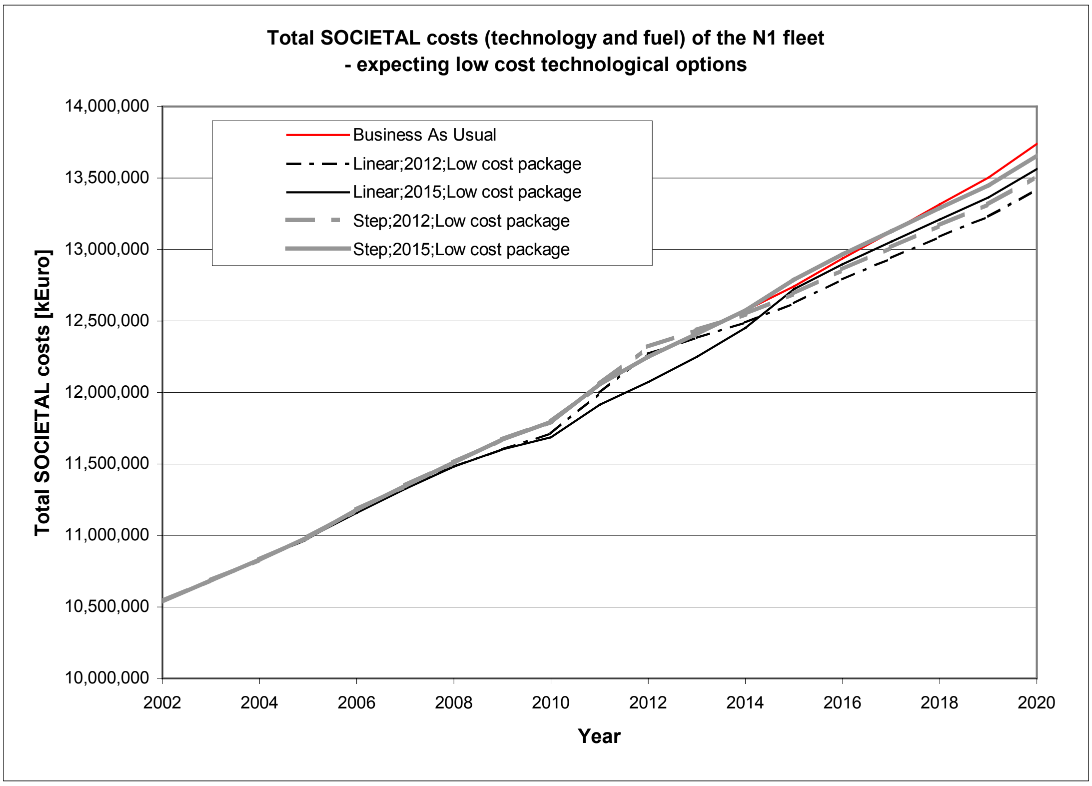

Figure 7-4: Societal costs of the linear and step-trend associated with low cost technological options

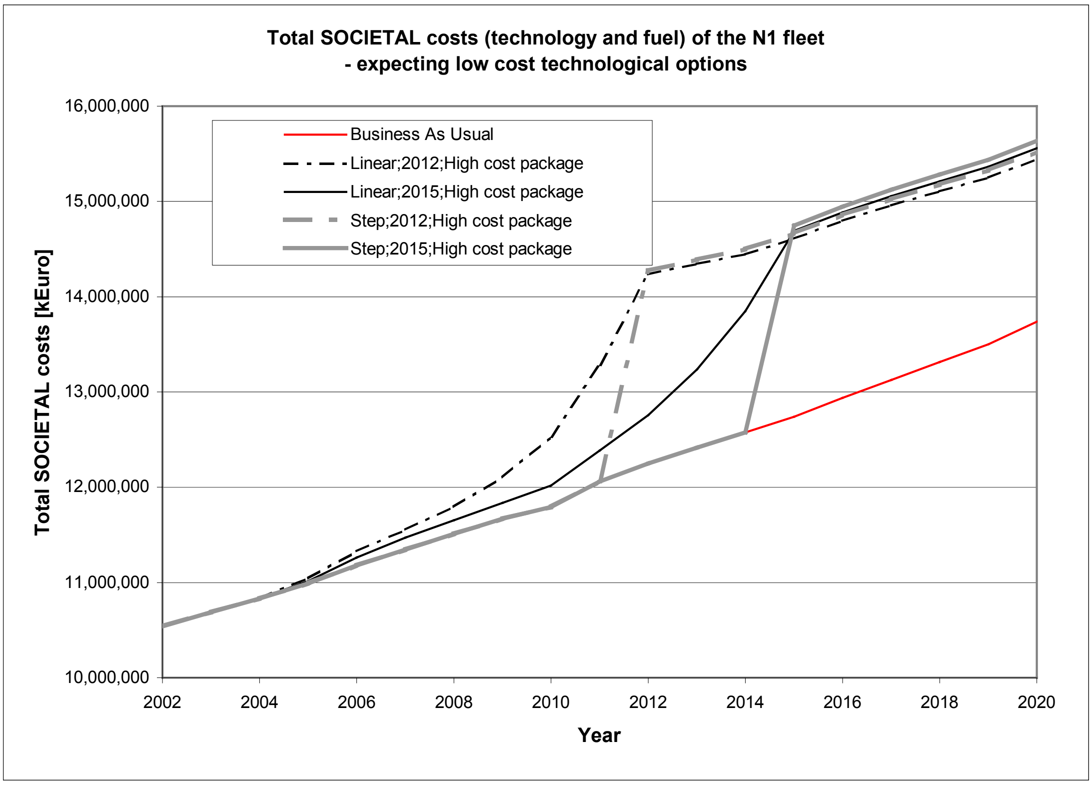

Figure 7-5: Societal costs of the linear and step-trend associated with high cost technological options

*Table 7-10: Total cumulative **societal** costs expecting a linear trend; measure effective from 2012*

kEuro	**2002**	**2005**	**2010**	**2015**	**2020**
BAU	10540923	43053091	100556628	162594309	229217066
Low cost	10540923	43040107	100373746	162142271	227616480
High cost	10540923	43110848	102433797	173354095	248914038

*Table 7-11: Total cumulative **societal** costs expecting a linear trend; measure effective from 2015*

kEuro	**2002**	**2005**	**2010**	**2015**	**2020**
BAU	10540923	43053091	100556628	162594309	229217066
Low cost	10540923	43047015	100305658	161722574	227809503
High cost	10540923	43075100	101313358	168242136	244323263

*Table 7-12: Total cumulative **societal** costs expecting a step-trend; measure effective from 2012*

kEuro	**2002**	**2005**	**2010**	**2015**	**2020**
BAU	10540923	43053091	100556628	162594309	229217066
Low cost	10540923	43053091	100556628	162613930	228488017
High cost	10540923	43053091	100556628	170446428	246346498

Table 7-13: Total cumulative ***societal*** *costs expecting a step-trend; measure effective from 2015*

kEuro	2002	2005	2010	2015	2020
BAU	10540923	43053091	100556628	162594309	229217066
Low cost	10540923	43053091	100556628	162643432	229136477
High cost	10540923	43053091	100556628	164602869	241029436

7.2.3 *Cost effectiveness*

Based on the Tables that present the cumulative CO_2 emissions and societal costs, the cost effectiveness on the basis of societal costs and costs to the consumer (Euro per saved CO_2 tonne) of the different scenarios is assessed. The approach is straightforward: the cumulative saved CO_2 emissions are calculated for each scenario by subtracting the cumulative CO_2 emissions of the applied scenario from the cumulative CO_2 emissions for 'Business As Usual'; this procedure is also applied to calculate the additional costs that incur in comparison with 'Business As Usual'. The cost effectiveness is than produced by dividing the additional costs by the CO_2 saving. The results of this exercise are summarised in Table 7-14 and Table 7-15 for the societal costs respectively costs to the consumer.

The main conclusion is that in the case of low technological options, total CO_2 emissions can be reduced with actual costs savings since fuel cost savings are higher than the additional costs for applying new technologies. The effects of different trends and introduction years are different for the different calculation years for which cost effectiveness is assessed. However, the final decision regarding which scenario will be applied depends on the final target (total CO_2 emissions from the N1 fleet) that has to be reached in a certain year.

Table 7-14: Cost effectiveness ***(societal costs)*** *of different scenarios (Euro/tonne CO_2)*

ktonnes CO_2 reduction - compared to 'Business As Usual'					
	2002	**2005**	**2010**	**2015**	**2020**
Linear;2012;low cost	0	123	7250	33699	72962
Linear;2015;low cost	0	76	4482	23947	58066
Linear;2012;high cost	0	282	16522	76513	165824
Linear;2015;high cost	0	192	11226	59557	144494
Step;2012;low cost	0	0	0	20815	56720
Step;2015;low cost	0	0	0	5082	35790
Step;2012;high cost	0	0	0	49936	136393
Step;2015;high cost	0	0	0	13486	95524
additional total costs in kEuro (technology and fuel) - compared to 'Business As Usual'					
Linear;2012;low cost	0	-12984	-182882	-452038	-1600587
Linear;2015;low cost	0	-6076	-250970	-871735	-1407563
Linear;2012;high cost	0	57756	1877169	10759786	19696972
Linear;2015;high cost	0	22009	756730	5647827	15106197
Step;2012;low cost	0	0	0	19620	-729049
Step;2015;low cost	0	0	0	49123	-80589
Step;2012;high cost	0	0	0	7852119	17129432
Step;2015;high cost	0	0	0	2008560	11812370
cost effectiveness of different scenarios (Euro/tonne CO_2 reduction)					
Linear;2012;low cost	0	-105	-25	-13	-22
Linear;2015;low cost	0	-80	-56	-36	-24
Linear;2012;high cost	0	205	114	141	119
Linear;2015;high cost	0	115	67	95	105
Step;2012;low cost	0	0	0	1	-13
Step;2015;low cost	0	0	0	10	-2
Step;2012;high cost	0	0	0	157	126
Step;2015;high cost	0	0	0	149	124

Table 7-15: Cost effectiveness ***(costs to the consumer)*** *of different scenarios (Euro/tonne CO_2)*

ktonnes CO_2 reduction - compared to 'Business As Usual'					
	2002	**2005**	**2010**	**2015**	**2020**
Linear;2012;low cost	0	123	7250	33699	72962
Linear;2015;low cost	0	76	4482	23947	58066
Linear;2012;high cost	0	282	16522	76513	165824
Linear;2015;high cost	0	192	11226	59557	144494
Step;2012;low cost	0	0	0	20815	56720
Step;2015;low cost	0	0	0	5082	35790
Step;2012;high cost	0	0	0	49936	136393
Step;2015;high cost	0	0	0	13486	95524
additional total costs in kEuro (technology and fuel) - compared to 'Business As Usual'					
Linear;2012;low cost	0	-41728	-1300573	-5278710	-12715913
Linear;2015;low cost	0	-22084	-1091726	-4915874	-10542789
Linear;2012;high cost	0	82584	1811686	12461562	19683351
Linear;2015;high cost	0	21599	190696	4225789	12989351
Step;2012;low cost	0	0	0	-2703076	-8958873
Step;2015;low cost	0	0	0	-588955	-5016009
Step;2012;high cost	0	0	0	9768105	17996030
Step;2015;high cost	0	0	0	2405706	12191147
cost effectiveness of different scenarios (Euro/tonne CO_2 reduction)					
Linear;2012;low cost	0	-339	-179	-157	-174
Linear;2015;low cost	0	-291	-244	-205	-182
Linear;2012;high cost	0	293	110	163	119
Linear;2015;high cost	0	113	17	71	90
Step;2012;low cost	0	0	0	-130	-158
Step;2015;low cost	0	0	0	-116	-140
Step;2012;high cost	0	0	0	196	132
Step;2015;high cost	0	0	0	178	128

8 Conclusions and recommendations

Based on the findings presented and discussed in this report and the objectives that specifically had to be addressed according to the tender, the following conclusions can be drawn:

With regard to the **collection and processing of information**:

- A clear overview of the N1 vehicle market has been summarised taking into account the key players (manufacturers, joint ventures and buyers), the types of vehicles that are sold and insight in the procedures that are applied to grant type approval to these types of vehicles.

- Collection on data regarding new registrations and N1 vehicle fleet proved to be a challenging task since the data provided is either different on level of detail or is not consistent since Member States apply different definitions for Light Commercial Vehicles. In addition, the detail regarding vehicle parameters that is needed to determine weighted averages is currently not available.

- The RAND report provided a rather helpful overview on the technological options that can be applied in the (near) future in order to reduce CO_2-emissions from N1 vehicles. Besides the 'Business As Usual' scenario, from these data four different technology packages have been defined for which average cost/benefit trends have been derived. N1 vehicles of class III proved to achieve the highest grams CO_2-reduction having the lowest costs.

With regard to the **modelling methodology** applied

- Several vehicles were measured in the framework of this project on different load conditions (mass and air drag resistance). The results were used for validating the models applied and verifying the data sources used.

- Advisor (the modelling software used) was successfully applied for analysing the issues (amongst others completed multi-stage vehicles, family concept and predicting emissions for laden vehicles) to be addressed in this study. The average deviation of computed results from measurements was found in the order of ±2.5% in terms of NEDC CO_2-emissions.

- A load of 50% of the vehicle's load carrying capacity was found to increase fuel consumption by 5.6% for all classes.

With regard to the **provisions of the Directive 2004/3/EC**:

- Data from engines that are type approved according to Directive 88/77/EEC can be used for predicting fuel consumption of a complete vehicle and thus granting type approval, provided that vehicle simulations are performed. Engine maps derived from ESC-13 points can be used for the modelling procedure with a deviation in the order of ±6%. Provided that full engine maps are available (based on at least of 20 measured points, most of them on low engine speeds and loads), the deviation can be less than 2%.

- Granting type approval to completed multi-stage vehicles based solely on chassis-engine-gear ratios combinations is possible and technically acceptable. The type approval for completed multi-stage vehicles can be granted via either modelling of the complete vehicle or by comparison with a completed vehicle that is equipped with the same engine, has the same gear ratios and has already received type approval by using table values of Directive 96/44/EC. In case of the comparison for granting type approval, the difference in the weight of the two vehicles can be accounted for as follows:

a) if the two vehicles have the same weight the same value of fuel consumption can be used;
b) in all other cases a 1.5% increase (decrease) in the fuel consumption should be considered per inertia class.

- The way vehicle families are currently established does not allow direct comparison with the 6% derogation rule also introduced in 2004/3/EC. The 6% derogation is less strict than the family concept (±2%) and provides an upper limit to fuel consumption, while the family concept introduces a lower limit. In case the vehicle family should allow a 6% fuel consumption deviation within its members, the vehicle family criteria should be redefined.

- A detailed analysis of the three major factors (mass, frontal area, gear ratios) and their effects (individual or combined) to fuel consumption was performed. The results can be used for revising the vehicle family criteria.

- The analysis and measuring experience in this study indicated that the values that determine the chassis dynamometer settings for type approval according to Directive 96/44/EC produce significantly lower fuel consumption and CO_2-emissions than those derived from coast down tests. This fact may lead to market distortions and cancel competitive advantages of vehicles with improved design that are less fuel consuming.

With regard to the **emissions calculations:**

- Data from the most sold N1 vehicles in 2002 and RAND's report were used for acquiring a picture of the N1 fleet with respect to manufacturer group and class. It is not expected that the composition of the fleet will change significantly in the years to come.

- With respect to the classes, the N1 fleet consists of 27.5% Class I, 33% Class II and 39.5% Class III vehicles. In the case of manufacturer's grouping, 91% of the vehicle fleet originates from ACEA manufacturers, 7% from JAMA and 1% from KAMA.

- CO_2-emission factors were derived from type approval databases and tests conducted in the scope of this project. These data is included in relevant databases owned by the consortium.

- Emission factors for this study are based on the NEDC driving cycle on which the vehicle is tested unloaded. Since the average CO_2-emissions that have been calculated in the RAND study are based on real world derived values (loaded and real-world driving cycles), the averages calculated in the current study are lower.

- The methodology of CO_2-emissions calculation currently used in TRENDS was revised and new lifetime functions were used for emissions prediction.

With regard to the **evaluation of different policy options:**

- A detailed breakdown is given on the issue of policy options that could probably be applied to reduce CO_2-emissions from N1 vehicles. In addition, the pros and cons for practical application of a policy measure have been intensively addressed.

- CO_2-emissions for all types of N1 vehicles will not be available before 2010. Therefore, it will be difficult to introduce CO_2-emission limit values or labelling procedures on a short term.

- The most promising policy options that could be practically applied and are acceptable for consumers, manufacturers and policy makers are the introduction of emission limit values (ELVs) and voluntary agreements (VA). In addition, monitoring and labelling could be of interest as well by just extending the current procedures that have been applied for M1s.

- It is unlikely that schemes like emission trading and bubble concept averaging are applied to N1s without being applied to M1s.

With regard to the **scenario study that have been conducted:**

- For the period 2002 to 2020, the cumulative CO_2-emissions that are produced by N1 vehicles and associated cumulative additional societal costs and costs to the customer are calculated for 9 different scenarios. Application of low cost technology packages can - as compared with the 'Business As Usual' scenario - result in CO_2 reduction and saving of costs. However, the total CO_2-reductions achieved could be insufficient in case low cost technology packages are applied. High cost technological options could keep the CO_2 emissions produced by N1 vehicles of about the same level as it was in 2002, however this will have its costs.

- In case a linear trend is expected from the date it have been decided that a measure will come into force in the future, the cost effectiveness of the CO_2 reduction is better than the one of a step trend (emission reduction at the moment the measure comes into force). Therefore, applying a monitoring scheme that evaluates whether intermediate reduction targets are met is cost-effective.

Based on the experience acquired in the course of this study, a number of **recommendations** for future actions can be made.

- There appears to be rather high differences in available data-sets regarding the new registrations and N1 vehicle fleet in the EU in general and more specifically for each Member State. It is therefore recommended to prescribe guidelines that Member States have to apply on registering new N1 vehicles in order to make the different data-sets more comparable. Such guidelines will already be introduces in case the monitoring process - which is currently in use for M1 vehicles - will be extended to cover N1 vehicles as well.

- There is the need to re-evaluate the type approval legislation with a more particular focus on CO_2-emissions. Currently the type approval legislation provides a robust framework for controlling and monitoring gaseous emissions, however, amendments seem necessary to improve its efficiency in terms of fuel consumption, CO_2-emissions and energy saving policy.

- Publicising fuel consumption data should be compulsory for all N1 vehicles and the measuring procedures should be enhanced in order to provide results that are closer to the real world performance of the vehicles.

- Improved design of vehicles and the use of fuel-efficient engines should be promoted. For this reason type approval procedures mentioned in 80/1268/EEC must be revised especially for the case of predefined chassis dynamometer settings (as last amended by Directive 96/44/EC). Additionally, the possibility of disconnecting air drag coefficients from the mass of the vehicle should be thoroughly studied.

- This study has shown that computer models may be deployed for accurately predicting the fuel consumption and CO_2-emissions of vehicles. This procedure can be beneficial for both manufacturers and authorities. It is strongly suggested that the possibility of granting type approval through the use of computer simulation data is seriously considered.

- Since CO_2-emission factors for real-world Urban and Motorway driving are in general higher and for Rural driving in general lower than the type approval CO_2-emissions, the issue whether type approval CO_2 emissions can be applied to estimate total CO_2 emissions for driving in real-life has to be assessed more thoroughly. Additional insight is needed about the number of kilometres driven with N1 vehicles in Urban, Rural and Motorway conditions.

- Next investigation steps have to be taken to more thoroughly explore the practicality of the measure Technology Standard and Labelling. Utility parameters - describing the purpose of the vehicle - have to defined and assessments have to be made to find relations with CO_2-emissions.

9 References

[ACEA,2000]	ACEA website: http://www.acea.be/ACEA/NewReg-2000-byCountry_Manuf.xls - sales data for 2000
[ACEA,2002]	ACEA website: http://www.acea.be/ACEA/NewReg-2002-byCountry.xls - sales data for 2002
[Elst,2004]	Elst, D.A.M.M. et al, Measuring and preparing reduction measures for CO2-emissions from N1 vehicles - first interim report. Report number: 04.OR.VM.013.1/DE, May 2004
[Fontaras,2004]	Fontaras, G., Comparison of modelling techniques for Heavy- and Light-Duty Vehicles, COST 346 short term scientific mission report, September 2004.
[Gillespie,1992]	Gillespie, T.D, Fundamentals of Vehicle Dynamics, Society of Automotive Engineers (SAE), 1992
[Jol,2004]	K. Jol, Alle bestelauto's 2004 - ISBN 90-6013-437-0
[Joumard,2001]	Joumard, R. et al, Emission unitaires de polluant des vehicules utilitaires legers, April 2001
[KBA,2003]	Type approval factors database of the Kraftfahrt Bundes Amt, 2003
[Lastauto und Omnibus,2004]	Lastauto und Omnibus Katalog, 2004
[Lu,2003]	Lu, C. et al, Preparation of measures to reduce CO2-emissions from N1 vehicles. April 2003
[Mathworks]	The Mathwork Inc., Advisor 3.2 Documentation provided with Advisor software
[Mehlin,2004]	Mehlin, M. et al, Preparation of the 2003 review of the commitment of car manufacturers to reduce CO2-emissions from M1 vehicles, March 2004
[Ntziachristos,2000]	Ntziachristos, L. and Samaras, Z., COPERT III computer programme to calculate emissions from road transport; Methodology and emission factors – (version 2.1), November 2000
[Peugeot,2004]	Peugeot, Peugeot Boxer specification and pricing 2004, downloaded from www.peugeot.com
[Ten Brink et al, 2004]	Ten Brink et al., Service contract to carry out economic analysis and business impact assessment of CO_2 emissions reduction measures in the automotive sector, October 2004
[De Ceuster,2004]	De Ceuster, G. Van Herbruggen, B., Logghe, S. and Proost, S. TREMOVE 2.0 model description, Report to the European Commission DG ENV, March 2004
[Trends,2002]	LAT, DTU, PSIAMTK, INFRAS. TRENDS main report to the European Commission, October 2002.
[VCA,2003]	Type approval factors database of the VCA (UK), 2003
[Zachariadis, 1995]	Zachariadis, T., Samaras, Z., Zierock, K.H., Dynamic modelling of vehicle population, North Holland, 1995

A Project structure

The work packages in which the project was split-up are indicated below, the responsible consortium partner is indicated between brackets and the task description as is indicated in the technical annex of the tender is given between –dashes–. Due to the existing overlap in the tasks specified in the tender, some work packages deal with more than one task.

The project structure is as follows:

Task 1 - WP 100 - Collect further data and information

WP110: The N1 vehicle market in the EU **(IEEP)** –A.–
WP120: The specific CO_2-emissions and fuel consumption of new N1 vehicles and the specific annual averages of the fleets sold by member companies of ACEA, JAMA and KAMA **(TNO)** –A.–
WP130: State of technology and potential technical measures to reduce CO_2-emissions (including costs) **(TNO)** –A.–
WP140: Member States, car manufacturers and NGOs activities aiming at specific CO_2-emission reduction of N1 vehicles **(IEEP)** –A.–
WP150: Future evolution of N1 specific CO_2-emissions **(LAT)** –A.–

Task 2 - WP200 - Modelling methodology and model validation by measurements

WP210: Study the possibilities of a methodology to predict CO_2-emissions on the procedure prescribed in 80/1268/EEC (NEDC-test) for vehicles whose engine is type approved according to Directive 88/77/EEC (ESC-test) **(LAT)** –D.–
WP220: Validation of the proposed methodology of WP210 by measurements **(LAT)** –D.–
WP230: Proposal of a methodology to predict CO_2-emissions for laden N1 vehicles in real use conditions and completed multi-stage N1's **(LAT)** –C. and D.–
WP240: Measurement of CO_2-emissions and fuel consumption of the 20 most sold N1 vehicles in the EU and validation of the proposed methodology of WP230 **(TNO)** –B. and D.–
WP250: Evaluation and possible improvement of the N1 family concept as introduced in Directive 80/1268/EEC by Amendment 2004/3/EC **(LAT)** –E.–

Task 3 - WP600 to WP900 - Scenario studies and policy option evaluation; incorporation in the Directive

WP600: Put forward an estimate of the 2002 EU N1 fleet CO_2 average, for totals, the 3 subclasses and for associations ACEA/JAMA/KAMA **(LAT)** –F.–
WP700: Study the identified potential policy options to reduce CO_2-emissions from N1 vehicles (accounting for costs, market aspects etc.) **(IEEP)** –G.–
WP800: Study in depth the practical, legal and organisational problems of the most promising policy options **(IEEP)** –H.–
WP900: Make pragmatic proposals for the monitoring and evaluation of progress **(TNO)** –I.–

Task 4 – Project management

WP1000: Project management (TNO)

B Annex II B of Directive 92/53/EEC

DEFINITION OF VEHICLE TYPE
1. For the purposes of category M1:

A ’type’ shall consist of vehicles that do not differ in at least the following essential respects:

- the manufacturer,
- the manufacturer’s type designation,
- essential aspects of construction and design:
- chassis/floor pan (obvious and fundamental differences),
- power plant (internal combustion/electric/hybrid).

’Variant’ of a type means vehicles within a type, which do not differ in at least the following essential respects:

- body style (e.g. saloon, hatchback, coupe, cabriolet, wagon, etc.),
- power plant:
- working principle (as in item 3.2.1.1 of Annex III),
- number and arrangement of cylinders,
- power differences of more than 30 % (the highest is more than 1,3 times the lowest),
- capacity differences of more than 20 % (the highest is more than 1,2 times the lowest),
- powered axles (number, position, interconnection),
- steered axles (number and position).

’Version’ of a variant means a vehicle that consist of permitted combinations of items shown in the information package in accordance with Annex III and Annex VIII.
Full identification of the vehicle just from the designations of type, variant and version must be consistent with a single accurate definition of all the technical characteristics required for the vehicle to be put into service, and particularly the parameter(s) necessary for determining the taxes applicable to the vehicle. These parameters will be established in the relevant Annexes that cover the information to be provided for type-approval purposes.

C Basic configurations of light commercial vehicles

Source: Centre of Automotive Industry Research (CAIR), Mr. Peter Wells
The following gives a brief outline of the basic configurations of light commercial vehicles available in Europe:

- Car-derived van. This is a vehicle derived from a mainstream and usually mid-size car. The front seats and most of the vehicle structure and mechanical components are the same as the car, the main difference being that the area behind the front seats is an enclosed steel 'box' with rear access doors. The general position is that these are vehicles of less than 1.8 tonnes GVW, and these vehicles are all subject to the M1 type approval process, including CO2 emissions figures.
- Standard panel van. This is a vehicle typically up to 3.5 tonnes GVW with an all-steel enclosed rear body area, diesel engine, and two front seats or a bench seat. In the industry there is often an informal division of this class into light, medium and heavy panel van.
- Flatbed van. This is the same as the panel van, except that the rear load area is open, usually with short sidewalls and a downward-hinged rear gate. Note that some US-style pick-up trucks may be classified as cars (M1) in European markets and again subject to the usual M1 Type Approval process.
- Minibus. Usually derived from a panel van platform, the minibus seats say 7 to 17 people depending upon configuration. Usually these have sliding door access on the side of the vehicle, as well as rear door access. They also have side and rear windows. Although often 'commercial' in operation, these belong in class M.
- Camper bus. This is usually a converted panel van, designed to provide living / sleeping accommodation for up to four people and is used by private consumers.
- Chassis-cab. This is a base vehicle that needs to be completed according to the specific needs of a customer, by a body builder.

It is worth noting that in the UK, as an example of Member State definitions having an impact on statistics, the Land Rover Defender is classified as a light commercial vehicle, although no other Land Rover models are so classified. The vehicle is sold mainly to the military, infrastructure companies, and to farmers, but by no means exclusively so. In all the UK data shows 46 categories of commercial vehicles, only some of which can definitely be said to be exclusively heavy commercial vehicles, with panel vans accounting for the largest single category. However, in other countries different types of light commercial vehicles dominate, e.g. in France car-derived vans are the most popular light commercial vehicle type.

In addition, a reasonably high proportion of light commercial vehicles is customised in various ways. This is less likely to be the case for car-derived vans. Generally speaking, the customisation concerns the 'working' body area of the vehicle rather than the platform itself, the engine or the drivetrain (though there can be specialist conversions or variants of these also). So, the customisation can involve a different shape of body and/or the fittings inside the body. Both sorts of customisation can change certain performance aspects of the vehicle, most obviously the frontal area and vehicle unladen weight. At the extreme these changes can be significant for vehicle performance compared with the base vehicle from which the variant has been derived, including CO_2-emissions - for example the armour-plated cash/security van.

Customisation is carried out by one of three parties:

- The original vehicle manufacturer. In these cases the vehicle manufacturers have to make a decision on the balance between the benefits of standardisation, and the extra value generated by undertaking customisation. Vehicle manufacturers are reluctant to ‘slow down’ mainstream assembly lines with high levels of customisation, but do sometimes have a secondary area off-line where such work can be done.
- The main user. As is discussed below, there are some major buyers of light commercial vehicles and these may decide that they would prefer to undertake customisation themselves. Equally, the bigger purchasers can also request modifications from the vehicle manufacturers and be important enough to get the work done for them.
- Independent converters. These tend to be fairly small companies, specialised in certain types of conversion suited to particular market applications.

D Development of the modelling methodology

As mentioned in section 4, two modelling approaches were investigated during this study. The first strategy was to use ADVISOR which is a commercial modelling tool for conventional or hybrid vehicles and the second was to create a simplified algorithm based on basic equations of resistances during the motion of the vehicle that would predict fuel consumption in relation to the basic characteristics of the vehicle [Gillespie,1992]. Both strategies were thoroughly studied and validated. For these purposes a series of existing experimental data was used as well as new ones that were derived from the experiments conducted in the framework of this project.

At this point it is necessary to make a short introduction to both models and their function and take a look at the results of their validation. This procedure is vital for building confidence in the models which were used for addressing several issues of the study. The tasks which has to be assessed by the models are mentioned below. The models were used for:

- determine the effect of the most influencing parameters on the CO_2-emissions and fuel consumption;
- predict CO_2-emissions from N1 vehicles in laden real use conditions;
- evaluate the family concept (link 6% derogation to vehicle differences)
- predict emissions for a N1 vehicle that contains an engine that granted emission type approval according to Directive 88/77/EEC
- predict emissions for completed multi-stage vehicles (influence of mass, C_w*A, CO2-emissions from 13 mode test).

ADVISOR

A detailed modelling of N1 vehicles can be performed through ADVISOR – Advanced VehIcle SimulatOR – software. ADVISOR is an easy to use tool for modelling various types of vehicles. It is based on Simulink, a flexible and user friendly modelling software included in Matlab. More specifically, Advisor is designed for quick analysis of the performance and fuel economy of conventional, electric, and hybrid vehicles. It also provides a backbone for the detailed simulation and analysis of user defined drivetrain components.

Generally Advisor operates based on fundamental principals of vehicle dynamics and user provided data regarding the engine's performance and the vehicle characteristics. It is known that the main factors affecting fuel consumption are the vehicle mass, aerodynamic resistance and the engine efficiency. Mass is related to rolling resistances and is easily definable. Aerodynamic resistance is defined by the vehicle's frontal area (FA) and design (factor C_w) and their result is always combined, therefore from now on we will refer to the product C_w*FA as aerodynamic factor. The efficiency of the engine is related to the load and speed of the vehicle and therefore in a predefined cycle, such as NEDC, the efficiency is linked to mass and aerodynamic resistance. It should be noted that all vehicle tests – experimental or computational – were conducted using specific driving cycles; thus from now on any reference to engine efficiency will correspond to the mean engine efficiency throughout the cycle. This engine efficiency multiplied by a factor of 0.9 [Gillespie,1992] which is more or less the efficiency of all other mechanical parts (gearbox, clutch, final drive), provides the mean overall efficiency of the vehicle throughout the cycle which from now on will be referred to efficiency. It is possible to determine the engine efficiency for a certain vehicle, driven in a certain driving pattern, when the specific fuel consumption map of the engine is given. This is the basis on which Advisor operates. Further details about the software are provided below [Mathworks].

ADVISOR can be used to:
- estimate the fuel economy of unbuilt vehicles;
- learn about how conventional, hybrid, or electric vehicles use (and lose) energy throughout their drive-trains;
- compare tailpipe emissions produced on a number of driving cycles;
- evaluate a control logic for your hybrid vehicle's fuel converter;
- optimise the gear ratios in your transmission to minimize fuel use or maximize performance, etc..

The models in ADVISOR are mostly empirical, relying on drive-train component input/output relationships measured in the laboratory. These models are also quasi-static, using data collected in steady state (for example, constant torque and speed) tests and correcting them for transient effects such as the rotational inertia of drive-train components.

Capabilities and intended uses
ADVISOR uses simple physics and measured component performance to model existing or imagined vehicles. Its power lies in the prediction of the performance of vehicles that have not yet been built. It answers the question “what if we build a car with certain characteristics?” ADVISOR usually predicts fuel use, tailpipe emissions, acceleration performance, and grade-ability.
In general, the user takes two steps:
1. Define a vehicle using measured or estimated component and overall vehicle data.
2. Prescribe a speed versus time trace, along with road grade, that the vehicle must follow.

ADVISOR then puts the vehicle through its paces, making sure it meets the cycle to the best of its ability and measuring (or offering the opportunity to measure) just about every torque, speed, voltage, current, and power passed from one component to another. In this respect, ADVISOR allows the user to answer questions like:
- Was the vehicle able to follow the trace?
- How much fuel and/or electric energy were required in the attempt?
- What were the peak powers delivered by the drivetrain components?
- What was the distribution of torques and speeds that the piston engine delivered?
- What was the average efficiency?

It becomes clear that ADVISOR is suitable for the purposes of the current project, since it gives the possibility to run driving cycles with various vehicles in order to assess the effect of mass and frontal area on fuel consumption, as well as to evaluate other factors that might affect the vehicle’s performance. Moreover, ADVISOR is capable of providing the engine’s efficiency throughout the cycle as well as the total efficiency of the vehicle . Evidently, the data from such tests have to be validated against a limited number of full scale real world measurements, in order to evaluate the accuracy of the modelling.

Simplified Methodology

Predicting fuel consumption and thus CO_2-emissions of a vehicle is a challenging task. The general idea behind this simplified methodological approach is that fuel consumption (and CO_2-emissions) is directly linked to energy consumption. Evaluating all the parameters that affect the energy balance in a moving car is a quite difficult exercise. However the use of simple laws of physics and vehicle dynamics for evaluating the energy flow in a vehicle operating in a known driving cycle can lead to acceptable results.

The necessary power to maintain the motion of the vehicle during the driving cycle is divided into three separate parts, which can be expressed through an analytical equation as follows:

Rolling Resistance

$$Pf = m \cdot g \cdot f \cdot v$$

Aerodynamic drag

$$Pa = \frac{1}{2} \cdot \rho \cdot Cw \cdot A \cdot v^2 \cdot v$$

Inertia

$$Pi = m \cdot \frac{dv}{dt} \cdot v$$

According to the above we conclude that the power needed to maintain the vehicle's motional status at any moment 't' during a driving cycle can be expressed as the sum of the three equations. Knowing the function of power in relation with time we can easily integrate in order to calculate the necessary energy for accomplishing the entire cycle.

$$Etot = \int_0^T (Pf + Pa + Pi) \cdot dt$$

The value of limit T depends on the driving cycle. The above equation can be analysed to:

$$Etot = \frac{1}{2} \cdot \rho \cdot Cw \cdot A \cdot \int v^3 \cdot dt + m \cdot g \cdot f \cdot \int v \cdot dt + m \cdot \int \frac{du}{dt} \cdot v \cdot dt$$

The numerical evaluation of the three integrals mentioned above can be easily achieved for any driving cycle because the value of the vehicle's velocity at each time moment is predefined. The values of the integrals are independent of the vehicle's characteristics and are only related to the driving cycle. Therefore the total energy needed is given by the equation:

$$Etot = \frac{1}{2} \cdot \rho \cdot Cw \cdot A \cdot K + m \cdot (g \cdot f \cdot L + M)$$

The values of the integrals K, L, M for NEDC are shown in Table D-1

Table D-1: Values of integrals for the NEDC cycle

K	3491667 ($m^3/sec^{2)}$
L	9426 (m)
M	1288 (m^2/sec^2)

In order to calculate the vehicle's fuel consumption (in litres per 100 km), it is possible to assume an overall efficiency 'k' for the vehicle. This factor k is the mean efficiency of all the vehicle's mechanical parts that intervene between the fuel and the wheel of the vehicle. For example if the engine has an average efficiency over the cycle of 25%, the clutch and the gearbox an average efficiency of 94% and the wheel-axle system 95% the k parameter should be about 22% (0.25x0.95x0.94). Knowing the specific heat of diesel Hu and its density d, we can predict the fuel consumption of the car (in litres per 100/km) with the equation:

$$FC = \frac{q}{k \cdot Hu \cdot d} \cdot (\frac{1}{2} \cdot \rho \cdot Cw \cdot A \cdot K + m \cdot (g \cdot f \cdot L + M)) + c$$

with:

q:	conversion factor (for NEDC=9.09)
d:	density of fuel applied ~aprox. 0.835 kg/lt
k:	average efficiency (engine, gearbox, clutch, final drive)
Hu:	specific heat of fuel applied ~43 MJ/kg
m:	vehicle mass in [kg]
A:	frontal area in [m^2]
C_w	air drag coefficient [-]
K, L,M:	constant factors for the driving cycle, dependant on vehicle speed
g:	gravity 9.81 m/s^2
f:	rolling resistance coefficient, usually ~0.009
ρ:	air density 1.2 kg/m^3
c:	idling consumption [lt/100km]

Factor q is 100km / (length of the cycle in km) in order to obtain a per 100km result. Factor c is a constant introduced for calculating the fuel consumed at idling. Its value – expressed in (lt/100km) - depends on the total idling time of the cycle and the fuel consumption of the engine at idling conditions. The value of c for the engines of N1s for NEDC is between 0.3 and 0.5 lt/100km with higher values corresponding to engines of higher capacities.

It becomes clear from the above equation that fuel consumption of a specific vehicle for NEDC depends only on factors C_w, A, m and k. It can be expressed through a simple function of the form:

$$FC(m, A \cdot Cw, k) = \frac{1}{k} \cdot (a \cdot m + b \cdot A \cdot Cw) + c$$

At this point we should note that "b" has a constant value of **0.53** for all vehicles for NEDC. Factor "a" depends on the rolling resistance coefficient (f) which is calculated for each vehicle through the coast down time or the legislated tables (Appendix F). For all vehicles and NEDC the value of "a" is:

$$a = 234 \cdot 10^{-4} \cdot f + 3258 \cdot 10^{-7}$$

The only detail missing for having a complete fuel consumption function is the value of k. There is no way of analytically evaluating k without having the specific fuel consumption map of the engine. What is though possible is to try and find an empirical formula connecting k to m and A*C_w something which was done by using the measurements conducted on a VW Golf 1.9 TDi in the framework of this project.

The main purpose for developing this simplified equation was for predicting the change in the fuel consumption of the vehicle when certain changes in its mass or aerodynamics occur. The limits of these changes were set by the definition of the vehicle family in 2004/3/EC. The first approach was to assume that in these narrow limits factor k does not change. This assumption produces a linear function between fuel consumption m and C_w*A which in a 3-d space represents a plane. This assumption validates the approach presented in the family concept analysis which introduces a linear relation between fuel consumption and mass and fuel consumption and C_w*FA. However results produced with constant k had greater deviation than expected (over 5%). Therefore a different approach was examined.

A linear equation was assigned to the efficiency k in relation to the vehicle mass and air drag. This equation was derived from fuel consumption data by calculating factor k for 3 different vehicle measurements (base, mass+220, air drag*1.2). So on this occasion:

$$k = 0.10934{+}0.061232 \cdot \mathrm{Cw} \cdot \mathrm{FA}{+}6.8182 \cdot 10\text{^-}5 \cdot \mathrm{m}$$

In this case fuel consumption remains a function of air drag and vehicle mass of the form:

$$FC(m, A \cdot Cw) = \frac{(a \cdot m + b \cdot A \cdot Cw)}{0.10934{+}0.061232 \cdot \mathrm{Cw} \cdot \mathrm{A}{+}6.8182 \cdot 10\text{^-}5 \cdot m} + c$$

Table D-2 provides an overview of the results and the accuracy of the two modelling approaches for VW Golf.

Table D-2: Comparison of Advisor simulation and the equation developed for VW Golf

Cycle	mass	Air Drag	Measured	Advisor	Equation	Deviation Meas.-Adv.	Deviation Meas.-Eq.	Deviation Eq.-Adv.
NEDC	1130	0.58	-	4.40	4.43	-	-	-0.7%
NEDC	1130	0.7	4.56	4.54	4.57	-0.4%	0.3%	-0.7%
NEDC	1130	0.84	-	4.71	4.73	-	-	-0.4%
NEDC	1360	0.58	-	4.68	4.67	-	-	0.2%
NEDC	1360	0.7	4.81	4.82	4.80	0.2%	-0.2%	0.4%
NEDC	1360	0.84	4.94	4.99	4.94	0.9%	-0.1%	1.0%
NEDC	1590	0.58	-	4.96	4.89	-	-	1.4%
NEDC	1590	0.7	5.05	5.11	5.01	1.2%	-0.7%	2.0%
NEDC	1590	0.84	-	5.26	5.13	-	-	2.5%

The surface that is produced through this linear efficiency factor approach is presented in figure D-1. It should be noted that this surface is not a plane in the 3 dimensional space. However if we zoom in the area of interest of for this study which is more or less defined by the vehicle family criteria mentioned in chapter 4 we see that the surface tends to become a plane. This observation is very important because it verifies the linear relations between mass, air drag and fuel consumption introduced in chapter 4 of this study.

A similar approach could be adopted for all vehicles. The problem is that at least 3 measurements are necessary for retrieving the efficiency function. Since Advisor proved very reliable and allows a more detailed approach of the vehicle modelling, it was chosen for the purposes of the study. In spite the fact that this approach was not used, it has provided interesting and should be investigated more for possible future use.

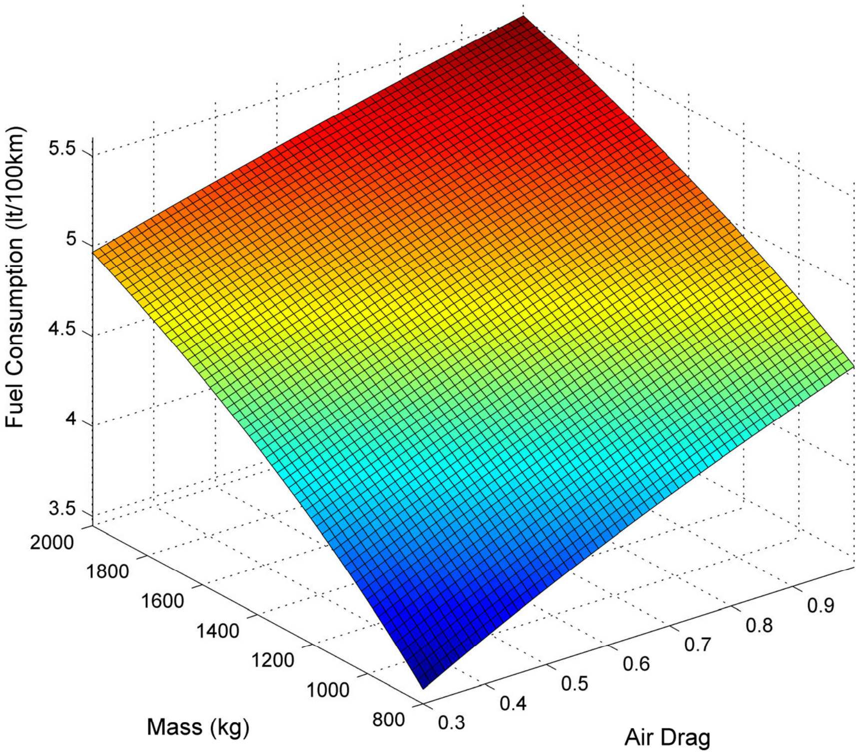

Figure D-1: Fuel consumption plane for Golf

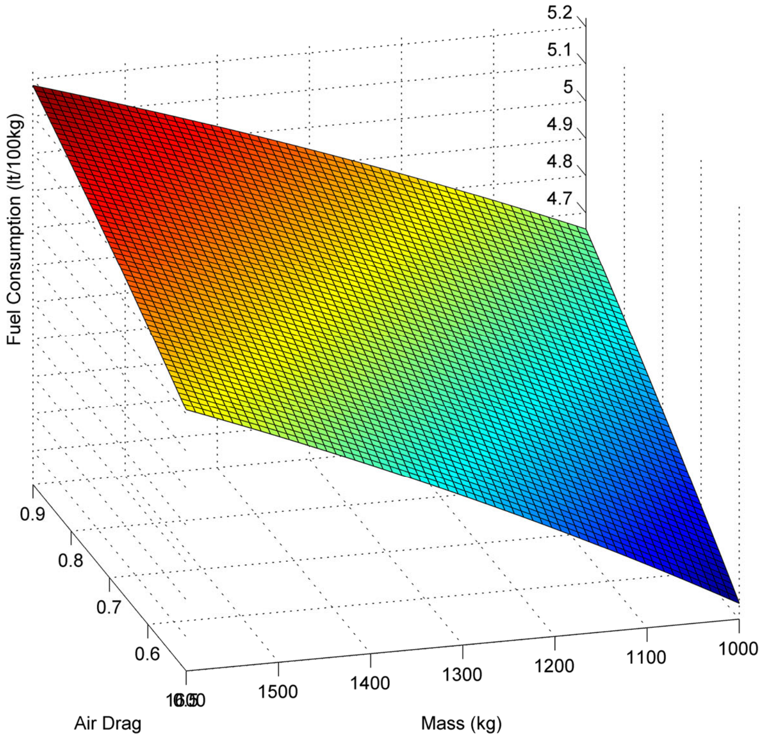

Figure D-2: Fuel consumption plane (limited area)

Validation of the methodology proposed

In this paragraph the modelling approach developed for this project are going to be validated and evaluated. For this purpose experimental data retrieved from tests on the chassis dyno are going to be used as well as other taken from relevant databases.

As presented earlier, a number of measurements were conducted in different vehicles at different mass and aerodynamic drag points. These points were chosen not only for acquiring an image of how these factors affect the fuel consumption of the vehicle but also for creating a basis on which the models would be tested and validated. Furthermore the results from these measurements were compared to the values that exist in the KBA emissions database in order to see how accurate this information provided by the manufacturers is.

Several models of real vehicles where simulated in ADVISOR with full and 13 point engine maps and the results where compared to measurements conducted in the framework of this project and with existing values from relevant databases e.g. KBA. The comparison between experimental and simulated results is presented thoroughly in Tables D-3 to D-5.

Table D-3: Simulated and experimental results for Peugeot Boxer

	Driving cycle	Mass (kg)	Air Drag	Part	FC [l/100km]	Advisor [l/100km]	Advisor 13 points [l/100km]	Diff FC	Diff FC 13
Boxer	MVEG-B Conditions: cold	1930	1930 equiv.	UDC	12.42	11.74	11.28	-5.85%	-10.11%
				EUDC	8.57	8.48	8.10	-1.09%	-5.87%
				Total	9.99	9.67	9.19	-3.34%	-8.77%
	MVEG-B Conditions: cold	2270	2270 equiv.	UDC	12.67	12.18	11.56	-4.03%	-9.55%
				EUDC	8.88	8.91	8.50	0.28%	-4.51%
				Total	10.28	10.10	9.62	-1.80%	-6.91%
	MVEG-B Conditions: hot	1930	1930 equiv.	UDC	10.73	10.62	10.29	-1.02%	-4.28%
				EUDC	8.57	8.51	7.95	-0.57%	-7.74%
				Total	9.36	9.27	8.81	-0.96%	-6.34%
	MVEG-B Conditions: hot	2150	1930 equiv.	UDC	10.75	11.25	10.57	4.40%	-1.74%
				EUDC	8.61	8.62	8.11	0.15%	-6.14%
				Total	9.40	9.58	9.01	1.87%	-4.36%
	MVEG-B Conditions: hot	2270	1930 equiv.	UDC	10.76	11.38	10.72	5.44%	-0.43%
				EUDC	8.80	8.71	8.20	-1.10%	-7.40%
				Total	9.53	9.68	9.11	1.62%	-4.51%
	MVEG-B Conditions: hot	1930	1930 equiv. 85%	UDC	10.84	10.90	10.22	0.56%	-6.04%
				EUDC	8.14	8.02	7.60	-1.41%	-7.06%
				Total	9.13	9.07	8.55	-0.67%	-6.75%
	MVEG-B Conditions: hot	1930	2270 equiv.	UDC	10.73	11.03	10.34	2.69%	-3.79%
				EUDC	8.55	8.65	8.18	1.20%	-4.51%
				Total	9.35	9.52	8.97	1.73%	-4.31%
	MVEG-B Conditions: hot	2270	2270 equiv.	UDC	11.06	11.42	10.76	3.11%	-2.77%
				EUDC	8.76	8.90	8.42	1.52%	-4.00%
				Total	9.61	9.82	9.28	2.09%	-3.59%

Table D-4: Simulated and experimental results for Peugeot Boxer

	Driving cycle	Mass (kg)	Air Drag	Part	FC [l/100km]	Advisor [l/100km]	Advisor 13 points [l/100km]	Diff FC	Diff
Daily	MVEG-B Conditions: cold	2040	2040 equiv.	UDC	14.33	12.07	11.54	-18.73%	-24.14%
				EUDC	8.42	8.45	8.50	0.42%	1.03%
				Total	10.59	9.78	9.61	-8.38%	-10.20%
	MVEG-B Conditions: hot	2040	2040 equiv.	UDC	11.64	11.21	10.71	-3.82%	-8.68%
				EUDC	8.14	8.33	8.36	2.22%	2.61%
				Total	9.43	9.38	9.22	-0.59%	-2.38%
	MVEG-B Conditions: hot	2040	2040 equiv.	UDC	11.62	11.21	10.71	-3.67%	-8.52%
				EUDC	8.09	8.33	8.36	2.91%	3.29%
				Total	9.40	9.38	9.22	-0.18%	-1.97%
	MVEG-B Conditions: hot	1930	2040 equiv.	UDC	11.62	11.06	10.55	-5.04%	-10.13%
				EUDC	8.03	8.25	8.28	2.67%	3.03%
				Total	9.37	9.28	9.11	-0.95%	-2.83%
	MVEG-B Conditions: hot	1930	2040 equiv. *85%	UDC	11.34	10.93	10.42	-3.75%	-8.91%
				EUDC	7.60	7.72	7.70	1.62%	1.28%
				Total	8.99	8.90	8.69	-1.09%	-3.51%
	MVEG-B Conditions: hot	2270	2040 equiv.	UDC	11.86	11.50	11.02	-3.10%	-7.55%
				EUDC	8.24	8.48	8.52	2.82%	3.23%
				Total	9.58	9.59	9.43	-0.01%	-1.64%

Table D-5: Simulated and experimental results for VW Golf

	Driving cycle	Mass (kg)	Air Drag	Part	FC [l/100km]	Advisor [l/100km]	Advisor 13 points [l/100km]	Diff FC	Diff FC 13
Golf	MVEG-B Conditions: hot	1130	Coast Down	UDC	5.54	5.75	5.97	3.6%	7.2%
				EUDC	4.00	3.84	4.07	-4.10%	1.73%
				NEDC	4.56	4.54	4.76	-0.39%	4.27%
	MVEG-B Conditions: hot	1360	Coast Down	UDC	5.83	6.10	6.40	4.40%	8.88%
				EUDC	4.23	4.09	4.32	-3.36%	2.21%
				NEDC	4.81	4.82	5.08	0.20%	5.31%
	MVEG-B Conditions: hot	1590	Coast Down	UDC	6.12	6.40	6.78	4.45%	9.80%
				EUDC	4.44	4.33	4.58	-2.49%	3.16%
				NEDC	5.05	5.10	5.40	1.03%	6.54%
	MVEG-B Conditions: hot	1360	Coast Down +20%	UDC	5.99	6.13	6.45	2.22%	7.07%
				EUDC	4.34	4.34	4.57	-0.07%	4.88%
				NEDC	4.94	4.99	5.25	0.93%	5.89%

As presented in these tables the accuracy of advisor's full engine map simulations is (for NEDC) below 5% in all but one cases. Additionally in the majority of NEDC simulations Advisor's accuracy is around 3% fact which shows that Advisor can be used for an NEDC based analysis of the issues addressed in this study. An interesting point is that if Advisor tends to overestimate the fuel consumption of the base vehicle then it will also overestimate all simulations that are performed for higher masses and air drag. This means that in cases of comparative analysis as the one presented in chapter 4 were the values of fuel consumption of certain vehicle configurations are compared to those of the basic configuration, the error of the simulation is reduced.

A more general overview of the model's performance for these three vehicles is presented in table D-6. Furthermore, engine data of 2.2l HDi engine was downgraded (lower power only) for modelling the Boxer vehicle. However, this engine is different from the one that was in the vehicle (DW12 vs. DW10 engine) belonging only to the same family of engines. This procedure applied is common in the modelling world and it is not a direct validation in an absolute sense. However in the case of this study it was more important to test Advisor's ability to provide results within certain accuracy limits and to use these results for evaluating measures proposed by 2004/3/EC than to create a strict model of certain N1 vehicles.

Table D-6: Minimum maximum and average deviation of simulated FC

Model	Value Characterization	Full map	13 point map	Cycle appeared
Boxer	Min	-5.9%	-10.1%	Cold UDC
	Max	5.4%	-0.4%	UDC
	Average (absolute)	2.1%	5.5%	
Daily	Min	-18.73%	-24.14%	Cold UDC
	Max	4.45%	9.80%	EUDC
	Average (absolute)	2.35%	4.90%	
Golf	Min	-4.10%	1.73%	EUDC
	Max	4.45%	9.80%	UDC
	Average (absolute)	2.27%	5.58%	

It should be noted that the simulations proved to be adequately accurate, fact which allowed the confident use of ADVISOR for the examination of different scenarios – loaded vehicles, changes in aerodynamic drag etc. – in NEDC cycles. Additionally the deviations that appear do not vary more than 1% within different loading conditions – e.g. all NEDC results for Boxer vary between 0.2% and 1.09% –; it is assumed that in a comparative analysis as the one conducted for the validation of the family, where the change of fuel consumption in relation to a change in the vehicle's characteristics is important, the final results are not affected by Advisor's deviation.

This average 2.5% accuracy which the model provides it is considered as very good. In fact CO_2 and FC can be predicted by a model and engine map however accuracy in most cases is +/- 2% due to:

- Transient effects which Advisor cannot evaluate
- The points that are measured (and for which data is available) in the engine map
- Other factors that cannot be estimated –age of the vehicle, fuel trim

In order to evaluate if modelling of “unknown vehicles” is possible the following steps have been taken. Using data of three different engines and gearbox ratios from our measurements, a number of simulations of unknown vehicles were conducted. Using KBA database certain vehicles were selected equipped with these engines or engines of the same engine family as well as similar or the same gearboxes. The variants that didn’t have any special features (e.g. automatic transmissions) were chosen and the equivalent inertia of these vehicles as well as their recorded NEDC emissions were retrieved from KBA. Advisor was then used for simulating their fuel consumption in NEDC. In cases like VW Caddy a VW Transporter where the gear ratios were not known to the study team, gear ratios from other vehicles equipped with the same engine – VW Golf – were used. Additionally for all vehicles the 96/44/EC values for simulating driving resistances were used. The results of this modelling exercise are shown in table D-7.

Table D-7: Measured vehicles simulated with Advisor using KBA data

Vehicle (Engine)	TEST	UDC	EUDC	NEDC
Partner (PSA HDi 1997cc)	KBA Variant 1	7.20	4.90	5.70
	KBA Variant 2	7.50	5.00	5.90
	Average	7.35	4.95	5.80
	Advisor	7.27	5.13	5.91
	Deviation Average-Advisor	-1.04%	3.51%	1.90%
Fiat Ducato (Iveco JTD 2800cc)	KBA Variant 1	12.40	8.20	9.80
	KBA Variant 2	10.60	8.50	9.30
	Average	11.50	8.35	9.55
	Advisor	12.07	8.57	9.82
	Deviation Average-Advisor	4.75%	2.59%	2.93%
Peugeot Boxer (Iveco JTD 2800cc)	KBA Variant 1	12.40	8.20	9.80
	KBA Variant 2	10.60	8.50	9.30
	Average	11.50	8.35	9.55
	Advisor	12.27	7.90	9.49
	Deviation Average-Advisor	6.24%	-5.70%	-0.61%
Transporter (VW 1896ccTDi)	KBA Variant 1 (1930kg)	9.30	6.50	7.50
	Advisor	8.80	6.65	7.44
	Deviation	-5.61%	2.24%	-0.80%
	KBA Variant 2 (2150kg)	9.50	6.70	7.70
	Advisor	9.09	6.90	7.70
	Deviation Average-Advisor	-4.51%	2.89%	-0.1%
CADDY (VW 1896cc TDi)	KBA Variant 1	7.20	4.70	5.60
	KBA Variant 2	7.30	4.80	5.70
	Average	7.25	4.75	5.65
	Advisor	7.58	4.50	5.61
	Deviation Average-Advisor	4.40%	-5.6%	-0.48%
BERLINGO (PSA HDi 1997cc)	KBA Variant 1	7.30	5.00	5.80
	KBA Variant 2	7.20	4.90	5.70
	Average	7.25	4.95	5.75
	Advisor	6.93	5.26	5.87
	Deviation	-4.6%	5.89%	2.06%

It should be noted that the results presented in the above table are for cold start conditions. Measurements under cold start conditions are more scattered than for warm start. Therefore, greater inaccuracies especially in the UDC are acceptable. As it can be seen the accuracy of the model compared to KBA's registered data is very good. In all cases for NEDC the deviation is within ±3%. Note that these simulations were conducted for conditions of minimum data availability.

These results show that CO_2-emissions and fuel consumption can be simulated in the legislated driving cycles with good accuracy when only the engine map, mass value and gear ratios are known. Therefore this procedure can be extended to complete multistage vehicles with type approved engines – in a similar way as it was shown in 4.2.1 – if a certain deviation is accepted. Furthermore it shows that with the existing type approval procedure which is oriented only on the vehicle's mass, it is acceptable to provide type approval based on the type approval of the engine.

When dealing with such low deviations, it is possible that the accuracy of the model can deteriorate due to inaccuracies of the measurement even though the latter are within accepted limits. In order to examine if such a correlation exist, the differentiation between the actual driven distance of the measured cycles and the nominal distance of the cycle was compared to the differentiation in fuel consumption between the model and the measurement. These comparisons for Boxer and Daily vehicles are presented in figures D-3 and D-4. This comparison has shown no specific relation between the two variations.

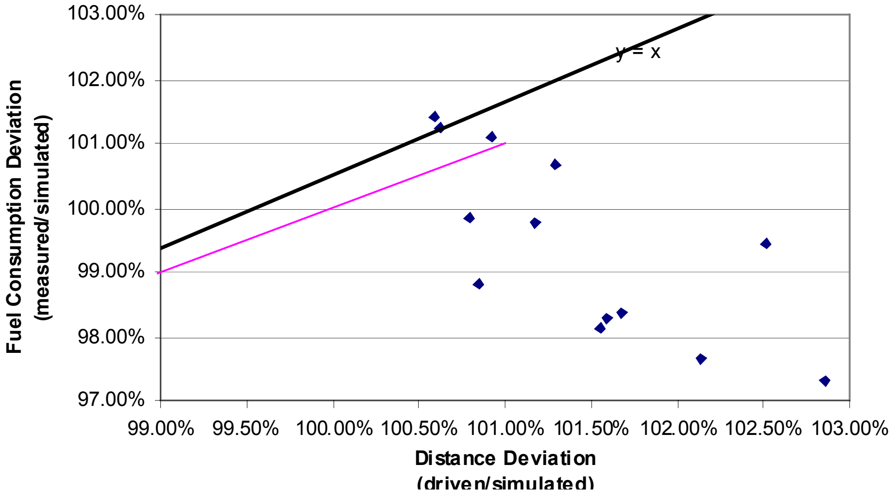

Figure D-3: Effect of driven distance in the accuracy of Boxer's simulation

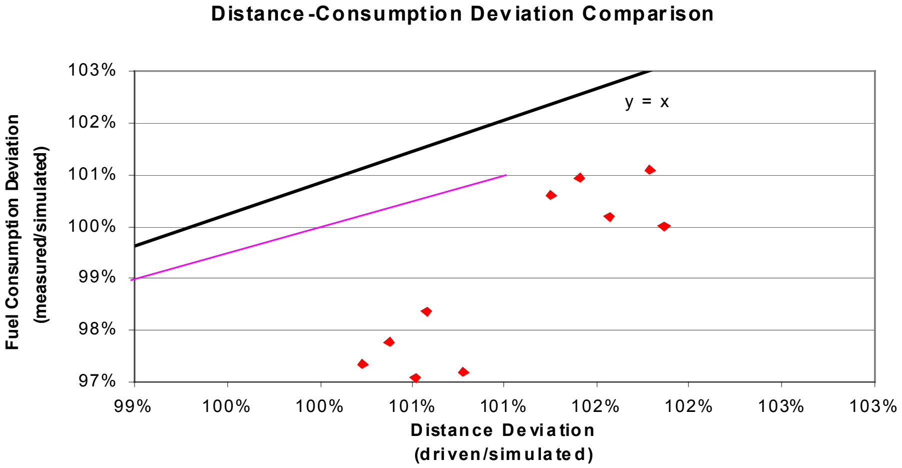

Figure D-4: Effect of driven distance in the accuracy of Daily's simulation

Finally it is important to add that in parallel to this study Advisor's performance was compared to that of modelling software, PHEM. PHEM modelling tool was created by VKM-THD at TU Graz as a detailed simulation program for Heavy Duty vehicle application with high accuracy using engine emission maps and transient correction functions. An expansion of the model for light duty vehicles is just in progress. Its operation is based - like Advisor's - on basic physics and vehicle dynamics. PHEM provides a number of functions that allows emissions estimations from various sources of measured data as well as the possibility of transient phenomena correction through a statistical analysis of real world data.

The models were used to simulate the operation of two different vehicles. The goal was to cover both heavy and light duty vehicles because they are very different in their characteristics and operation. Through this procedure it would be possible to determine how the models behave on each occasion and whether there are particular difficulties for each vehicle type. The first vehicle that was chosen was the Golf 1.9TDi and the second was a Volvo D12-D420 heavy duty vehicle. In the cases of both vehicles the models presented the same accuracy as far as fuel consumption is concerned, with the transient corrected simulations of PHEM producing a slightly more accurate result – not more than 0.5% difference.

E Validation of the type approval databases

CO_2-emission and fuel consumption data have been retrieved from existing databases, like KBA [KBA,2003] and VCA [VCA,2003]. In addition, results of measurements that have been conducted in several projects at different laboratories have been incorporated as well.

Since the values mentioned in the KBA and VCA database are valid for M1 class of vehicles, these values have been validated by conducting standard type approval tests in which CO_2 emissions and fuel consumption - based on the carbon balance method - were measured. For each of the N1 classes a vehicle has been selected (see Table E-1).

Table E-1:Vehicles selected for validation of the databases

N1 Class	Vehicle (brand and type)
I	Citroen Berlingo 1.9 Diesel
II	Ford Transit Connect 1.8 Diesel
III	Peugeot Boxer 2.2 Diesel

The results of the measurements that were conducted at the TNO laboratory and the CO_2-emissions that are taken from the available databases, are given in Table E-2.

Table E-2:CO_2 emissions: measured and from databases

Vehicle (brand and type)	NEDC CO_2 measured	NEDC CO_2 from databases	Difference
Citroen Berlingo 1.9 Diesel	185	181	2.2%
Ford Transit Connect 1.8 Diesel[15]	190		
Peugeot Boxer 2.2 Diesel	264	255	3.4%

For the Berlingo and the Boxer, the emissions measured are within the 6% derogation rule that is prescribed in Directive 80/1268/EEC. Unfortunately, the exact CO_2 emissions of the Transit Connect were neither found in the available databases nor in available type approval certificates. The closest match is a vehicle that contains the same engine; CO_2 emission for that vehicle was 166 g/km causing a 14.5% difference in comparison with the measurement. However, from the results of these measurements on the Berlingo and Boxer it was decided that the CO_2 emissions from the databases could be applied for N1 vehicles as well.

Also consecutive measurements have been carried out in order to address the repeatability of carrying out emission tests. For CO_2 emissions the values of 4 results are within ±1% of the average value.

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[15] Unfortunately, CO_2-emissions of the exact vehicle could not be found in the available databases and type approval certificates

F Table values for type approval (70/220/EEC)

Table F-1:Table values for type approval from 96/44/EC (amendment to 70/220/EEC)

Reference mass of vehicles	Equivalent inertia	Power and load absorbed by the dynamometer at 80 km/h		Coefficients	
RW (kg)	kg	kW	N	a (N)	b (N/(km/h)$^{2)}$
RW < 480	455	3.8	171	3.8	0.0261
480 < RW < 540	510	4.1	185	4.2	0.0282
540 < RW < 595	570	4.3	194	4.4	0.0296
595 < RW < 650	625	4.5	203	4.6	0.0309
650 < RW < 710	680	4.7	212	4.8	0.0323
710 < RW < 765	740	4.9	221	5	0.0337
765 < RW < 850	800	5.1	230	5.2	0.0351
850 < RW < 965	910	5.6	252	5.7	0.0385
965 < RW < 1 080	1020	6	270	6.1	0.0412
1 080 < RW < 1 190	1130	6.3	284	6.4	0.0433
1 190 < RW < 1 305	1250	6.7	302	6.8	0.046
1 305 < RW < 1 420	1360	7	315	7.1	0.0481
1 420 < RW < 1 530	1470	7.3	329	7.4	0.0502
1 530 < RW < 1 640	1590	7.5	338	7.6	0.0515
1 640 < RW < 1 760	1700	10.14	351	10.27	0.06968
1 760 < RW < 1 870	1810	10.53	365	10.66	0.07241
1 870 < RW < 1 980	1930	10.92	378	11.05	0.07501
1 980 < RW < 2100	2040	11.18	387	11.31	0.07683
2 100 < RW < 2210	2150	11.44	396	11.57	0.07865
2210 < RW < 2380	2270	11.7	405	11.83	0.08047
2380 < RW < 2610	2271	12.22	423	12.35	0.08398
2610 < RW	2272	12.74	441	12.87	0.08762

For N1 vehicles with inertia equal or greater than 1700kg the values must be multiplied with a factor of 1.3.

G Overview of policy options gathered by IEEP

Table G-1: Policy measures used by Member States to reduce CO2 emissions from light commercial vehicles (LCVs) and other vehicles

Member State	*Policy measures and source*	
	LCVs	*Other vehicles and fuels*
Austria	Motor Vehicle Tax – recurrent taxes for registration of all vehicles for categories of weights below 3.5 tonnes with engine effect ranging between 24 and 134 KW. Plus those of vehicle weight over 3.5 tonnes. Prices range from 1EUR – 66EUR per month dependent upon weight and engine effect.	Motor Vehicle Tax – recurrent taxes for registration of all vehicles for categories of weights below 3.5 tonnes with engine effect ranging between 24 and 134 KW. Plus those of vehicle weight over 3.5 tonnes. Prices range from 1EUR – 66EUR per month dependent upon weight and engine effect. There is also road transport duty for the use of lorries and trailers with a total maximum weight larger than 12 tons on Austrian roads, with prices depending on duration of use on the roads, for example prices are incurred for use, from as little as a day, a week, a month and a year. Prices range from 6EUR-1214EUR. Source: OECD A fuel consumption/pollution tax (known as NoVA) is levied on the purchase price (net) or commercial leasing fee of new passenger card and on passenger cars not yet registered. Tax exemptions exist for electric cars and other such as taxis, ambulances etc. Source: ACEA guide

Belgium	No information received	Circulation tax for all vehicles based on engine size and type of vehicle, with reductions for vehicles powered by LPG. Registration tax based on power of engine. Source: OECD The government is considering new vehicle taxing systems which should stimulate the purchase and use of new cars and other vehicles with relatively low energy consumption and with emission values in accordance with the Euro 3 or Euro 4 emission standards. These new taxing schemes would partly replace the existing vehicle and fuel taxes. Source: IEA Database.
Denmark	Annual vehicle taxes are differentiated by weight which could be seen to affect CO2 emissions. Weight / Circulation Tax / Extra for Diesel / Extra for Private 0-500 850kr 360kr 900kr 501-1,000 1090kr 520kr 900kr 1,001 – 2,000 1810kr 710kr 900kr 2,001-2,500 3140kr 890kr 5040kr 2,501-3,000 3760kr 1010kr 5040kr 3,001-4,000 3760kr 1150kr 5040kr Source: Policy Questionnaire	In Denmark the difference of petrol and diesel tax changed significantly. For petrol it went from €0.31 in 1995 to €0.55 (77% increase) and for diesel it went from €0.26 in 1995 to €0.37 (42% increase). In 1997 the car taxation was changed from a weight based annual circulation tax to a fuel consumption differentiated annual circulation tax. This aimed to provide incentives for the use and purchase of more fuel-efficient cars. Prior to this, the annual circulation tax was based upon curb weight including seven different classes, differentiated for petrol and diesel. When the tax changed in 1997 24 consumption classes were established ranging from a petrol rate of less an annual tax of €59 for less than 5 litres per 100km up to €2,315 for more than 22.2 litres per 100km. Source: DLR report From 1 January 2000 the registration fee for cars has been changed in order to incentivise new energy efficient vehicles. The Danish Parliament reduced the registration tax for such cars (both gasoline and diesel) consuming less than 4 litre/100 km for gasoline cars and less than 3.6 litre/100 km for diesel cars. The reduction in the registration tax varies from 1/6 to 4/6 of the existing fee. In connection with this decision, the scale of the annual "green owner fee" for diesel cars has also been expanded. From 1 January 2000, another 4 categories have been added to the green owner fee, and the lowest tax category is now for diesel cars which consume less than 3,1 litres per 100 kilometres. Source: IEA database

Finland	The annual vehicle tax consists of the basic tax and when the driving power of a vehicle is not petrol, the fuel tax of the annual vehicle tax. The maximum permissible laden weight of a vehicle influences the fuel tax of the annual vehicle tax. There is also a very low excise duty on natural gas (methane) used as propellant in vehicles. Furthermore, m1 and n1 -vehicles using natural gas (or other methane) are exempted from annual diesel tax (levied normally on vehicles using other fuel than gasoline). Source: Policy Questionnaire	Fuel efficiency in cars has been emphasised through a yearly competition to designate the most ecological car of the year in co-operation with the most widely read motoring magazine in Finland. Source: IEA Database
France	The finance law of 30 December 2002 extends until 31 December 2005 the tax credit for the acquisition of a new vehicle operating on natural gas, liquefied natural gas and hybrid vehicles (electric/combustion). Exemptions may be granted for all or a portion of the differential tax on alternative vehicles fuelled by electricity, natural gas or LPG. French government and industry leaders pledged to promote the use of natural gas in personal and public transport vehicles as a clean-fuel alternative to other petroleum products. The new, wide-range co-operation agreement aims to dramatically increase the use of natural gas for vehicles (NGV) by 2005, focusing particularly on public transport and government owned utility vehicles. It is expected to provide an immediate boost to NGV use - at least 1000 NGV powered buses are expected to be on the roads by the end of 2001. Source: IEA Database	In 2001 the annual circulation tax was abolished for private cars. This resulted in tax savings with respect to car size range from 80EUR per year for a com-pact car up to 1,500-2,300EUR per year for a luxury car. Before 2001 the annual circulation tax was dependent upon cylinder capacity, age of car and district. Source: DLR Report The Clean Vehicles Plan (Plan Véhicules Propres) is the result of collaboration between the Ministries of Ecology, Research and Industry and has as principal objectives: - To support additional research (€40 million in addition to existing funding) to accelerate the commercial viability of less polluting and more energy efficient vehicle; - Provide an additional incentive to encourage the promoting of alternative energy vehicles. A reduction has been made in the taxation gap between diesel and unleaded gasoline in the transport sector. In 1998, the taxation gap was 1,43 F/l; it was reduced to 1,36 F/l in 1999 and to 1,29 F/l for 2000. Source: IEA Database

Germany	Annual vehicle taxes are differentiated by the technically permissible maximum mass: up to 2000 kg = 11,25 € per 200 kg up to 3000 kg = 12,02 € per 200 kg up to 3500 kg = 12,78 € per 200 kg. Tax differentials exist to encourage the use of alternative fuels, ie a tax exemption for biofuels and tax allowances for NG and LPG Source: Policy Questionnaire	The so-called 'ecological tax reform' resulted in increases between 1999 and 2003. Fuel tax increased for petrol from €0.50 in 1995 to €0.66 in 2003 (a 32% increase) and for diesel, from €0.32 in 1995 to €0.47 in 2003 (a 47% increase). In contrary to the fuel tax, the circulation tax decreased for new cars. However the fuel tax aims to reduce CO2 emissions whereas the lower circulation tax is a result of benefits for Euro 3 and Euro 4 cars and is mainly related to engine capacity - with lower tax rates for those with more sophisticated exhaust gas treatment standards. Source: DLR Report Registration taxes for lorries for varying weights between 3,500 kg – 13,600 kg range from 121 EUR – 665 EUR per year depending on which waste gas emission class they are in. Source: OECD Germany is considering policies to reduce transport emissions by 20 million tons by 2005, to be reached through the speed limit and air traffic levy as well as investments in public transportation and more efficient cars. Source: IEA Database
Greece	According to a new law (2682/99), a differentiation of the registration tax on vehicles (cars, trucks, motorcycles) according to their motor horsepower and their anti-pollution specifications is being provided. Source: IEA Database	Registration costs of passenger cars are dependent upon size of cylinder volumes ranging from below 785cc to above 1929cc, with cost ranging from 3.07 EUR to 153.57EUR respectively. Source OECD In accordance with the Law 2836/2000, lower tax rates were set for unleaded petrol. In 2001, the excise tax was raised for leaded petrol, as well as for unleaded petrol with special additives to be used in conventional engine. These regulations will provide an incentive for replacing old-technology passenger cars by new ones. CNG (compressed natural gas) buses are exempted from the excise taxes. A pilot project for the use of biofuels in transport is in progress. The project is financed within the framework of the ALTENER programme. Up to now, bio-diesel is imported from abroad (Austria), while it is exempted from the taxation on fossil fuels. Furthermore, the Ministry for Transport awarded recently a

		feasibility study concerning the production and use of biofuels in Greece. Electric cars or hybrid cars with motors satisfying the specifications of the EC Directive 94/12 or more recent directives are exempted from the tax. Source: IEA Database
Ireland	Vehicles under 3,000 kg are taxed at a flat rate but above 3,000 kg tax rates are banded in increasing rates every 1,000 kg. Vehicle Registration Tax (purchase tax) is charged at a 50 euros flat rate for large vans. Small vans are charged at 13.3% of the vehicle's Open Market Selling Price. There is a 50% rebate of VRT for certain hybrid vehicles. Source: Policy Questionnaire	All diesel sold in Ireland as of 1 March 2002 is low sulphur. Source: ACEA Guide
Italy	Italy's public sector has been mandated to raise the share of electric, hybrid, and natural-gas fuelled vehicles it purchases to 50% of the total new vehicle procurement over the next 5 years. The decree covers state-owned service companies, such as utilities and postal and telecommunications services, as well as national and regional government bodies and towns and cities with a population above 25,000. Given the size and replacement of their fleets, the environment ministry calculates that by 2003, the measure would put some 60,000 "clean" vehicles on Italy's roads. Source: IEA Database	Under Decree Law 2/7/2003 No. 183, which amends Ministerial Decree 17/7/98 No. 256, the incentives offered to private persons have been more than doubled for the purchase of new gas powered cars and for those converted within one year of leaving the factory. In addition, persons ordering the installation of a CNG or LPG system on their own car (or that belonging to a family member at the same address) within twelve months of the new car first being registered are given a discount of 650 Euro at fitter's workshops taking part in the scheme (under the previous decree the sum was of 309.87). Those in Italy buying – also through hire purchase – a new approved car with either a hybrid or exclusively CNG or LPG system can count on a 1,500 discount on the pricelist (this amount was previously 413.17). Monitoring is ensured by the Programme Agreement between the sector associations and the Ministry of Production Activities. In May 2002, the European Union approved the biodiesel tax exemption program, totalling around 80% of all of the biofuels tax incentives programme included in the financial law for the year 2001.The financial law for the year 2001 funded biofuels through excise exemption over a period of three years. The Italian Government is offering incentives for the purchase of cars not powered by traditional petroleum, or for the conversion of older cars to liquefied petroleum gas and methane. The

		scheme is a joint project by the Ministries of Production, Environment and Transport and has set aside an initial funding of □7.230m. It will give between □300 to □400 to motorists who are buying or converting old cars (1988 to 1992 models). Italy’s Council of Ministers has announced that the government will eventually cut out all but "green" petrol in order to keep prices down and reduce GHG emissions as mandated by the Kyoto Protocol. After 1 January 2002, leaded fuel will not be sold, leaving only unleaded and much cleaner "green" petrol available to Italian consumers. A carbon tax, applicable to all hydrocarbon compounds, was established in December 1998 (Law 448/1998). The Law established the value of the excise taxes for 1999 (0.52 □ per metric ton of coal, petroleum coke and “orimulsion” used in combustion plants) and those for 2005, to be reached progressively. The increases between 1999 and 2004 are to be decided on a yearly basis by the Government and set by decrees of the President of the Ministers’ Cabinet. Source: IEA Database
Luxembourg	No information received.	Registration and annual vehicle tax depends on size of engine for passenger cars and weight of vehicle for lorries. Source: OECD The government introduced in January 2001 a grant scheme to promote the purchase of vehicles producing low CO2 emissions. The scheme aims to incite people to buy cars with CO2 emissions below an average value of 95 g/km (corresponding to a fuel At present, big car manufacturers develop and market cars whose consumption of fuels is very low. To encourage consumers to acquire vehicles with reduced consumption, a gRAND-ducal regulation is being prepared to subsidise cars consuming less than 3 litres per 100 km. Source: IEA Database.

Netherlands	No information received.	The Netherlands has differentiated taxes for petrol, diesel and LPG fuelled cars. For petrol, taxes are set to 176EUR at 100kg net weight per year plus 37EUR per extra 100kg. For diesel the cost is 534EUR at 100kg net weight per year plus 72EUR per extra 100kg. For LPG it is 578 EUR at 100kg net weight per year plus 76EUR per extra 100kg. There are also taxes for lorries ranging from 15,000 to 40,000 kg (with various numbers of axels) – ranging from costs between 372EUR to 940EUR. Source: OECD Tax deductions for commuting in a private car were eliminated from 1 January 2001. An additional change to the tax code as of that date was aimed at discouraging the personal use of company cars. This change involved differentiation of the income imputed for using a company car for private purposes. The imputed income is now lower for less-than-average personal kilometres, and higher for above-average personal kilometres. Source: IEA Database Tax reductions for low sulphur gas and diesel were stopped on 1 January 2004. Source: ACEA Guide.
Portugal	Annual vehicle taxes are differentiated by weight for example Annual Taxes are: Weight < 2500 kg 24EUR 2500 > weight < 3500 kg 41EUR Purchase taxes are also differentiated in a similar way. Source: Policy Questionnaire	State budget 2001, introduced in 2000, provides for a 50% reduction of the tax on the purchase of vehicles when they use exclusively liquefied petroleum gas (LPG) or natural gas. When they are driven by hybrid engines that use conventional fuels but can also use LPG, natural gas, electricity, or solar energy, a 40% reduction of that tax is provided. These measures create an incentive for the market penetration of low-carbon fuels. The establishment of a differential excise treatment of LPG and Natural Gas as compared to petrol and diesel for road vehicles provides an incentive for the penetration of low carbon fuels for transportation. Source: IEA Database

Spain	Also, vehicles are classified according to engine power, and taxes increase following this classification. Purchase taxes are proportional to retail prices. Biofuels are totally free from specific fuel taxation (according to the Law 53/2002 on Economic and Fiscal Measures); the only tax applied is the standard VAT. GNC/GLP are charged with a lower rate fuel tax than petrol or Diesel. Labelling has been established for private passenger cars but not lcv's. Regarding driver training for light commercial vehicles, some campaigns have been carried out. There are not, however, regular training programs. Source: Policy questionnaire	Annual vehicle taxes for passenger cars are based on 'fiscal horsepower' ranging from vehicle categories between 12-16 horsepower, with costs ranging between 72EUR to 90EUR per year respectively. Lorry taxation is determined on capacity to transport certain weights. These range from being able to transport below 1000kg to more than 9,000kg. Costs range from 42EUR to 148EUR per year respectively. Source: OECD
Sweden	In Sweden the annual vehicle taxation is differentiated according to weight. Light commercial vehicles that operate on electricity (electric vans) or LCV's that operate on both electricity and propellant (electric hybrid vans) are exempted from annual vehicle taxation for the first five years after the first registration. Source: Policy Questionnaire An exhaust emission inspection fee of SEK 75 is paid on every new car and commercial vehicle registered. An environmental fee of SEK 30 is paid on new lead batteries. This fee covers the collection and recycling of lead batteries	In Sweden the annual vehicle taxation is differentiated according to weight but Sweden does not have registration or purchase taxes. Cars that operate on electricity (electric cars) or cars that operate on both electricity and propellant (electric hybrid cars) are exempted from annual vehicle taxation for the first five years after the first registration. They also have in place reduced company car taxation for cars that operate on environmentally friendly alternatives to conventional fuel (e.g. biofuels, electricity, natural gas or hybrid versions). Sweden is planning to make biofuels totally exempt from excise duties. The exemption needs to be approved by the Commission according to the state aid rules before it can be implemented. Some municipalities have free parking or special parking places for cars that run on alternative fuels. The Swedish Government has appointed a committee that shall look into the way in which road traffic taxation is being formulated and in particular consider issues pertaining to the

	in Sweden. Source: ACEA taxation guide	environment, traffic safety and competition. The Commission will present its proposal to the Government on May 31st 2004. The Swedish Government has appointed another committee that shall propose a national indicative target and a national strategy for the introduction of renewable fuels. The committee will present its proposal in the end of December 2004. The committee has presented an interim report in January 2004. Source: Policy Questionnaires An exhaust emission inspection fee of SEK 75 is paid on every new car and commercial vehicle registered. An environmental fee of SEK 30 is paid on new lead batteries. This fee covers the collection and recycling of lead batteries in Sweden. Source: ACEA taxation guide
United Kingdom	No information received.	Between 1995 and 2003 the circulation tax has changed twice. The tax rate of £140 for all cars was replaced in 1999 by a tax taking the engine capacity as a base. In the second step, tax was based on CO2. It rises in six steps from less than 100g CO2/km (£74/65 per year for diesel/petrol) to the class of more than 185g CO2/km, which costs £165/160 per year for diesel/petrol. There was also a change for company cars in the UK's annual circulation tax in 2001. The new system was based on CO2 emissions. With cleaner and more fuel efficient cars being rewarded by linking the tax and National Insurance Contributions (NICs) to the car's CO2 emissions. Previously the benefit in kind tax rate for a company car was 35% of the list price if less than 18,000 miles were travelled and 25% if the amount of business miles was more than this number. The change resulted in the amount being reduced to 15% and 18% respectively for petrol and diesel if the car emits less than 165g CO2/km to 35% for both petrol and diesel if it has an emission rate of more than 260g CO2/km for petrol and more than 245g CO2/km for diesel. Source: DLR Report Cars without an approved CO2 emissions rating will be taxed on their engine size (cc). Source: ACEA Guide

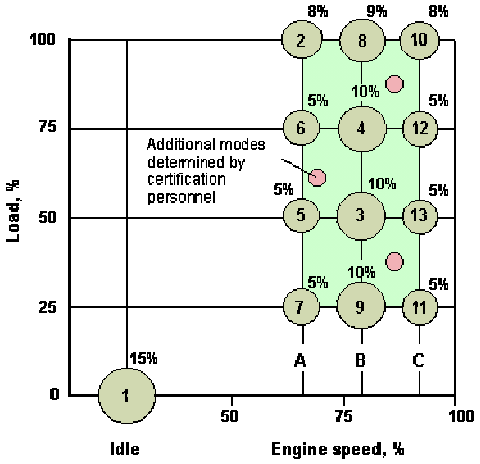
Czech Republic	The introduction of tax differentials for alternative fuels as part of the program of energy saving and using of renewable sources in the transport sector will be introduced between 2005 and 2008. Source: Policy Questionnaire	Road tax is required for passenger cars in the Czech Republic based on cylinder capacity. Categories range from vehicles with a cc of less than 801 to above 3000. Prices for these categories range from between 52EUR to 123EUR per year. There are also tax bands for different categories of lorries. These range from those with 1-3 axels and weighing between less than 1 tonne to 36 tonnes. Prices for these categories range from between 52EUR to 1295EUR per year. Source: OECD Vehicles meeting EURO emissions limits have a reduced rate (by 25% or 50%) until 31 December 2003. As of 1 January 2002 only trucks complying with the EURO 2 level of the UN ECE special regulations were entitled to 25% tax abatement till 31 December 2003. Fuel taxes – neither wholesale nor retail prices are regulated. The prices are adjusted on the basis of competition. There are no financial incentives except for the supporting system for the production of biofuels – although new measures are being prepared to comply with the EU system. Source: ACEA Guide.
Estonia	No information received.	In Estonia there is an annual registration tax of 0.32EUR per KW for passenger cars. Source: OECD
Hungary	A motor vehicle tax is based on weight/mass of the vehicle as from 1 January 2003, the rates vary for passenger cars and commercial vehicles, with 20% reductions available for various measures such as the fitting of catalytic converter equipped petrol engines. Source: ACEA Guide	There is an annual registration tax of between 2 to 3 EUR per 100kg for passenger cars. Source: OECD The sale of fuel is subject to VAT (25%), excise duty (variable) and a specific fuel tax which is as follows: Leaded petrol – 11.3 HUF/litre Unleaded petrol- 10.5 HUF/litre Diesel (gas) oil – 9.00 HUF/litre

		A motor vehicle tax is based on weight/mass of the vehicle as from 1 January 2003, the rates vary for passenger cars and commercial vehicles, with 20% reductions available for various measures such as the fitting of catalytic converter equipped petrol engines. Source: ACEA Guide
Latvia	There is also a road traffic tax for passenger cars and commercial vehicles. This is calculated on maximum gross weight in kg. Source: ACEA Guide	Motor vehicle tax is calculated only for passenger cars and motorcycles and is calculated in proportion to the vehicle's age. Source: ACEA Guide
Lithuania	There are annual vehicle taxes for both light and heavy-duty vehicles. There is also a road tax for companies of 0.1-1% of the companies income. Source: OECD	
Poland	In Poland there are charges for vehicle (both cars and LCV's) registration at 12 EUR, costs for registration plates – 9 EUR and for a registration certificate at 7 EUR. Source: OECD	In Poland there are charges for vehicle registration (both cars and LCV's) at 12 EUR, costs for registration plates – 9 EUR and for a registration certificate at 7 EUR. Source: OECD
Slovak Republic	Commercial vehicle tax based on engine size ranging between 27EUR – 95EUR. Source: OECD. A person registered for VAT is allowed to deduct VAT on the purchase of commercial vehicles for professional use. This is not applicable for passenger cars. Source: ACEA Guide	
Slovenia	No information received	VAT on new passenger cars – 19% of the sale price. Source: OECD
Cyprus	No information received	
Malta	No information received	

H European Stationairy Cycle (ESC) – 88/77/EEC

European Stationary Cycle (ESC)
The ESC test cycle (also known as OICA/ACEA cycle) has been introduced, together with the ETC (European Transient Cycle) and the ELR (European Load Response) tests, for emission certification of heavy-duty diesel engines in Europe starting in the year 2000 (Directive 1999/96/EC of December 13, 1999). The ESC is a 13-mode, steady-state procedure that replaces the R-49 test.

The engine is tested on an engine dynamometer over a sequence of steady-state modes. The engine must be operated for the prescribed time in each mode, completing engine speed and load changes in the first 20 seconds. The specified speed shall be held to within ±50 rpm and the specified torque shall be held to within ±2% of the maximum torque at the test speed. Emissions are measured during each mode and averaged over the cycle using a set of weighting factors. Particulate matter emissions are sampled on one filter over the 13 modes. The final emission results are expressed in g/kWh.



During emission certification testing, the certification personnel may request additional random testing modes within the cycle control area. Maximum emissions at these extra modes are determined by interpolation between results from the neighbouring regular test modes.

The engine speeds are defined as follows:

The high speed n_{hi} is determined by calculating 70% of the declared maximum net power. The highest engine speed where this power value occurs (i.e. above the rated speed) on the power curve is defined as n_{hi}.

The low speed n_{lo} is determined by calculating 50% of the declared maximum net power. The lowest engine speed where this power value occurs (i.e. below the rated speed) on the power curve is defined as n_{lo}.

The engine speeds A, B, and C to be used during the test are then calculated from the following formulas:

$$A = n_{lo} + 0.25(n_{hi} - n_{lo})$$
$$B = n_{lo} + 0.50(n_{hi} - n_{lo})$$
$$C = n_{lo} + 0.75(n_{hi} - n_{lo})$$

The ESC test is characterised by high average load factors and very high exhaust gas temperatures.

I Ageing of the vehicle fleet

The function describing the survival rates of a vehicle, known also as lifetime function, has the form of a "modified Weibull" distribution [Zachariadis, 1995] containing two parameters. The formula of such a function is:

$$\phi i(k) = \exp - \left[\left(\frac{k + bi}{Ti} \right)^{bi} \right] \text{ and } \phi i(0) \equiv 1$$

where k is the age expressed in years
φ(k) is the presence probability of vehicles of type I having age k
bi is the failure steepness of the vehicle type i
Ti the characteristic service life for vehicles of type i

This methodology is integrated in TRENDS [Trends,2002] for making predictions of future emissions from commercial and passenger cars fleet. TRENDS uses predefined b and T factors which were calculated in the past. However the composition as well as the technological characteristics of the fleet has changed through the years. For the purpose of this study these factors were recalculated and new presence probability curves were used.

The calculation of the new values of these factors was performed using statistical data retrieved from Eurostat. Eurostat provides annual data about the age class distribution of lorries for each country. The lorries category includes apart from N1s, heavier vehicles that belong to different categories. However, for this study and since no other statistical data is provided it is assumed that the ageing process of lorries and N1s is the same. Having the age distribution as well as the total number of registered lorries for each year it is possible to divide the number of vehicles in each age class with the number of vehicles registered in the time interval covered by the class. In simple words: dividing the number of vehicles that were up to 2 years old in 2001 with the new registrations of 2001 and 2000 we result the percentage of the vehicles that survives the first to years of operation.

Table I-1 summarises this procedure for all age classes and years for Germany. Note that some parts of the data could not be validated – e.g. the total number and the sum of the age classes deviated –. The data that were thought to be misleading or unreliable were excluded. Finally, the average value of survival for each age class was taken as representative for the country. In most cases 3 pairs of values were retrieved connecting years to survival rates. These data sets were used for fitting a lifetime function of the form mentioned above and the bi, Ti values that produced the least error fit are the characteristic values of the country. Figure I-1 shows the scatter of the data for Germany, the curve that was produced by the fitting process and its characteristics.

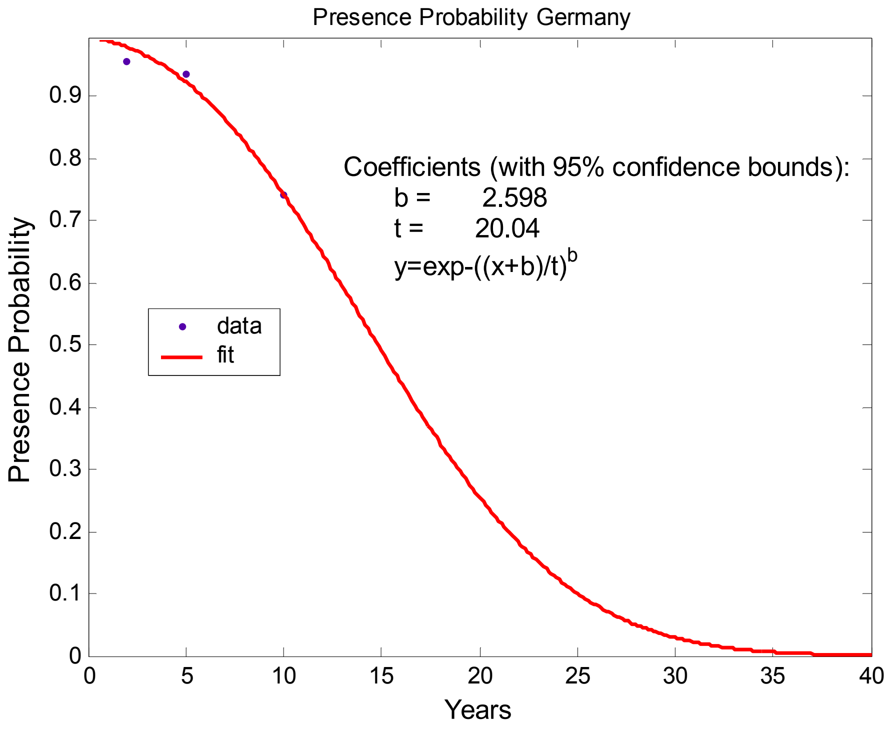


Figure I-1: Presence probability curve for Germany

Characteristic values of Ti and bi for lorries were calculated with this procedure for Germany, France, Sweden, Ireland and Austria. There has been an effort to apply this process to all EU-15 countries. However, the data provided by Eurostat regarding the age distribution are not for all countries as detailed as they are for Germany. Furthermore in some cases the age distribution numbers appeared to have great declinations from those of the new registrations resulting ratios of more than 110%. These cases were abandoned. In general terms this age classification of vehicles performed by Eurostat was initiated rather recently so the quality of the data varies significantly between countries and years. However, it is expected that the situation will improve and this kind of analysis will be possible in the future for all countries and with more accurate results.

For the rest of Europe where the procedure mentioned above was not applicable, values bi, Ti occurred by considering similarities between countries. Therefore the same factors were assigned to Sweden, Denmark and Finland as these countries have common geographical and population characteristics. Austria's factors were applied to the Netherlands and Luxembourg shares the same values as Germany; note that the difference of Germany's and Austria's characteristic factors is quite small fact which implies similar fleet evolution for these four countries. Values of bi and Ti for France were also applied to Belgium, Italy, Spain and UK. For the last three, the size of population and the fact that these countries have their own N1 production - as France also does - were the facts that supported this decision. In the case of Belgium the decision was based on similar cultural and consuming characteristics that the two countries share. Finally, Portugal and Greece share the same factors as Ireland based on the fact that Ireland has the longest renewal rate for N1s between the 5 calculated countries, something which should apply also in the case of Greece and Portugal, countries that have the smallest purchasing power in EU-15.

Before closing the discussion about the factors that describe the ageing of the vehicles and their calculation, it is interesting to take a look at figure I-2. The curves of Figure I-2 represent the lifetime functions of N1 and M1 vehicles in Germany. More specifically, the blue curve stands for the function previously used by TRENDS for commercial vehicles and the red the one that was adopted after this study. The green curve is the one that TRENDS uses for M1 vehicles. It becomes clear that the results of this study bring the ageing process of lorries closer to that of passenger cars than it was thought to be. This result is justified by the fact that a significant proportion of commercial vehicles have almost identical technical characteristics as M1s – e.g. N1 class I vehicles –. Moreover commercial vehicles are operated under hard conditions and it is not logical to have a 90% survival ratio after 20 years of operation as the old curve indicates. Generally the 15 years lifetime of the 50% of the vehicles indicated by the new fit is thought to correspond better to the conditions that exist today.

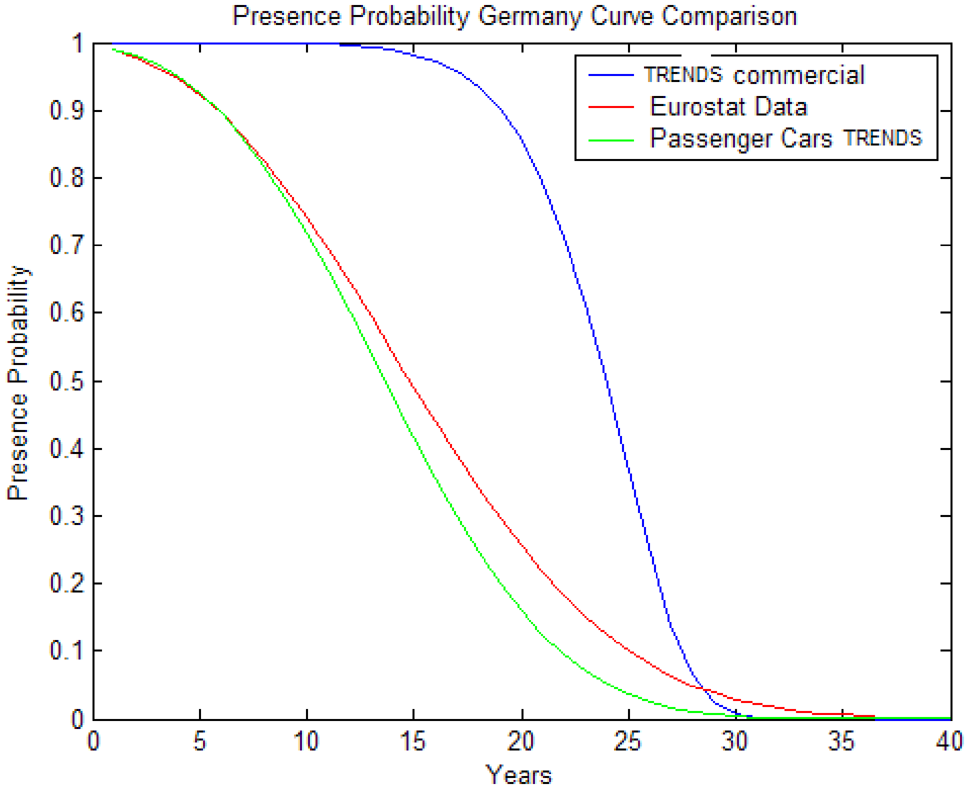


Figure I-2: Lifetime functions comparison

The values of bi and Ti for the rest of the countries are presented in figures I-3 to I-6 in together with the calculated curves and the statistical data points used.

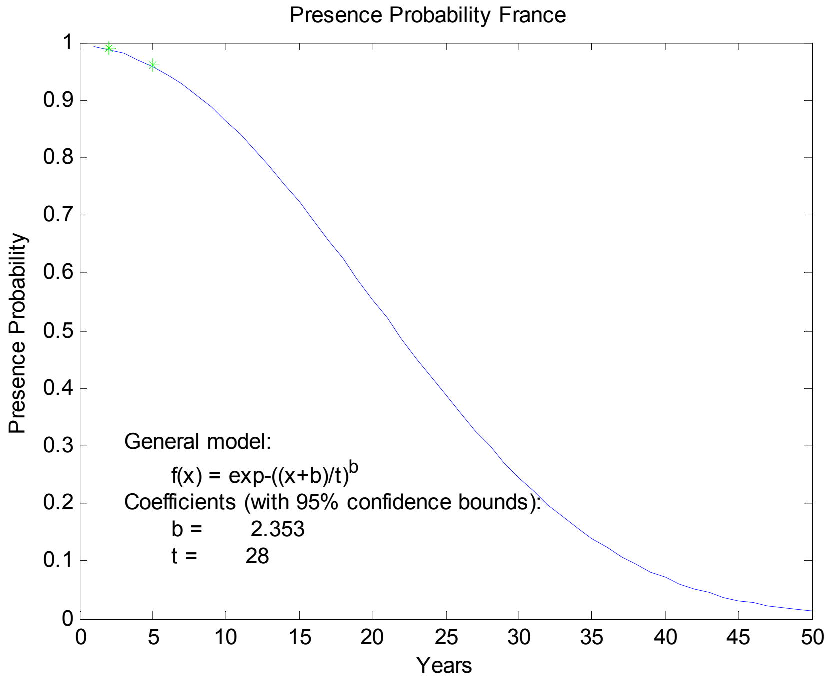


Figure I-3: Presence probability curve for France

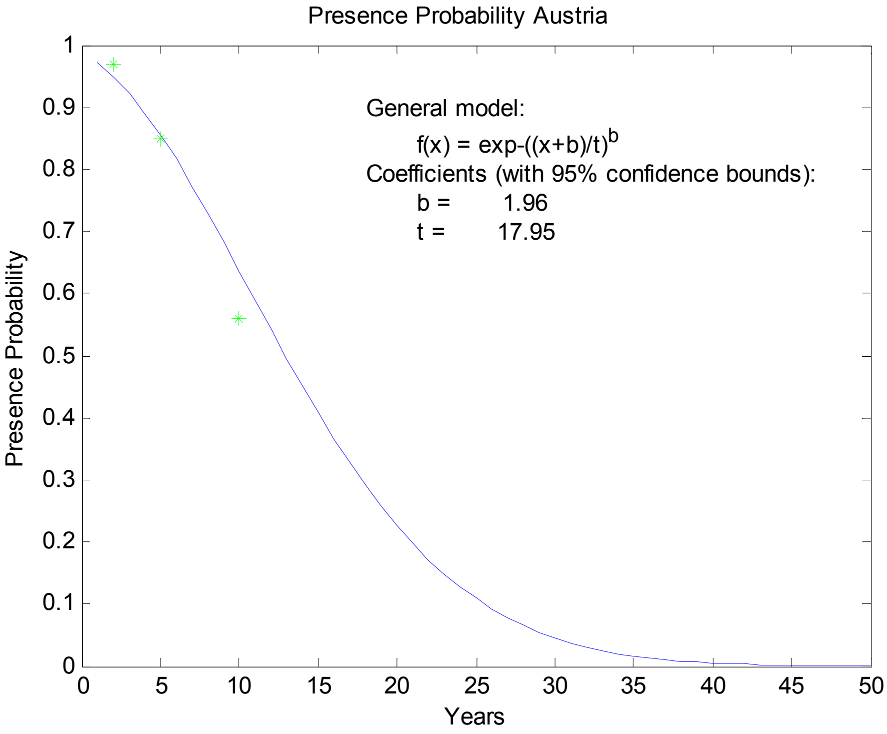


Figure I-4: Presence probability curve for Austria

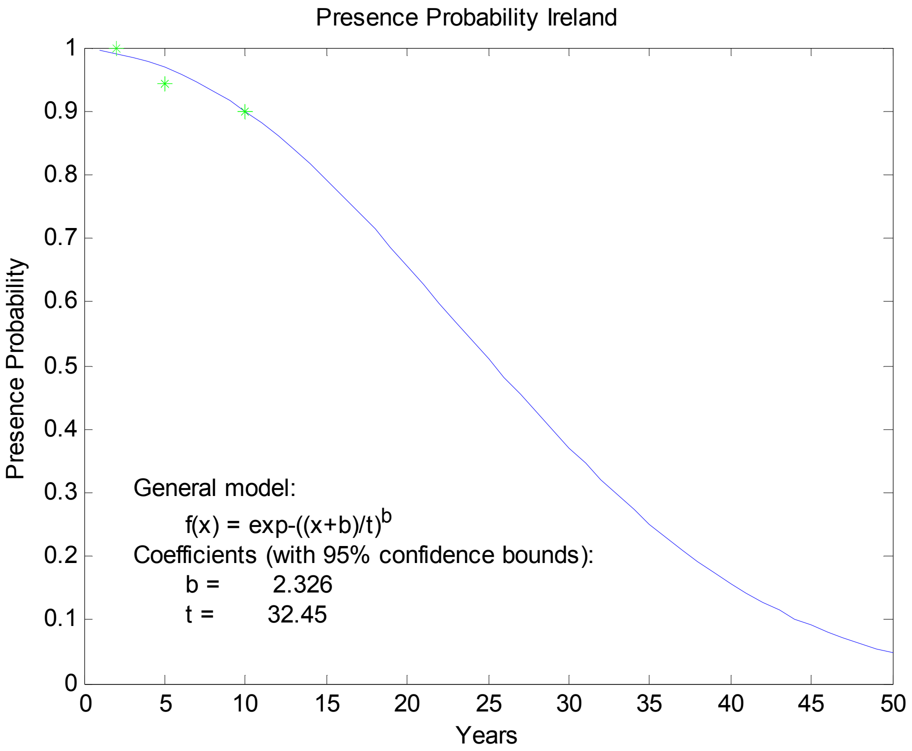


Figure I-5: Presence probability curve for Ireland

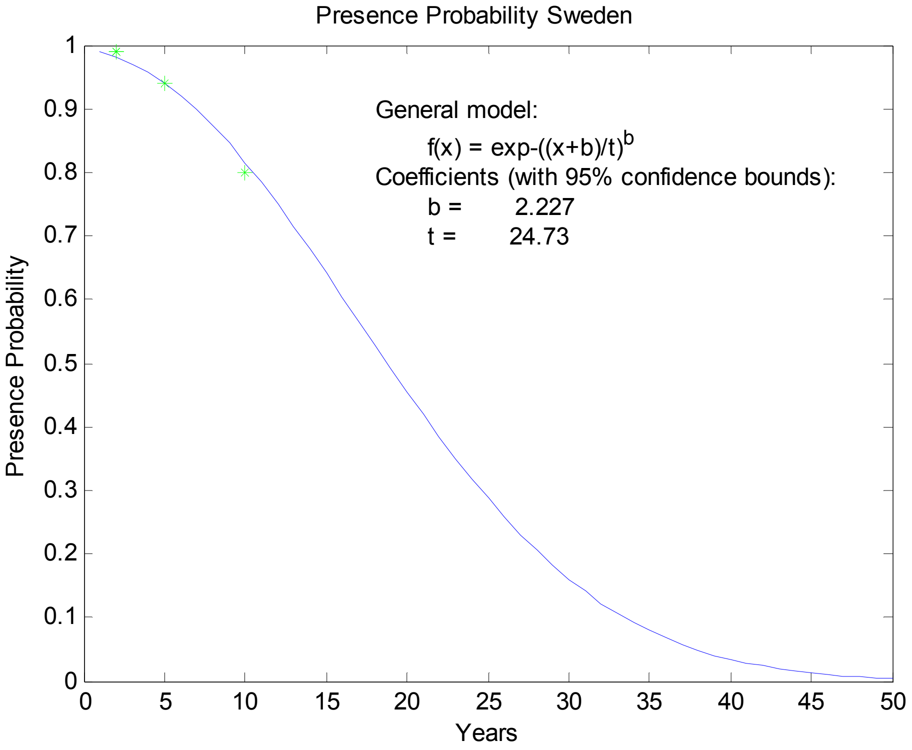


Figure I-6: Presence probability curve for Sweden

Table I-1: Statistical data for calculating lifetime function of lorries in Germany

Country	**Year**	*2001*	*2000*	*1999*	*1998*	*1997*	*1996*	*1995*	*1994*	*1993*	*1992*
Germany	**Registered**	228826	246432	257905	237034	212899	199851	212345	216821	210109	271589
	total	2649097	2610885	2465535	2370599	2315483	2273493	2215236	2113751	2015452	1727779
	0-2years	468736	497069	452667	406731	392967	402388	411809	373217		
	2-5years	651174	608399	590291	591179	653767	686513	719259	703505		
	5-10years	834403	905306	873997	842374	767516	667541	567566	582311		
	Over 10y	694784	600111	548580	530315	517500	517051	516602	456171		
	Percentages (no of vehicles in category / sum of vehicles registred in the category's time interval)										Average
	0-2y	98.6%	98.6%	91.5%	90.4%	95.2%	97.6%	96.0%			95.4%
	2-5y	92.0%	93.6%	94.4%	94.0%						93.5%
	5-10y	75.1%	72.8%								74.0%

J Light Duty Vehicles

In order to make any predictions concerning the future of the N1 vehicles' CO_2-emissions, a detailed image of the N1 vehicle market is necessary. Furthermore, time series of new registrations and fleet population are also vital for making accurate future estimations. However most of the sources containing relevant data refer to the load carrying capacity of the vehicle. Thus it was necessary to verify if and at what point the load carrying capacity varies between different classes of vehicles. Legislation defines N1 vehicles as light commercial vehicles not exceeding 3.5 tons of maximum – Gross Vehicle Weight (GVW) –. Using data from real N1s currently sold in Germany, Figure J-1 linking GVW to the load carrying capacity of the vehicles was formed.

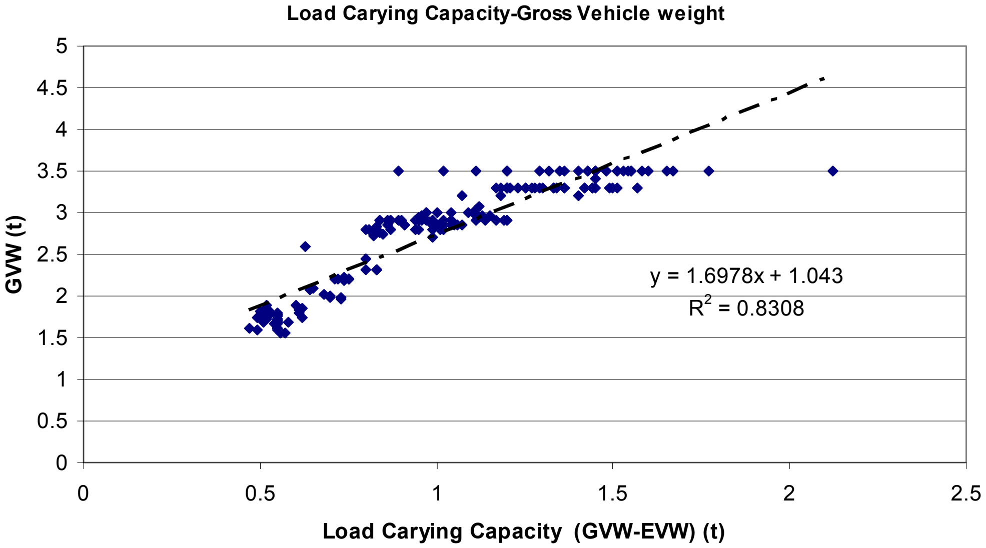


Figure J-1: Gross Vehicle Weight related to the Load carrying capacity of the vehicle

It appears that a linear relation exists between the load carrying capacity of the vehicle and the GVW. It is also clear that manufacturers "push down" the GVW to the 3.5 tons in some cases as this GVW value have the greatest scatter. One reason for doing this is in order to keep a vehicle in the N1 category and not go to other categories where the characterisation of the vehicle and the applied standards would change. It is clear from the above that all the vehicles having a load carrying capacity up to 1.5 tons can be considered of GVW less than 3.5 tons and so it is assumed that they belong to N1 category.

This data, retrieved from catalogue [Lastauto und Omnibus,2004] of commercial vehicles was further used in order to study how the load carrying capacity of N1s varies within the different classes (Figure J-2). This short research has shown that according to the mass of the vehicle there are escalations in its load carrying capacity. Vehicles of the first class have mostly load carrying capacities of 500 or 600 kg. Class II of N1s is in between the other two classes having load carrying capacities of 700 to 800 kg with some vehicles coming from their class I relatives having load carrying capacities again between 500-600 kg. On the other hand, class III appears to be much more scattered –

class III cars have also more variants – with the majority of the vehicles being between 800 and 1500 kg.

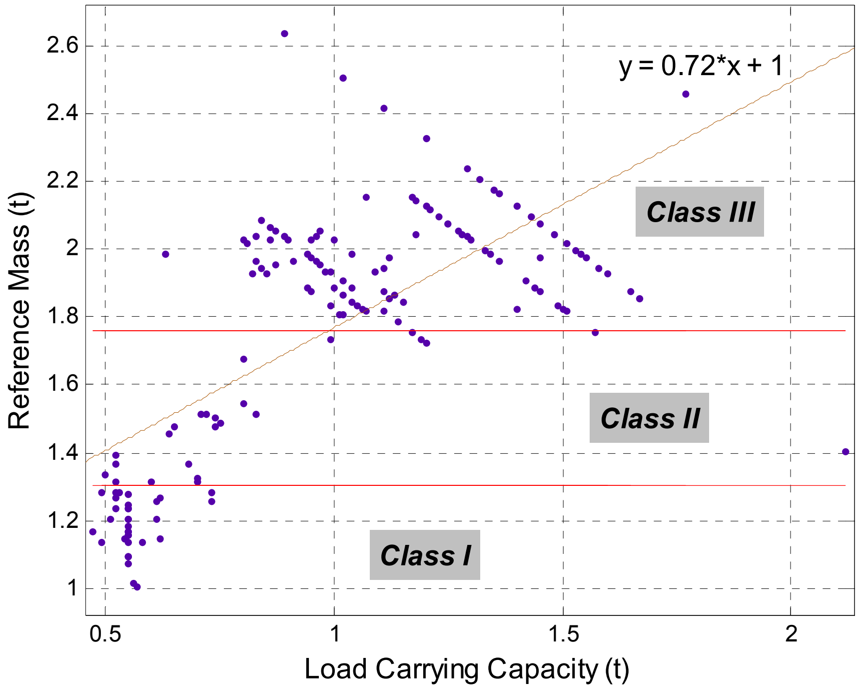


Figure J-2: Reference mass as a relation of the load carrying capacity of N1s

Table J-1: Registrations of light duty vehicles per country – source CCFA

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002
Germany	101393	81494	125384	178697	172171	185832	203796	218036	212290	206299	193152
Austria	15473	16458	21539	21427	22383	23585	24956	25066	27243	24107	22405
Belgium	30609	33506	52490	33067	36010	45311	50317	58205	54090	60594	50059
Denmark	15711	32362	19649	25465	26998	30193	29078	33026	33092	31477	32292
Spain	88042	114285	229821	166082	184226	218181	255048	309600	299246	287722	269135
Finland	12574	14624	27507	7525	10049	13394	15832	16383	15056	15089	15419
France	277887	304041	393795	312841	331297	312793	347119	375419	414966	433872	404919
Greece	45124	18507	29480	16131	12989	18022	16812	21640	23008	20603	18799
Ireland	8640	13855	24136	13732	16192	19834	27349	33898	41474	38704	34821
Italy	109270	100655	156995	139083	142554	136802	168182	190847	225517	225960	264522
Luxembourg	1014	879	1863	2217	2067	2215	2592	3121	3083	3810	3944
Norway	11395	38090	20582	33789	32490	32516	31537	29188	31627	33820	24653
The Netherlands	33498	50045	53080	51835	68344	82001	96690	99345	96570	84238	81133
Portugal	38597	20065	64236	66253	84699	103291	119874	127172	152836	98901	79493
The United Kingdom	212042	232261	247728	198223	208329	230038	243385	237766	245163	259811	271796
Sweden	12038	16228	26362	10856	15154	20739	26393	28435	31854	29033	28849
Switzerland	18091	17185	22753	16160	17027	18228	19826	21739	24121	25370	22527
EU	***790064***	***867605***	***1398657***	***1243434***	***1333462***	***1442231***	***1627417***	***1777959***	***1875488***	***1820220***	***1770738***
Europe(17countries)	**1031398**	**1104540**	**1517400**	**1293383**	**1382979**	**1492975**	**1678780**	**1828886**	**1931236**	**1879410**	**1817918**

Table J-2:Light commercial vehicles in use - source ANFAC

LIGHT COMMERCIAL VEHICLES (<3.5t) in use in *('000 units)*

	1995	1996	1997	1998	1999	2000	2001	2002	Growth 02 / 01
AUSTRIA	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
BELGIUM	295	309	328	351	378	399.6	421.8	436.6	3.5
DENMARK	n.a	292	298	309	324	335.3	343.5	353.3	2.9
FINLAND	203	208	213	223	233	236.3	241.1	244.3	1.3
FRANCE	4.513	4.617	4.750	4.867	4.974	5.110	5.248	5.338	1.7
GERMANY *	n.a	n.a	n.a	n.a	2.087	2.240	2.305	2.323	0.8
GREAT BRITAIN	2.499	2.532	2.594	2.662	2.666	2.723	2.774	2.842	2.5
GREECE	665	680	711	742	773	801	802.3	823.3	2.6
IRELAND	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
ITALY	n.a	n.a	n.a	n.a	2.417,0	2.555	2.797,5	n.a	n.a
NETHERLANDS	514	525	567	628	696	756	797	836	4.9
PORTUGAL	740	790	855	945	920	1.008	1.057	1.097	3.8
SPAIN	2.730	2.852	2.999	3.181	3.384	3.553	3.714	3.851	3.7
SWEDEN	235	240	249	264	278	297	318	332	4.5
EUROPEAN UNION**	12.394	13.046	13.563	14.171	19.130	20.016	20.822	18.479	-11.3

Source: ANFAC : Asociación Española de Fabricantes de Automóviles y Camiones

**.- 1995-1999 (1 st July), 2000 and 2001(31st december).*

**- For available data