# NORDIC VEHICLE CONFIGURATION FROM VIEWPOINT OF FUEL AND TRANSPORT ECONOMY, EMISSION REDUCTION AND ROAD WEAR IMPACT

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## ABSTRACT

The paper includes, firstly, a technical descpription of the Nordic Vehicle Configuration and its advantages and benefits compared to the vehicle configurations in the other European countries. Secondly it includes a short description of the Vehicle Motion Simulator (VMS), its principles, input and output data and analysis output data. The results obtained in this study have been created by this simulation system.

The Nordic Vehicle Configuration (NVC) currently in Finland and Sweden and restrictedly in Norway and Denmark (truck + trailer, gross combination mass of 60 tons and maximum length of 25.25 meters) is much more efficient measured by energy consumption [ l//100 tkm] and much more environmental friendly measured by pollutant emissions [g/tkm] than the Central European vehicle combinations (gross combination mass of 40 tons and maximum length of 18.75 meters). The payload of the Nordic vehicle configuration is approximately 42 tons, but the one of the Central European is only approximately 25 tons. Though the fuel consumption per the traffic product unit [vehicle*km] increases with the mass, calculated per the transport product unit [ton*kilometer] it decreases remarkably as well as the pollutant emissions.

These results and many more have been obtained by using the simulation system together with digital road data. The results of this simulation system have been validated with field measurements.

The simulation system is based on vehicle dynamics. In the case of road traffic, input data of the simulation system includes three data categories: 1) engine and vehicle data, 2) road data and 3) driving patterns. The principal engine data consists of engine maps of fuel and emissions.

## INTRODUCTION

This paper deals with the comparison of the Nordic vehicle configuration and the Central European vehicle configuration. The comparison is made so that the comparison quantities are produced for the Nordic Vehicle Configuration and the Central European Vehicle Configuration in the same conditions (on the same road sections in Finland).

The tool used in the calculations is a vehicle motion simulator based on the vehicle dynamics. The simulator outputs directly the used time, the fuel consumption and the emissions by components for any vehicle type. The economical impacts are produced indirectly by using the simulation results and unit prices.

In this case the simulation has been applied for the Nordic vehicle configuration and the Central European vehicle configuration on the selected road sections. A short description of the simulator is given in Appendix of this paper. There are two kinds of comparison quantities; physical and monetary. The both are related to the traffic product [vehicle kilometers] and to the transport product [ton kilometers]. The physical quantities are: the used time, the fuel consumption, the emissions by items and the equivalent single axle loads (ESAL). The monetary quantities are: the variable and fixed vehicle operating costs.

The road sections included in the simulations represent three (3) types of topography in Finland: average, flat and hilly. The lengths of the road sections used in the simulations are 169.7, 176.1 and 50.8 km.

## VEHICLE DIMENSIONS AND MASSES IN THE EUROPEAN UNION AND SOME OTHER COUNTRIES

Heavy duty vehicles for goods transport are different in the European countries. When there is question of long haulage transportation, in general, goods are not transported by single unit trucks (without trailers), but the transportation occurs with vehicle combinations. This means that trucks are equipped either with semi-trailers or with trailers. However, the regulations concerning the masses and dimensions of these vehicles in national transportation vary from country to country.

### Vehicle dimensions

The dimensions are more homogeneous, because they have been harmonized within the European Union with few exceptions, but the masses can be decided at the national level. A common length for an articulated vehicle (truck + semi-trailer) is 16.5 m and for a road train (truck + trailer) is 18.75 m. In Finland the maximum length for all road trains is 25.25 m as well as in Sweden for module combinations. If the road train in Sweden is not a module combination (genuine), the maximum length is only 24 m. In Norway (not a member state of the EU) the maximum length for a truck trailer combination in timber transportation is 22 m, otherwise 19 m. Restrictedly the modular concept (60 t, 25.25 m) can be utilized. In Denmark the maximum length is 18.75 m, but as in Norway the modular concept can be used restrictedly.

### Maximum gross mass of a vehicle combination

The maximum gross mass of a vehicle combination is in general 40 t in the Central European countries. Before the year of 2000 in Switzerland (not a member state of the EU) this was 28 t. In Denmark the maximum gross mass of a vehicle combination is 48 t and in the Netherlands 50 t as well as in Norway so far. In the Netherlands the modular concept is also known, and it is used restrictedly.

In Finland the maximum gross mass for a road train is 60 t, if the combinations has at least seven (7) axles, 53 t with six (6) axles at least, 44 t with five (5) axles at least and 36 t with four (4) axles at least. For an articulated vehicle the maximum gross mass is 48 t.

In Sweden from the viewpoint of the gross combination mass there is no separation between an articulated vehicle and a road train. The maximum gross mass is 60 t, but naturally the number of axles restricts that as well as in Finland.

**Nordic vehicle configuration**

The solution utilized in Finland and Sweden is called here a NORDIC VEHICLE CONFIGURATION (NVC). As said above Norway, Denmark and the Netherlands have adopted this concept and apply this restrictedly.

The main idea in the Nordic Vehicle Configuration is to save energy, reduce emissions and decrease transportation costs. Also the road wear will be reduced, while a reduced vehicle fleet with increased loads can take care of the same transport product [ton*kilometers] distributed on an increased number of (real) axles, but a decreased number of equivalent axles. The solution utilized in the Central European countries is called here a CENTRAL EUROPEAN VEHICLE CONFIGURATION.

## TYPE VEHICLES, TRANSPORTATION ROUTES AND DRIVING TECHNIQUE IN THE CASE STUDY

In this presentation some cases are studied. The fuel consumption and emissions have been analyzed by the computer simulation system for the motion of any road and rail vehicle. The simulation method has been validated by several field tests. The calculations concerning the vehicle operation costs are based on the current cost and price level in Finland, and the road wear survey is based on the AASHO road tests started in the early 1960's in USA and continued later all over the world

**Type vehicles**

In order the comparison between the different vehicle types would be possible the load space in all cases is assumed to be a sheeted body. Because the mass of the test vehicles varies between 40 and 80 t, the vehicle performance is also different. Therefore four (4) different engines (rated power range 309 … 460 kW) are tested throughout the whole vehicle fleet. All these engines are different versions of the same base engine. This has six (6) cylinders in a row and its swept volume is approximately 12 l. The rated power of this base version is 309 kW at 1900 rpm, and the version with a compound turbo has 345 kW at 1900 rpm. With eight (8) cylinders (V8) the respective values are 412 kW at 1900 rpm and 460 kW at 1900 rpm, and the swept volume is then approximately 16 l.

A very common vehicle type in Central Europe is an articulated vehicle (truck + semi-trailer). The truck has two (2) axles and the semi-trailer has three (3) axles. The semi-trailer has a triple bogie with single wheels at each axle. In Finland the gross mass of this vehicle combination can be 42 t, but in Central Europe it is normally 40 t. In this survey the gross combination mass is 40 t for this vehicle type, and then the payload (load capacity) is 25.7 t.

In those countries, where the gross mass is 48 to 50 t a very common vehicle combination is a 3-axled truck with 3-axled trailer. In Finland the gross mass of this type vehicle is 53 t. The payload is 35.5 t. This is selected for the second type vehicle to be surveyed.

In Finland and Sweden the most common combination is a 3-axled truck with a 4-axled trailer. Then the gross mass is 60 t and the payload 41.2 t. This is the third type vehicle.

So far the gross mass of 60 t is the maximum, although the combination has more than seven (7) axles. This occurs in general in case of the length of 25.25 m, because the turning rule requires five (5) axles in the trailer. In order to utilize the full capacity of the axle masses the gross mass of this combination could be 68 t (truck 26 t and trailer 42 t) and respectively the

payload would be 47.7 t. This is not yet legal, but it might be the next step in the future solutions. This is selected for the fourth type vehicle in this survey.

By using 4-axled or 5-axled trucks the number of axles in the combination can still be increased. With a 4-axled truck the combination has nine (9) axles and gross train mass could be 74 t and the payload 52.4 t. This is the fifth type vehicle.

The sixth type vehicle is a 5-axled truck (38 t) and a 5-axled trailer (42 t). The gross train mass is then 80 t and the payload 58.0 t. See Table 1.

**Transportation routes**

Three (3) test road sections have been selected. The first represents an average road by the topography. This is the highway no. 7 leading eastbound from HELSINKI to VIROLAHTI (Russian border). The second is the highway no. 8 between KOKKOLA-OULU on the coast of Western Finland, where the terrain is very flat, and therefore this section represents a flat road. The third is the highway no. 26 between HAMINA-TAAVETTI representing a hilly road. In this way the impacts of the terrain topography can be observed.

The technical characteristics of those road sections are:

| Road # | Direction | | Length km | Rate of rise m/km | Rate of fall m/km | Rate of rise and fall m/km |
|---|---|---|---|---|---|---|
| 7 | Eastbound | average | 169.707 | 4.614 | 4.602 | 9.216 |
| 8 | Northbound | flat | 176.191 | 2.605 | 2.673 | 5.278 |
| 26 | Northbound | hilly | 50.833 | 11.607 | 10.033 | 21.639 |

The topography (gradients) of those road sections is shown is Fig. 1.

Because the simulation is based on the laws of physics, its results are applicable on any route and road type in any country of the globe.

**Driving technique**

The legal speed for trucks is 80 km/h, but the speed limiter is set to 90 km/h. The test drives are made here with two target speeds 80 km/h and 90 km/h. On downward slopes, where the gravitation accelerates the vehicles the target speed can be temporarily exceeded by 10 km/h before brakes are used. The accelerator pedal is then in the upward position and no fuel flow occurs. This is called "swinging".

The rated engine speed in all versions is 1900 rpm. A gear shift down takes place, when the engine speed falls to 1000 rpm and up, when it reaches 1600 rpm. In shifting down the whole step is used, but in shifting up the splitter is used.

## RESULTS OF THE CASE STUDY

**Fuel consumption**

When the vehicle size is increasing the fuel consumption calculated per driven distance unit [l/100 km] is also increasing. However, the net load is increasing also, and if the fuel consumption is calculated per transport product unit [ton kilometer], the fuel consumption is decreasing. In this survey there are three (3) road sections. The highway no. 7 represents an average road, the highway no 8 a flat terrain and the highway no.26 a hilly terrain. The results

of the fuel consumption concerning direction A (eastbound and northbound) are presented in Tables 2A … 2D.

**Emissions**

The emissions of nitrogen oxides, carbon monoxide, hydro carbons, particulate matters and carbon dioxide were also analyzed. The results concerning direction A (eastbound and northbound) are presented in Tables 3A … 3D.

**Vehicle operation costs**

The vehicle operating costs can be divided into variable and fixed costs. The variable costs are:

- fuel costs
- lubricant costs
- repair & maintenance costs
- tire costs

The fixed costs are:

- capital costs: depreciation and interest
- wages + overhead costs
- insurance costs
- vehicle tax (drive power tax)
- administrative costs

Normally the vehicle operating costs [€/km] or [€/h] increase with the vehicle size. The purchasing price is higher (capital costs), and also wages, insurance costs and fixed taxes are higher. The variable operating costs [€/km] increase also, and the most obvious example of this is the fuel consumption and thus the fuel costs. But there is also an indirect impact on other variable operating costs. All the factors that affect the fuel consumption affect the other cost components in the same way. In this study a linear relationship has been applied; so a certain relative change of the fuel consumption has been converted directly to the lubricant, repair & maintenance and tire costs. This is called Wehner's principle.

In the examples presented here the driving product (mileage) per vehicle has been assumed to be 150 000 km/a and the operation time is respectively 3 000 h/a. The results are presented in Tables 4A … 4D and in Fig. 2 and Fig. 3.

**Impacts on road wear**

Concerning the road wear attention must be paid to the number of equivalent axles in the vehicle combination and the net load size. The real axles of the vehicle are converted to the equivalent single axle loads (ESAL) according to the rules of the AASHO Road Test.

The unit of this quantity is a single axle of 10 tons with twin wheels, and the other types of axles or axle groups are converted to these units.

From the viewpoint of road wear the most "road friendly" vehicle is the one that has the maximum load per equivalent axle, or inversely when a certain amount of goods must be transported, the number of equivalent axles shall be minimized.

The characteristics of the type vehicles from the road wear viewpoint are seen in Table 5.

## CONCLUSIONS

### General conclusion concerning the way of analysis

The Vehicle Motion Simulator based on vehicle dynamics is an effective tool for analyzing impacts of the characteristics of the different vehicle configurations on the motion state, fuel consumption and emissions.

### Conclusions concerning the Nordic Vehicle Configuration vs. the Central European Vehicle Configuration

The Nordic Vehicle Configuration is in many aspects superior to the Central European Vehicle Configuration.

The transportation of goods in general by the Central European vehicle is approximately 33 percent more expensive per the transport product unit [tkm] than by the Nordic vehicle.

The Central European articulated vehicle consumes approximately 32 percent more fuel per the transport product unit [tkm] than the Nordic road train.

Respectively, carbon dioxide emissions are also 32 percent higher in the Central Europe than in the Nordic countries.

The Central European articulated vehicle generates approximately 41 percent more nitrogen oxides per the transport product unit [tkm] than the Nordic road train.

The Central European articulated vehicle wears approximately 64 percent more road pavement per the transport product unit [tkm] than the Nordic road train.

## Table 1. Characteristics of the type vehicles

| No. | Configuration | Number of axles | | | Gross mass | Payload |
|---|---|---|---|---|---|---|
| | | truck | trailer | total | | |
| | | # | # | # | t | t |
| 1 | Truck + semi-trailer | 2 | 3 | 5 | 40 | 25.7 |
| 2 | Truck + trailer | 3 | 3 | 6 | 53 | 35.5 |
| 3 | Truck + trailer | 3 | 4 | 7 | 60 | 41.2 |
| 4 | Truck + trailer | 3 | 5 | 8 | 68 | 47.7 |
| 5 | Truck + trailer | 4 | 5 | 9 | 74 | 52.4 |
| 6 | Truck + trailer | 5 | 5 | 10 | 80 | 58.0 |

## Optional engines

| Engine # | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Bore | [mm] | 127 | 127 | 127 | 127 |
| Stroke | [mm] | 154 | 154 | 154 | 154 |
| Number of cylinders | | 6 | 6 | 8 | 8 |
| Swept volume | [l] | 11.705 | 11.705 | 15.607 | 15.607 |
| Rated power/ | [kW] | 309 | 345 | 412 | 460 |
| rated engine speed | [rpm] | 1900 | 1900 | 1900 | 1900 |
| Maximum torque/ | [Nm] | 2100 | 2160 | 2800 | 2880 |
| engine speed | [rpm] | 1300 | 1200 | 1300 | 1200 |

## Table 2A. Fuel consumption vs. vehicle size

**Rated engine power 309 kW**

**TARGET SPEED 80 km/h**

**GCM = GROSS COMBINATION MASS**

| GCM t | LOAD t | ROAD | AVERAGE SPEED km/h | FUEL CONSUMPTION l/100 km | l/100 tkm | CARBON DIOXIDE g/km | g/tkm |
|---|---|---|---|---|---|---|---|
| 40 | 25.7 | AVG. | 80.06 | 35.85 | 1.39 | 953 | 37.09 |
| 40 | 25.7 | FLAT | 80.16 | 35.17 | 1.37 | 935 | 36.39 |
| 40 | 25.7 | HILLY | 78.59 | 42.15 | 1.64 | 1120 | 43.58 |
| 53 | 35.5 | AVG. | 79.42 | 41.65 | 1.17 | 1107 | 31.19 |
| 53 | 35.5 | FLAT | 80.08 | 40.68 | 1.15 | 1082 | 30.47 |
| 53 | 35.5 | HILLY | 76.83 | 49.19 | 1.39 | 1307 | 36.81 |
| 60 | 41.2 | AVG. | 78.93 | 44.54 | 1.08 | 1184 | 28.74 |
| 60 | 41.2 | FLAT | 79.97 | 43.41 | 1.05 | 1154 | 28.02 |
| 60 | 41.2 | HILLY | 75.89 | 52.56 | 1.28 | 1397 | 33.90 |
| 68 | 47.7 | AVG. | 78.25 | 47.71 | 1.00 | 1268 | 26.58 |
| 68 | 47.7 | FLAT | 79.68 | 46.39 | .97 | 1233 | 25.86 |
| 68 | 47.7 | HILLY | 74.67 | 56.31 | 1.18 | 1496 | 31.36 |
| 74 | 52.4 | AVG. | 77.69 | 50.21 | .96 | 1334 | 25.46 |
| 74 | 52.4 | FLAT | 79.43 | 48.77 | .93 | 1297 | 24.75 |
| 74 | 52.4 | HILLY | 73.75 | 59.13 | 1.13 | 1571 | 29.98 |
| 80 | 58.0 | AVG. | 77.07 | 52.70 | .91 | 1401 | 24.15 |
| 80 | 58.0 | FLAT | 79.24 | 51.18 | .88 | 1361 | 23.46 |
| 80 | 58.0 | HILLY | 72.80 | 61.99 | 1.07 | 1647 | 28.40 |

**TARGET SPEED 90 km/h**

| GCM t | LOAD t | ROAD | AVERAGE SPEED km/h | FUEL CONSUMPTION l/100 km | l/100 tkm | CARBON DIOXIDE g/km | g/tkm |
|---|---|---|---|---|---|---|---|
| 40 | 25.7 | AVG. | 89.72 | 39.48 | 1.54 | 1051 | 40.88 |
| 40 | 25.7 | FLAT | 90.06 | 39.11 | 1.52 | 1041 | 40.50 |
| 40 | 25.7 | HILLY | 87.96 | 44.24 | 1.72 | 1177 | 45.79 |
| 53 | 35.5 | AVG. | 88.80 | 45.11 | 1.27 | 1200 | 33.82 |
| 53 | 35.5 | FLAT | 89.88 | 44.77 | 1.26 | 1191 | 33.56 |
| 53 | 35.5 | HILLY | 86.01 | 50.79 | 1.43 | 1351 | 38.05 |
| 60 | 41.2 | AVG. | 88.14 | 47.72 | 1.16 | 1270 | 30.81 |
| 60 | 41.2 | FLAT | 89.67 | 47.39 | 1.15 | 1261 | 30.62 |
| 60 | 41.2 | HILLY | 84.94 | 53.83 | 1.31 | 1432 | 34.75 |
| 68 | 47.7 | AVG. | 87.40 | 50.68 | 1.06 | 1349 | 28.27 |
| 68 | 47.7 | FLAT | 89.36 | 50.30 | 1.05 | 1339 | 28.07 |
| 68 | 47.7 | HILLY | 83.80 | 57.26 | 1.20 | 1523 | 31.93 |
| 74 | 52.4 | AVG. | 86.73 | 52.95 | 1.01 | 1409 | 26.89 |
| 74 | 52.4 | FLAT | 89.10 | 52.61 | 1.00 | 1400 | 26.72 |
| 74 | 52.4 | HILLY | 82.83 | 59.85 | 1.14 | 1592 | 30.38 |
| 80 | 58.0 | AVG. | 86.00 | 55.17 | .95 | 1468 | 25.31 |
| 80 | 58.0 | FLAT | 88.78 | 54.91 | .95 | 1461 | 25.20 |
| 80 | 58.0 | HILLY | 81.74 | 62.58 | 1.08 | 1664 | 28.70 |

## Table 2B. Fuel consumption vs. vehicle size

**Rated engine power 345 kW**

**TARGET SPEED 80 km/h**

**GCM = GROSS COMBINATION MASS**

| GCM t | LOAD t | ROAD | AVERAGE SPEED km/h | FUEL CONSUMPTION l/100 km | l/100 tkm | CARBON DIOXIDE g/km | g/tkm |
|---|---|---|---|---|---|---|---|
| 40 | 25.7 | AVG. | 79.95 | 36.65 | 1.43 | 938 | 36.50 |
| 40 | 25.7 | FLAT | 80.13 | 36.07 | 1.40 | 923 | 35.92 |
| 40 | 25.7 | HILLY | 78.63 | 42.09 | 1.64 | 1078 | 41.94 |
| 53 | 35.5 | AVG. | 79.40 | 41.99 | 1.18 | 1075 | 30.28 |
| 53 | 35.5 | FLAT | 80.06 | 41.42 | 1.17 | 1060 | 29.87 |
| 53 | 35.5 | HILLY | 77.03 | 48.67 | 1.37 | 1246 | 35.10 |
| 60 | 41.2 | AVG. | 78.97 | 44.63 | 1.08 | 1142 | 27.73 |
| 60 | 41.2 | FLAT | 79.97 | 44.04 | 1.07 | 1126 | 27.34 |
| 60 | 41.2 | HILLY | 76.13 | 51.93 | 1.26 | 1329 | 32.26 |
| 68 | 47.7 | AVG. | 78.37 | 47.55 | 1.00 | 1217 | 25.52 |
| 68 | 47.7 | FLAT | 79.71 | 46.86 | .98 | 1198 | 25.12 |
| 68 | 47.7 | HILLY | 75.05 | 55.41 | 1.16 | 1418 | 29.72 |
| 74 | 52.4 | AVG. | 77.84 | 49.82 | .95 | 1275 | 24.33 |
| 74 | 52.4 | FLAT | 79.48 | 49.09 | .94 | 1255 | 23.95 |
| 74 | 52.4 | HILLY | 74.14 | 58.10 | 1.11 | 1487 | 28.37 |
| 80 | 58.0 | AVG. | 77.29 | 52.10 | .90 | 1334 | 22.99 |
| 80 | 58.0 | FLAT | 79.29 | 51.35 | .89 | 1313 | 22.63 |
| 80 | 58.0 | HILLY | 73.28 | 60.70 | 1.05 | 1553 | 26.77 |

**TARGET SPEED 90 km/h**

| GCM t | LOAD t | ROAD | AVERAGE SPEED km/h | FUEL CONSUMPTION l/100 km | l/100 tkm | CARBON DIOXIDE g/km | g/tkm |
|---|---|---|---|---|---|---|---|
| 40 | 25.7 | AVG. | 89.69 | 39.88 | 1.55 | 1021 | 39.71 |
| 40 | 25.7 | FLAT | 90.03 | 39.57 | 1.54 | 1014 | 39.46 |
| 40 | 25.7 | HILLY | 88.12 | 44.13 | 1.72 | 1130 | 43.96 |
| 53 | 35.5 | AVG. | 88.92 | 45.17 | 1.27 | 1155 | 32.54 |
| 53 | 35.5 | FLAT | 89.93 | 45.19 | 1.27 | 1154 | 32.52 |
| 53 | 35.5 | HILLY | 86.26 | 50.29 | 1.42 | 1287 | 36.25 |
| 60 | 41.2 | AVG. | 88.32 | 47.61 | 1.16 | 1218 | 29.55 |
| 60 | 41.2 | FLAT | 89.76 | 47.73 | 1.16 | 1218 | 29.57 |
| 60 | 41.2 | HILLY | 85.30 | 53.14 | 1.29 | 1359 | 32.99 |
| 68 | 47.7 | AVG. | 87.63 | 50.34 | 1.06 | 1287 | 26.99 |
| 68 | 47.7 | FLAT | 89.50 | 50.50 | 1.06 | 1289 | 27.02 |
| 68 | 47.7 | HILLY | 84.26 | 56.34 | 1.18 | 1441 | 30.21 |
| 74 | 52.4 | AVG. | 87.04 | 52.44 | 1.00 | 1341 | 25.59 |
| 74 | 52.4 | FLAT | 89.22 | 52.67 | 1.01 | 1344 | 25.65 |
| 74 | 52.4 | HILLY | 83.37 | 58.84 | 1.12 | 1505 | 28.72 |
| 80 | 58.0 | AVG. | 86.38 | 54.47 | .94 | 1393 | 24.02 |
| 80 | 58.0 | FLAT | 88.96 | 54.80 | .94 | 1399 | 24.12 |
| 80 | 58.0 | HILLY | 82.38 | 61.16 | 1.05 | 1564 | 26.97 |

## Table 2C. Fuel consumption vs. vehicle size

**Rated engine power 412 kW**

**TARGET SPEED 80 km/h**

**GCM = GROSS COMBINATION MASS**

| GCM t | LOAD t | ROAD | AVERAGE SPEED km/h | FUEL CONSUMPTION l/100 km | l/100 tkm | CARBON DIOXIDE g/km | g/tkm |
|---|---|---|---|---|---|---|---|
| 40 | 25.7 | AVG. | 80.30 | 38.18 | 1.49 | 1015 | 39.49 |
| 40 | 25.7 | FLAT | 80.17 | 37.47 | 1.46 | 996 | 38.76 |
| 40 | 25.7 | HILLY | 79.97 | 44.84 | 1.74 | 1191 | 46.35 |
| 53 | 35.5 | AVG. | 80.27 | 44.07 | 1.24 | 1172 | 33.01 |
| 53 | 35.5 | FLAT | 80.22 | 43.03 | 1.21 | 1144 | 32.23 |
| 53 | 35.5 | HILLY | 78.97 | 52.77 | 1.49 | 1402 | 39.50 |
| 60 | 41.2 | AVG. | 80.13 | 47.04 | 1.14 | 1251 | 30.35 |
| 60 | 41.2 | FLAT | 80.22 | 45.78 | 1.11 | 1217 | 29.55 |
| 60 | 41.2 | HILLY | 78.39 | 56.50 | 1.37 | 1501 | 36.43 |
| 68 | 47.7 | AVG. | 79.86 | 50.33 | 1.06 | 1338 | 28.05 |
| 68 | 47.7 | FLAT | 80.19 | 48.83 | 1.02 | 1298 | 27.22 |
| 68 | 47.7 | HILLY | 77.61 | 60.65 | 1.27 | 1611 | 33.77 |
| 74 | 52.4 | AVG. | 79.59 | 52.94 | 1.01 | 1407 | 26.86 |
| 74 | 52.4 | FLAT | 80.14 | 51.26 | .98 | 1363 | 26.01 |
| 74 | 52.4 | HILLY | 76.95 | 63.78 | 1.22 | 1694 | 32.33 |
| 80 | 58.0 | AVG. | 79.29 | 55.54 | .96 | 1476 | 25.45 |
| 80 | 58.0 | FLAT | 80.09 | 53.69 | .93 | 1428 | 24.62 |
| 80 | 58.0 | HILLY | 76.33 | 66.85 | 1.15 | 1776 | 30.62 |

**TARGET SPEED 90 km/h**

| GCM t | LOAD t | ROAD | AVERAGE SPEED km/h | FUEL CONSUMPTION l/100 km | l/100 tkm | CARBON DIOXIDE g/km | g/tkm |
|---|---|---|---|---|---|---|---|
| 40 | 25.7 | AVG. | 90.12 | 42.21 | 1.64 | 1123 | 43.69 |
| 40 | 25.7 | FLAT | 90.11 | 41.78 | 1.63 | 1111 | 43.24 |
| 40 | 25.7 | HILLY | 89.60 | 47.77 | 1.86 | 1271 | 49.46 |
| 53 | 35.5 | AVG. | 89.96 | 48.11 | 1.36 | 1280 | 36.06 |
| 53 | 35.5 | FLAT | 90.12 | 47.46 | 1.34 | 1263 | 35.57 |
| 53 | 35.5 | HILLY | 88.49 | 54.94 | 1.55 | 1462 | 41.17 |
| 60 | 41.2 | AVG. | 89.77 | 50.87 | 1.23 | 1354 | 32.86 |
| 60 | 41.2 | FLAT | 90.11 | 50.14 | 1.22 | 1334 | 32.38 |
| 60 | 41.2 | HILLY | 87.75 | 58.28 | 1.41 | 1550 | 37.62 |
| 68 | 47.7 | AVG. | 89.44 | 53.96 | 1.13 | 1436 | 30.10 |
| 68 | 47.7 | FLAT | 90.05 | 53.17 | 1.11 | 1415 | 29.66 |
| 68 | 47.7 | HILLY | 86.95 | 62.04 | 1.30 | 1650 | 34.59 |
| 74 | 52.4 | AVG. | 89.08 | 56.35 | 1.08 | 1499 | 28.61 |
| 74 | 52.4 | FLAT | 89.99 | 55.56 | 1.06 | 1479 | 28.22 |
| 74 | 52.4 | HILLY | 86.28 | 64.93 | 1.24 | 1727 | 32.96 |
| 80 | 58.0 | AVG. | 88.70 | 58.75 | 1.01 | 1563 | 26.95 |
| 80 | 58.0 | FLAT | 89.87 | 57.91 | 1.00 | 1541 | 26.57 |
| 80 | 58.0 | HILLY | 85.63 | 67.59 | 1.17 | 1798 | 30.99 |

## Table 2D. Fuel consumption vs. vehicle size

**Rated engine power 460 kW**

**TARGET SPEED 80 km/h**

**GCM = GROSS COMBINATION MASS**

| GCM | LOAD | ROAD | AVERAGE SPEED | FUEL CONSUMPTION | | CARBON DIOXIDE | |
|---|---|---|---|---|---|---|---|
| t | t | | km/h | l/100 km | l/100 tkm | g/km | g/tkm |
| 40 | 25.7 | AVG. | 80.12 | 39.62 | 1.54 | 1014 | 39.46 |
| 40 | 25.7 | FLAT | 80.11 | 38.70 | 1.51 | 990 | 38.51 |
| 40 | 25.7 | HILLY | 79.87 | 45.38 | 1.77 | 1163 | 45.25 |
| 53 | 35.5 | AVG. | 80.12 | 45.31 | 1.28 | 1160 | 32.67 |
| 53 | 35.5 | FLAT | 80.18 | 44.29 | 1.25 | 1133 | 31.91 |
| 53 | 35.5 | HILLY | 78.99 | 52.84 | 1.49 | 1353 | 38.12 |
| 60 | 41.2 | AVG. | 79.99 | 48.06 | 1.17 | 1231 | 29.87 |
| 60 | 41.2 | FLAT | 80.18 | 47.00 | 1.14 | 1203 | 29.20 |
| 60 | 41.2 | HILLY | 78.46 | 56.44 | 1.37 | 1445 | 35.08 |
| 68 | 47.7 | AVG. | 79.78 | 51.09 | 1.07 | 1308 | 27.42 |
| 68 | 47.7 | FLAT | 80.15 | 49.98 | 1.05 | 1279 | 26.82 |
| 68 | 47.7 | HILLY | 77.77 | 60.25 | 1.26 | 1543 | 32.34 |
| 74 | 52.4 | AVG. | 79.55 | 53.50 | 1.02 | 1370 | 26.14 |
| 74 | 52.4 | FLAT | 80.11 | 52.31 | 1.00 | 1340 | 25.56 |
| 74 | 52.4 | HILLY | 77.15 | 63.21 | 1.21 | 1618 | 30.89 |
| 80 | 58.0 | AVG. | 79.29 | 55.91 | .96 | 1432 | 24.68 |
| 80 | 58.0 | FLAT | 80.06 | 54.60 | .94 | 1399 | 24.11 |
| 80 | 58.0 | HILLY | 76.55 | 66.17 | 1.14 | 1694 | 29.21 |

**TARGET SPEED 90 km/h**

| GCM | LOAD | ROAD | AVERAGE SPEED | FUEL CONSUMPTION | | CARBON DIOXIDE | |
|---|---|---|---|---|---|---|---|
| t | t | | km/h | l/100 km | l/100 tkm | g/km | g/tkm |
| 40 | 25.7 | AVG. | 89.98 | 43.03 | 1.67 | 1104 | 42.94 |
| 40 | 25.7 | FLAT | 90.06 | 42.22 | 1.64 | 1086 | 42.25 |
| 40 | 25.7 | HILLY | 89.62 | 48.24 | 1.88 | 1236 | 48.10 |
| 53 | 35.5 | AVG. | 89.89 | 48.82 | 1.38 | 1250 | 35.22 |
| 53 | 35.5 | FLAT | 90.10 | 48.04 | 1.35 | 1233 | 34.73 |
| 53 | 35.5 | HILLY | 88.61 | 55.03 | 1.55 | 1409 | 39.70 |
| 60 | 41.2 | AVG. | 89.74 | 51.49 | 1.25 | 1318 | 31.98 |
| 60 | 41.2 | FLAT | 90.09 | 50.77 | 1.23 | 1301 | 31.59 |
| 60 | 41.2 | HILLY | 87.93 | 58.10 | 1.41 | 1488 | 36.10 |
| 68 | 47.7 | AVG. | 89.45 | 54.39 | 1.14 | 1392 | 29.18 |
| 68 | 47.7 | FLAT | 90.06 | 53.75 | 1.13 | 1377 | 28.87 |
| 68 | 47.7 | HILLY | 87.13 | 61.66 | 1.29 | 1578 | 33.09 |
| 74 | 52.4 | AVG. | 89.15 | 56.66 | 1.08 | 1450 | 27.66 |
| 74 | 52.4 | FLAT | 90.01 | 56.13 | 1.07 | 1436 | 27.41 |
| 74 | 52.4 | HILLY | 86.52 | 64.36 | 1.23 | 1647 | 31.43 |
| 80 | 58.0 | AVG. | 88.80 | 58.91 | 1.02 | 1507 | 25.98 |
| 80 | 58.0 | FLAT | 89.94 | 58.46 | 1.01 | 1494 | 25.77 |
| 80 | 58.0 | HILLY | 85.90 | 66.95 | 1.15 | 1713 | 29.54 |

## Table 3A. Emissions vs. vehicle size

**Rated engine power 309 kW**

**TARGET SPEED 80 km/h**

**GCM = GROSS COMBINATION MASS**

| GCM | LOAD | ROAD | AVG.SPEED | NOx | | CO | | HC | |
|---|---|---|---|---|---|---|---|---|---|
| t | t | | km/h | g/km | g/tkm | g/km | g/tkm | g/km | g/tkm |
| 40 | 25.7 | AVG. | 80.06 | 9.58 | .373 | 1.292 | .0503 | .340 | .0132 |
| 40 | 25.7 | FLAT | 80.16 | 8.15 | .317 | 1.169 | .0455 | .335 | .0130 |
| 40 | 25.7 | HILLY | 78.59 | 13.62 | .530 | 2.040 | .0794 | .368 | .0143 |
| 53 | 35.5 | AVG. | 79.42 | 12.31 | .347 | 1.705 | .0480 | .373 | .0105 |
| 53 | 35.5 | FLAT | 80.08 | 10.46 | .295 | 1.347 | .0379 | .367 | .0103 |
| 53 | 35.5 | HILLY | 76.83 | 16.28 | .458 | 2.625 | .0739 | .417 | .0118 |
| 60 | 41.2 | AVG. | 78.93 | 13.64 | .331 | 1.901 | .0461 | .392 | .0095 |
| 60 | 41.2 | FLAT | 79.97 | 11.69 | .284 | 1.451 | .0352 | .383 | .0093 |
| 60 | 41.2 | HILLY | 75.89 | 17.43 | .423 | 2.608 | .0633 | .451 | .0110 |
| 68 | 47.7 | AVG. | 78.25 | 15.06 | .316 | 2.156 | .0452 | .412 | .0086 |
| 68 | 47.7 | FLAT | 79.68 | 13.02 | .273 | 1.644 | .0345 | .399 | .0084 |
| 68 | 47.7 | HILLY | 74.67 | 18.79 | .394 | 2.806 | .0588 | .483 | .0101 |
| 74 | 52.4 | AVG. | 77.69 | 16.13 | .308 | 2.269 | .0433 | .433 | .0083 |
| 74 | 52.4 | FLAT | 79.43 | 14.08 | .269 | 1.862 | .0355 | .411 | .0078 |
| 74 | 52.4 | HILLY | 73.75 | 19.83 | .378 | 3.015 | .0575 | .504 | .0096 |
| 80 | 58.0 | AVG. | 77.07 | 17.16 | .296 | 2.404 | .0414 | .451 | .0078 |
| 80 | 58.0 | FLAT | 79.24 | 15.11 | .260 | 1.889 | .0326 | .430 | .0074 |
| 80 | 58.0 | HILLY | 72.80 | 20.85 | .359 | 3.166 | .0546 | .528 | .0091 |

**TARGET SPEED 90 km/h**

| GCM | LOAD | ROAD | AVG.SPEED | NOx | | CO | | HC | |
|---|---|---|---|---|---|---|---|---|---|
| t | t | | km/h | g/km | g/tkm | g/km | g/tkm | g/km | g/tkm |
| 40 | 25.7 | AVG. | 89.72 | 10.28 | .400 | .786 | .0306 | .410 | .0160 |
| 40 | 25.7 | FLAT | 90.06 | 8.89 | .346 | .791 | .0308 | .393 | .0153 |
| 40 | 25.7 | HILLY | 87.96 | 13.93 | .542 | 1.219 | .0474 | .428 | .0167 |
| 53 | 35.5 | AVG. | 88.80 | 13.07 | .368 | .961 | .0271 | .451 | .0127 |
| 53 | 35.5 | FLAT | 89.88 | 11.35 | .320 | .799 | .0225 | .441 | .0124 |
| 53 | 35.5 | HILLY | 86.01 | 16.38 | .461 | 1.442 | .0406 | .481 | .0135 |
| 60 | 41.2 | AVG. | 88.14 | 14.37 | .349 | 1.147 | .0278 | .468 | .0114 |
| 60 | 41.2 | FLAT | 89.67 | 12.54 | .304 | .817 | .0198 | .464 | .0113 |
| 60 | 41.2 | HILLY | 84.94 | 17.54 | .426 | 1.622 | .0394 | .503 | .0122 |
| 68 | 47.7 | AVG. | 87.40 | 15.63 | .328 | 1.100 | .0231 | .497 | .0104 |
| 68 | 47.7 | FLAT | 89.36 | 13.87 | .291 | .864 | .0181 | .488 | .0102 |
| 68 | 47.7 | HILLY | 83.80 | 18.75 | .393 | 1.638 | .0343 | .535 | .0112 |
| 74 | 52.4 | AVG. | 86.73 | 16.65 | .318 | 1.193 | .0228 | .514 | .0098 |
| 74 | 52.4 | FLAT | 89.10 | 14.93 | .285 | .922 | .0176 | .508 | .0097 |
| 74 | 52.4 | HILLY | 82.83 | 19.78 | .377 | 1.856 | .0354 | .551 | .0105 |
| 80 | 58.0 | AVG. | 86.00 | 17.66 | .304 | 1.309 | .0226 | .529 | .0091 |
| 80 | 58.0 | FLAT | 88.78 | 16.00 | .276 | 1.004 | .0173 | .526 | .0091 |
| 80 | 58.0 | HILLY | 81.74 | 20.75 | .358 | 2.044 | .0352 | .573 | .0099 |

## Table 3B. Emissions vs. vehicle size

**Rated engine power 345 kW**

**TARGET SPEED 80 km/h**

**GCM = GROSS COMBINATION MASS**

| GCM | LOAD | ROAD | AVG.SPEED | NOx | | CO | | HC | | PM | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| t | t | | km/h | g/km | g/tkm | g/km | g/tkm | g/km | g/tkm | g/km | g/tkm |
| 40 | 25.7 | AVG. | 79.95 | 7.50 | .292 | .509 | .0198 | .229 | .0089 | .058 | .0023 |
| 40 | 25.7 | FLAT | 80.13 | 6.37 | .248 | .493 | .0192 | .241 | .0094 | .046 | .0018 |
| 40 | 25.7 | HILLY | 78.63 | 11.50 | .447 | .540 | .0210 | .215 | .0084 | .066 | .0026 |
| 53 | 35.5 | AVG. | 79.40 | 9.80 | .276 | .553 | .0156 | .228 | .0064 | .073 | .0020 |
| 53 | 35.5 | FLAT | 80.06 | 8.03 | .226 | .526 | .0148 | .239 | .0067 | .085 | .0024 |
| 53 | 35.5 | HILLY | 77.03 | 13.77 | .388 | .667 | .0188 | .229 | .0065 | .082 | .0023 |
| 60 | 41.2 | AVG. | 78.97 | 10.90 | .265 | .574 | .0139 | .230 | .0056 | .074 | .0018 |
| 60 | 41.2 | FLAT | 79.97 | 9.00 | .218 | .545 | .0132 | .238 | .0058 | .090 | .0022 |
| 60 | 41.2 | HILLY | 76.13 | 14.71 | .357 | .682 | .0166 | .240 | .0058 | .086 | .0021 |
| 68 | 47.7 | AVG. | 78.37 | 12.15 | .255 | .614 | .0129 | .234 | .0049 | .079 | .0017 |
| 68 | 47.7 | FLAT | 79.71 | 10.05 | .211 | .574 | .0120 | .239 | .0050 | .095 | .0020 |
| 68 | 47.7 | HILLY | 75.05 | 15.84 | .332 | .727 | .0152 | .250 | .0052 | .092 | .0019 |
| 74 | 52.4 | AVG. | 77.84 | 13.09 | .250 | .646 | .0123 | .237 | .0045 | .082 | .0016 |
| 74 | 52.4 | FLAT | 79.48 | 10.83 | .207 | .615 | .0117 | .241 | .0046 | .098 | .0019 |
| 74 | 52.4 | HILLY | 74.14 | 16.70 | .319 | .773 | .0148 | .258 | .0049 | .095 | .0018 |
| 80 | 58.0 | AVG. | 77.29 | 14.04 | .242 | .654 | .0113 | .240 | .0041 | .085 | .0015 |
| 80 | 58.0 | FLAT | 79.29 | 11.57 | .200 | .625 | .0108 | .244 | .0042 | .098 | .0017 |
| 80 | 58.0 | HILLY | 73.28 | 17.56 | .303 | .818 | .0141 | .265 | .0046 | .099 | .0017 |

**TARGET SPEED 90 km/h**

| GCM | LOAD | ROAD | AVG.SPEED | NOx | | CO | | HC | | PM | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| t | t | | km/h | g/km | g/tkm | g/km | g/tkm | g/km | g/tkm | g/km | g/tkm |
| 40 | 25.7 | AVG. | 89.69 | 8.12 | .316 | .515 | .0200 | .265 | .0103 | .065 | .0025 |
| 40 | 25.7 | FLAT | 90.03 | 7.00 | .273 | .512 | .0199 | .274 | .0107 | .064 | .0025 |
| 40 | 25.7 | HILLY | 88.12 | 11.48 | .447 | .477 | .0186 | .235 | .0091 | .077 | .0030 |
| 53 | 35.5 | AVG. | 88.92 | 10.34 | .291 | .533 | .0150 | .262 | .0074 | .072 | .0020 |
| 53 | 35.5 | FLAT | 89.93 | 8.72 | .246 | .554 | .0156 | .286 | .0081 | .069 | .0020 |
| 53 | 35.5 | HILLY | 86.26 | 13.48 | .380 | .548 | .0154 | .247 | .0070 | .084 | .0024 |
| 60 | 41.2 | AVG. | 88.32 | 11.41 | .277 | .551 | .0134 | .260 | .0063 | .076 | .0018 |
| 60 | 41.2 | FLAT | 89.76 | 9.60 | .233 | .571 | .0139 | .285 | .0069 | .070 | .0017 |
| 60 | 41.2 | HILLY | 85.30 | 14.50 | .352 | .596 | .0145 | .251 | .0061 | .088 | .0021 |
| 68 | 47.7 | AVG. | 87.63 | 12.52 | .262 | .561 | .0118 | .260 | .0055 | .080 | .0017 |
| 68 | 47.7 | FLAT | 89.50 | 10.57 | .222 | .588 | .0123 | .285 | .0060 | .073 | .0015 |
| 68 | 47.7 | HILLY | 84.26 | 15.51 | .325 | .583 | .0122 | .258 | .0054 | .090 | .0019 |
| 74 | 52.4 | AVG. | 87.04 | 13.39 | .255 | .556 | .0106 | .261 | .0050 | .082 | .0016 |
| 74 | 52.4 | FLAT | 89.22 | 11.35 | .217 | .601 | .0115 | .284 | .0054 | .075 | .0014 |
| 74 | 52.4 | HILLY | 83.37 | 16.33 | .312 | .614 | .0117 | .263 | .0050 | .093 | .0018 |
| 80 | 58.0 | AVG. | 86.38 | 14.23 | .245 | .565 | .0097 | .262 | .0045 | .085 | .0015 |
| 80 | 58.0 | FLAT | 88.96 | 12.17 | .210 | .608 | .0105 | .283 | .0049 | .078 | .0013 |
| 80 | 58.0 | HILLY | 82.38 | 17.18 | .296 | .666 | .0115 | .268 | .0046 | .096 | .0017 |

## Table 3C. Emissions vs. vehicle size

**Rated engine power 412 kW**

**TARGET SPEED 80 km/h**

**GCM = GROSS COMBINATION MASS**

| GCM | LOAD | ROAD | AVG.SPEED | NOx | | CO | | HC | |
|---|---|---|---|---|---|---|---|---|---|
| t | t | | km/h | g/km | g/tkm | g/km | g/tkm | g/km | g/tkm |
| 40 | 25.7 | AVG. | 80.30 | 8.97 | .349 | 1.310 | .0510 | .405 | .0158 |
| 40 | 25.7 | FLAT | 80.17 | 7.79 | .303 | 1.331 | .0518 | .409 | .0159 |
| 40 | 25.7 | HILLY | 79.97 | 14.00 | .545 | 2.312 | .0900 | .405 | .0158 |
| 53 | 35.5 | AVG. | 80.27 | 11.57 | .326 | 1.598 | .0450 | .427 | .0120 |
| 53 | 35.5 | FLAT | 80.22 | 9.71 | .274 | 1.456 | .0410 | .428 | .0121 |
| 53 | 35.5 | HILLY | 78.97 | 16.99 | .479 | 2.517 | .0709 | .469 | .0132 |
| 60 | 41.2 | AVG. | 80.13 | 12.92 | .314 | 1.750 | .0425 | .444 | .0108 |
| 60 | 41.2 | FLAT | 80.22 | 10.80 | .262 | 1.539 | .0374 | .440 | .0107 |
| 60 | 41.2 | HILLY | 78.39 | 18.51 | .449 | 2.821 | .0685 | .491 | .0119 |
| 68 | 47.7 | AVG. | 79.86 | 14.47 | .303 | 1.984 | .0416 | .461 | .0097 |
| 68 | 47.7 | FLAT | 80.19 | 12.06 | .253 | 1.651 | .0346 | .455 | .0095 |
| 68 | 47.7 | HILLY | 77.61 | 20.05 | .420 | 3.153 | .0661 | .520 | .0109 |
| 74 | 52.4 | AVG. | 79.59 | 15.66 | .299 | 2.191 | .0418 | .477 | .0091 |
| 74 | 52.4 | FLAT | 80.14 | 13.07 | .249 | 1.748 | .0334 | .468 | .0089 |
| 74 | 52.4 | HILLY | 76.95 | 21.14 | .404 | 3.391 | .0647 | .543 | .0104 |
| 80 | 58.0 | AVG. | 79.29 | 16.80 | .290 | 2.297 | .0396 | .494 | .0085 |
| 80 | 58.0 | FLAT | 80.09 | 14.11 | .243 | 1.830 | .0316 | .483 | .0083 |
| 80 | 58.0 | HILLY | 76.33 | 22.10 | .381 | 3.240 | .0559 | .580 | .0100 |

**TARGET SPEED 90 km/h**

| GCM | LOAD | ROAD | AVG.SPEED | NOx | | CO | | HC | |
|---|---|---|---|---|---|---|---|---|---|
| t | t | | km/h | g/km | g/tkm | g/km | g/tkm | g/km | g/tkm |
| 40 | 25.7 | AVG. | 90.12 | 9.48 | .369 | .962 | .0374 | .475 | .0185 |
| 40 | 25.7 | FLAT | 90.11 | 8.21 | .320 | 1.038 | .0404 | .462 | .0180 |
| 40 | 25.7 | HILLY | 89.60 | 14.12 | .549 | 1.011 | .0393 | .501 | .0195 |
| 53 | 35.5 | AVG. | 89.96 | 12.17 | .343 | .989 | .0278 | .515 | .0145 |
| 53 | 35.5 | FLAT | 90.12 | 10.33 | .291 | 1.031 | .0290 | .493 | .0139 |
| 53 | 35.5 | HILLY | 88.49 | 17.21 | .485 | 1.416 | .0399 | .542 | .0153 |
| 60 | 41.2 | AVG. | 89.77 | 13.54 | .329 | 1.037 | .0252 | .534 | .0130 |
| 60 | 41.2 | FLAT | 90.11 | 11.45 | .278 | 1.036 | .0251 | .513 | .0125 |
| 60 | 41.2 | HILLY | 87.75 | 18.50 | .449 | 1.725 | .0419 | .563 | .0137 |
| 68 | 47.7 | AVG. | 89.44 | 15.09 | .316 | 1.131 | .0237 | .553 | .0116 |
| 68 | 47.7 | FLAT | 90.05 | 12.73 | .267 | 1.038 | .0218 | .536 | .0112 |
| 68 | 47.7 | HILLY | 86.95 | 19.87 | .417 | 1.761 | .0369 | .596 | .0125 |
| 74 | 52.4 | AVG. | 89.08 | 16.25 | .310 | 1.249 | .0238 | .568 | .0108 |
| 74 | 52.4 | FLAT | 89.99 | 13.76 | .263 | 1.044 | .0199 | .556 | .0106 |
| 74 | 52.4 | HILLY | 86.28 | 20.92 | .399 | 1.853 | .0354 | .620 | .0118 |
| 80 | 58.0 | AVG. | 88.70 | 17.37 | .300 | 1.341 | .0231 | .586 | .0101 |
| 80 | 58.0 | FLAT | 89.87 | 14.79 | .255 | 1.052 | .0181 | .574 | .0099 |
| 80 | 58.0 | HILLY | 85.63 | 21.96 | .379 | 2.051 | .0354 | .637 | .0110 |

## Table 3D. Emissions vs. vehicle size

**Rated engine power 460 kW**

**TARGET SPEED 80 km/h**

**GCM = GROSS COMBINATION MASS**

| GCM | LOAD | ROAD | AVG.SPEED | NOx | | CO | | HC | | PM | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| t | t | | km/h | g/km | g/tkm | g/km | g/tkm | g/km | g/tkm | g/km | g/tkm |
| 40 | 25.7 | AVG. | 80.12 | 7.30 | .284 | .642 | .0250 | .306 | .0119 | .051 | .0020 |
| 40 | 25.7 | FLAT | 80.11 | 6.59 | .256 | .649 | .0253 | .329 | .0128 | .034 | .0013 |
| 40 | 25.7 | HILLY | 79.87 | 11.88 | .462 | .651 | .0253 | .268 | .0104 | .069 | .0027 |
| 53 | 35.5 | AVG. | 80.12 | 9.17 | .258 | .650 | .0183 | .298 | .0084 | .071 | .0020 |
| 53 | 35.5 | FLAT | 80.18 | 7.78 | .219 | .641 | .0181 | .321 | .0090 | .047 | .0013 |
| 53 | 35.5 | HILLY | 78.99 | 14.42 | .406 | .684 | .0193 | .279 | .0079 | .083 | .0023 |
| 60 | 41.2 | AVG. | 79.99 | 10.23 | .248 | .662 | .0161 | .297 | .0072 | .077 | .0019 |
| 60 | 41.2 | FLAT | 80.18 | 8.49 | .206 | .645 | .0156 | .318 | .0077 | .058 | .0014 |
| 60 | 41.2 | HILLY | 78.46 | 15.68 | .380 | .728 | .0177 | .285 | .0069 | .089 | .0022 |
| 68 | 47.7 | AVG. | 79.78 | 11.55 | .242 | .691 | .0145 | .296 | .0062 | .082 | .0017 |
| 68 | 47.7 | FLAT | 80.15 | 9.38 | .197 | .655 | .0137 | .315 | .0066 | .066 | .0014 |
| 68 | 47.7 | HILLY | 77.77 | 16.98 | .356 | .788 | .0165 | .293 | .0061 | .095 | .0020 |
| 74 | 52.4 | AVG. | 79.55 | 12.55 | .239 | .710 | .0136 | .297 | .0057 | .089 | .0017 |
| 74 | 52.4 | FLAT | 80.11 | 10.16 | .194 | .666 | .0127 | .314 | .0060 | .084 | .0016 |
| 74 | 52.4 | HILLY | 77.15 | 17.95 | .342 | .863 | .0165 | .301 | .0057 | .102 | .0020 |
| 80 | 58.0 | AVG. | 79.29 | 13.50 | .233 | .719 | .0124 | .297 | .0051 | .096 | .0017 |
| 80 | 58.0 | FLAT | 80.06 | 10.93 | .189 | .683 | .0118 | .313 | .0054 | .111 | .0019 |
| 80 | 58.0 | HILLY | 76.55 | 18.73 | .323 | .879 | .0152 | .311 | .0054 | .110 | .0019 |

**TARGET SPEED 90 km/h**

| GCM | LOAD | ROAD | AVG.SPEED | NOx | | CO | | HC | | PM | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| t | t | | km/h | g/km | g/tkm | g/km | g/tkm | g/km | g/tkm | g/km | g/tkm |
| 40 | 25.7 | AVG. | 89.98 | 7.87 | .306 | .663 | .0258 | .351 | .0137 | .072 | .0028 |
| 40 | 25.7 | FLAT | 90.06 | 7.11 | .276 | .656 | .0255 | .365 | .0142 | .065 | .0025 |
| 40 | 25.7 | HILLY | 89.62 | 11.74 | .457 | .549 | .0214 | .304 | .0118 | .087 | .0034 |
| 53 | 35.5 | AVG. | 89.89 | 9.74 | .274 | .666 | .0188 | .347 | .0098 | .080 | .0023 |
| 53 | 35.5 | FLAT | 90.10 | 8.41 | .237 | .660 | .0186 | .358 | .0101 | .076 | .0021 |
| 53 | 35.5 | HILLY | 88.61 | 14.24 | .401 | .585 | .0165 | .304 | .0086 | .097 | .0027 |
| 60 | 41.2 | AVG. | 89.74 | 10.79 | .262 | .670 | .0163 | .344 | .0083 | .084 | .0020 |
| 60 | 41.2 | FLAT | 90.09 | 9.13 | .222 | .671 | .0163 | .360 | .0087 | .079 | .0019 |
| 60 | 41.2 | HILLY | 87.93 | 15.35 | .373 | .664 | .0161 | .308 | .0075 | .102 | .0025 |
| 68 | 47.7 | AVG. | 89.45 | 12.02 | .252 | .665 | .0140 | .339 | .0071 | .090 | .0019 |
| 68 | 47.7 | FLAT | 90.06 | 10.03 | .210 | .678 | .0142 | .361 | .0076 | .089 | .0019 |
| 68 | 47.7 | HILLY | 87.13 | 16.43 | .344 | .688 | .0144 | .314 | .0066 | .108 | .0023 |
| 74 | 52.4 | AVG. | 89.15 | 12.96 | .247 | .677 | .0129 | .337 | .0064 | .093 | .0018 |
| 74 | 52.4 | FLAT | 90.01 | 10.74 | .205 | .697 | .0133 | .364 | .0069 | .091 | .0017 |
| 74 | 52.4 | HILLY | 86.52 | 17.29 | .330 | .708 | .0135 | .320 | .0061 | .111 | .0021 |
| 80 | 58.0 | AVG. | 88.80 | 13.84 | .239 | .688 | .0119 | .339 | .0058 | .096 | .0017 |
| 80 | 58.0 | FLAT | 89.94 | 11.51 | .198 | .711 | .0123 | .376 | .0065 | .092 | .0016 |
| 80 | 58.0 | HILLY | 85.90 | 18.18 | .313 | .741 | .0128 | .327 | .0056 | .114 | .0020 |

## Table 4A. Vehicle operating costs by type vehicles
## Rated engine power 309 kW

**PRESENT VEHICLES**

| | TYPE VEHICLE 1 | | | TYPE VEHICLE 2 | | | TYPE VEHICLE 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 t 5 axles | | | 53 t 6 axles | | | 60 t 7 axles | | |
| | €/a | €/km | €/tkm | €/a | €/km | €/tkm | €/a | €/km | €/tkm |
| FUEL | 48398 | .323 | .0126 | 56232 | .375 | .0106 | 60135 | .401 | .0097 |
| LUBRICANT | 1161 | .008 | .0003 | 1471 | .010 | .0003 | 1573 | .010 | .0003 |
| REPAIR&MAINT. | 14631 | .098 | .0038 | 15707 | .105 | .0029 | 16797 | .112 | .0027 |
| TYRES | 8975 | .060 | .0023 | 10540 | .070 | .0020 | 11271 | .075 | .0018 |
| VARIABLE | 73165 | .488 | .0190 | 83950 | .560 | .0158 | 89777 | .599 | .0145 |
| DEPRECIATION | 24046 | .160 | .0062 | 33634 | .224 | .0063 | 34786 | .232 | .0056 |
| INTEREST | 7214 | .048 | .0019 | 10090 | .067 | .0019 | 10435 | .070 | .0017 |
| WAGES | 54949 | .366 | .0143 | 57655 | .384 | .0108 | 57655 | .384 | .0093 |
| INSURANCES | 5652 | .038 | .0015 | 8076 | .054 | .0015 | 8076 | .054 | .0013 |
| VEHICLE TAX | 2037 | .014 | .0005 | 2373 | .016 | .0004 | 2373 | .016 | .0004 |
| FIXED | 93898 | .626 | .0244 | 111827 | .746 | .0210 | 113325 | .755 | .0183 |
| TOTAL | 167064 | 1.114 | .0433 | 195777 | 1.305 | .0368 | 203102 | 1.354 | .0329 |

**FUTURE VEHICLES**

| | TYPE VEHICLE 4 | | | TYPE VEHICLE 5 | | | TYPE VEHICLE 6 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 t 8 axles | | | 74 t 9 axles | | | 80 t 10 axles | | |
| | €/a | €/km | €/tkm | €/a | €/km | €/tkm | €/a | €/km | €/tkm |
| FUEL | 64412 | .429 | .0090 | 67779 | .452 | .0086 | 71149 | .474 | .0082 |
| LUBRICANT | 1685 | .011 | .0002 | 1773 | .012 | .0002 | 1861 | .012 | .0002 |
| REPAIR&MAINT. | 17992 | .120 | .0025 | 18932 | .126 | .0024 | 19873 | .132 | .0023 |
| TYRES | 12073 | .080 | .0017 | 12704 | .085 | .0016 | 13336 | .089 | .0015 |
| VARIABLE | 96162 | .641 | .0134 | 101189 | .675 | .0129 | 106219 | .708 | .0122 |
| DEPRECIATION | 35939 | .240 | .0050 | 38798 | .259 | .0049 | 41658 | .278 | .0048 |
| INTEREST | 10782 | .072 | .0015 | 11640 | .078 | .0015 | 12498 | .083 | .0014 |
| WAGES | 57655 | .384 | .0081 | 57655 | .384 | .0073 | 57655 | .384 | .0066 |
| INSURANCES | 8076 | .054 | .0011 | 8076 | .054 | .0010 | 8076 | .054 | .0009 |
| VEHICLE TAX | 2373 | .016 | .0003 | 2686 | .018 | .0003 | 2774 | .018 | .0003 |
| FIXED | 114825 | .765 | .0160 | 118856 | .792 | .0151 | 122661 | .818 | .0141 |
| TOTAL | 210987 | 1.407 | .0295 | 220045 | 1.467 | .0280 | 228881 | 1.526 | .0263 |

## Table 4B. Vehicle operating costs by type vehicles
## Rated engine power 345 kW

**PRESENT VEHICLES**

| | TYPE VEHICLE 1 | | | TYPE VEHICLE 2 | | | TYPE VEHICLE 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 t 5 axles | | | 53 t 6 axles | | | 60 t 7 axles | | |
| | €/a | €/km | €/tkm | €/a | €/km | €/tkm | €/a | €/km | €/tkm |
| FUEL | 49472 | .330 | .0128 | 56690 | .378 | .0106 | 60251 | .402 | .0097 |
| LUBRICANT | 1187 | .008 | .0003 | 1483 | .010 | .0003 | 1576 | .011 | .0003 |
| REPAIR&MAINT. | 14956 | .100 | .0039 | 15835 | .106 | .0030 | 16830 | .112 | .0027 |
| TYRES | 9174 | .061 | .0024 | 10626 | .071 | .0020 | 11293 | .075 | .0018 |
| VARIABLE | 74789 | .499 | .0194 | 84634 | .564 | .0159 | 89950 | .600 | .0146 |
| DEPRECIATION | 24046 | .160 | .0062 | 33634 | .224 | .0063 | 34786 | .232 | .0056 |
| INTEREST | 7214 | .048 | .0019 | 10090 | .067 | .0019 | 10435 | .070 | .0017 |
| WAGES | 54949 | .366 | .0143 | 57655 | .384 | .0108 | 57655 | .384 | .0093 |
| INSURANCES | 5652 | .038 | .0015 | 8076 | .054 | .0015 | 8076 | .054 | .0013 |
| VEHICLE TAX | 2037 | .014 | .0005 | 2373 | .016 | .0004 | 2373 | .016 | .0004 |
| FIXED | 93898 | .626 | .0244 | 111827 | .746 | .0210 | 113325 | .755 | .0183 |
| TOTAL | 168687 | 1.125 | .0438 | 196461 | 1.310 | .0369 | 203275 | 1.355 | .0329 |

**FUTURE VEHICLES**

| | TYPE VEHICLE 4 | | | TYPE VEHICLE 5 | | | TYPE VEHICLE 6 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 t 8 axles | | | 74 t 9 axles | | | 80 t 10 axles | | |
| | €/a | €/km | €/tkm | €/a | €/km | €/tkm | €/a | €/km | €/tkm |
| FUEL | 64189 | .428 | .0090 | 67252 | .448 | .0086 | 70338 | .469 | .0081 |
| LUBRICANT | 1679 | .011 | .0002 | 1759 | .012 | .0002 | 1840 | .012 | .0002 |
| REPAIR&MAINT. | 17929 | .120 | .0025 | 18785 | .125 | .0024 | 19647 | .131 | .0023 |
| TYRES | 12031 | .080 | .0017 | 12605 | .084 | .0016 | 13184 | .088 | .0015 |
| VARIABLE | 95828 | .639 | .0134 | 100402 | .669 | .0128 | 105009 | .700 | .0121 |
| DEPRECIATION | 35939 | .240 | .0050 | 38798 | .259 | .0049 | 41658 | .278 | .0048 |
| INTEREST | 10782 | .072 | .0015 | 11640 | .078 | .0015 | 12498 | .083 | .0014 |
| WAGES | 57655 | .384 | .0081 | 57655 | .384 | .0073 | 57655 | .384 | .0066 |
| INSURANCES | 8076 | .054 | .0011 | 8076 | .054 | .0010 | 8076 | .054 | .0009 |
| VEHICLE TAX | 2373 | .016 | .0003 | 2686 | .018 | .0003 | 2774 | .018 | .0003 |
| FIXED | 114825 | .765 | .0160 | 118856 | .792 | .0151 | 122661 | .818 | .0141 |
| TOTAL | 210653 | 1.404 | .0294 | 219258 | 1.462 | .0279 | 227670 | 1.518 | .0262 |

## Table 4C. Vehicle operating costs by type vehicles
## Rated engine power 412 kW

**PRESENT VEHICLES**

| | TYPE VEHICLE 1 | | | TYPE VEHICLE 2 | | | TYPE VEHICLE 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 t 5 axles | | | 53 t 6 axles | | | 60 t 7 axles | | |
| | €/a | €/km | €/tkm | €/a | €/km | €/tkm | €/a | €/km | €/tkm |
| FUEL | 51541 | .344 | .0134 | 59499 | .397 | .0112 | 63502 | .423 | .0103 |
| LUBRICANT | 1237 | .008 | .0003 | 1557 | .010 | .0003 | 1661 | .011 | .0003 |
| REPAIR&MAINT. | 15581 | .104 | .0040 | 16619 | .111 | .0031 | 17737 | .118 | .0029 |
| TYRES | 9558 | .064 | .0025 | 11152 | .074 | .0021 | 11902 | .079 | .0019 |
| VARIABLE | 77916 | .519 | .0202 | 88827 | .592 | .0167 | 94803 | .632 | .0153 |
| DEPRECIATION | 24046 | .160 | .0062 | 33634 | .224 | .0063 | 34786 | .232 | .0056 |
| INTEREST | 7214 | .048 | .0019 | 10090 | .067 | .0019 | 10435 | .070 | .0017 |
| WAGES | 54949 | .366 | .0143 | 57655 | .384 | .0108 | 57655 | .384 | .0093 |
| INSURANCES | 5652 | .038 | .0015 | 8076 | .054 | .0015 | 8076 | .054 | .0013 |
| VEHICLE TAX | 2037 | .014 | .0005 | 2373 | .016 | .0004 | 2373 | .016 | .0004 |
| FIXED | 93898 | .626 | .0244 | 111827 | .746 | .0210 | 113325 | .755 | .0183 |
| TOTAL | 171814 | 1.145 | .0446 | 200654 | 1.338 | .0377 | 208128 | 1.388 | .0337 |

**FUTURE VEHICLES**

| | TYPE VEHICLE 4 | | | TYPE VEHICLE 5 | | | TYPE VEHICLE 6 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 t 8 axles | | | 74 t 9 axles | | | 80 t 10 axles | | |
| | €/a | €/km | €/tkm | €/a | €/km | €/tkm | €/a | €/km | €/tkm |
| FUEL | 67951 | .453 | .0095 | 71474 | .476 | .0091 | 74984 | .500 | .0086 |
| LUBRICANT | 1778 | .012 | .0002 | 1870 | .012 | .0002 | 1962 | .013 | .0002 |
| REPAIR&MAINT. | 18980 | .127 | .0027 | 19964 | .133 | .0025 | 20945 | .140 | .0024 |
| TYRES | 12736 | .085 | .0018 | 13397 | .089 | .0017 | 14055 | .094 | .0016 |
| VARIABLE | 101445 | .676 | .0142 | 106704 | .711 | .0136 | 111946 | .746 | .0129 |
| DEPRECIATION | 35939 | .240 | .0050 | 38798 | .259 | .0049 | 41658 | .278 | .0048 |
| INTEREST | 10782 | .072 | .0015 | 11640 | .078 | .0015 | 12498 | .083 | .0014 |
| WAGES | 57655 | .384 | .0081 | 57655 | .384 | .0073 | 57655 | .384 | .0066 |
| INSURANCES | 8076 | .054 | .0011 | 8076 | .054 | .0010 | 8076 | .054 | .0009 |
| VEHICLE TAX | 2373 | .016 | .0003 | 2686 | .018 | .0003 | 2774 | .018 | .0003 |
| FIXED | 114825 | .765 | .0160 | 118856 | .792 | .0151 | 122661 | .818 | .0141 |
| TOTAL | 216270 | 1.442 | .0302 | 225560 | 1.504 | .0287 | 234607 | 1.564 | .0270 |

## Table 4D. Vehicle operating costs by type vehicles
## Rated engine power 460 kW

**PRESENT VEHICLES**

| | TYPE VEHICLE 1 | | | TYPE VEHICLE 2 | | | TYPE VEHICLE 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 t 5 axles | | | 53 t 6 axles | | | 60 t 7 axles | | |
| | €/a | €/km | €/tkm | €/a | €/km | €/tkm | €/a | €/km | €/tkm |
| FUEL | 53494 | .357 | .0139 | 61162 | .408 | .0115 | 64887 | .433 | .0105 |
| LUBRICANT | 1284 | .009 | .0003 | 1600 | .011 | .0003 | 1698 | .011 | .0003 |
| REPAIR&MAINT. | 16172 | .108 | .0042 | 17084 | .114 | .0032 | 18124 | .121 | .0029 |
| TYRES | 9920 | .066 | .0026 | 11464 | .076 | .0022 | 12162 | .081 | .0020 |
| VARIABLE | 80868 | .539 | .0210 | 91310 | .609 | .0171 | 96872 | .646 | .0157 |
| DEPRECIATION | 24046 | .160 | .0062 | 33634 | .224 | .0063 | 34786 | .232 | .0056 |
| INTEREST | 7214 | .048 | .0019 | 10090 | .067 | .0019 | 10435 | .070 | .0017 |
| WAGES | 54949 | .366 | .0143 | 57655 | .384 | .0108 | 57655 | .384 | .0093 |
| INSURANCES | 5652 | .038 | .0015 | 8076 | .054 | .0015 | 8076 | .054 | .0013 |
| VEHICLE TAX | 2037 | .014 | .0005 | 2373 | .016 | .0004 | 2373 | .016 | .0004 |
| FIXED | 93898 | .626 | .0244 | 111827 | .746 | .0210 | 113325 | .755 | .0183 |
| TOTAL | 174767 | 1.165 | .0453 | 203138 | 1.354 | .0381 | 210197 | 1.401 | .0340 |

**FUTURE VEHICLES**

| | TYPE VEHICLE 4 | | | TYPE VEHICLE 5 | | | TYPE VEHICLE 6 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 68 t 8 axles | | | 74 t 9 axles | | | 80 t 10 axles | | |
| | €/a | €/km | €/tkm | €/a | €/km | €/tkm | €/a | €/km | €/tkm |
| FUEL | 68969 | .460 | .0096 | 72224 | .481 | .0092 | 75478 | .503 | .0087 |
| LUBRICANT | 1804 | .012 | .0003 | 1890 | .013 | .0002 | 1975 | .013 | .0002 |
| REPAIR&MAINT. | 19265 | .128 | .0027 | 20174 | .134 | .0026 | 21083 | .141 | .0024 |
| TYRES | 12927 | .086 | .0018 | 13537 | .090 | .0017 | 14147 | .094 | .0016 |
| VARIABLE | 102966 | .686 | .0144 | 107825 | .719 | .0137 | 112682 | .751 | .0130 |
| DEPRECIATION | 35939 | .240 | .0050 | 38798 | .259 | .0049 | 41658 | .278 | .0048 |
| INTEREST | 10782 | .072 | .0015 | 11640 | .078 | .0015 | 12498 | .083 | .0014 |
| WAGES | 57655 | .384 | .0081 | 57655 | .384 | .0073 | 57655 | .384 | .0066 |
| INSURANCES | 8076 | .054 | .0011 | 8076 | .054 | .0010 | 8076 | .054 | .0009 |
| VEHICLE TAX | 2373 | .016 | .0003 | 2686 | .018 | .0003 | 2774 | .018 | .0003 |
| FIXED | 114825 | .765 | .0160 | 118856 | .792 | .0151 | 122661 | .818 | .0141 |
| TOTAL | 217791 | 1.452 | .0304 | 226681 | 1.511 | .0288 | 235343 | 1.569 | .0271 |

**Table 5. Characteristics of type vehicles from road wear viewpoint**

| Type | Gross mass | Net load | axles | equivalent axles | Net load/ eq. axle | Index |
|---|---|---|---|---|---|---|
| # | t | t | # | # | t/eq.axle | |
| 1 | 40 | 25.7 | 5 | 3.195 | 8.046 | 164 |
| 2 | 53 | 35.5 | 6 | 3.338 | 10.649 | 124 |
| 3 | 60 | 41.2 | 7 | 3.125 | 13.192 | 100 |
| 4 | 68 | 47.7 | 8 | 3.444 | 13.840 | 95 |
| 5 | 74 | 52.4 | 9 | 3.816 | 13.731 | 96 |
| 6 | 80 | 58.0 | 10 | 3.988 | 14.537 | 91 |

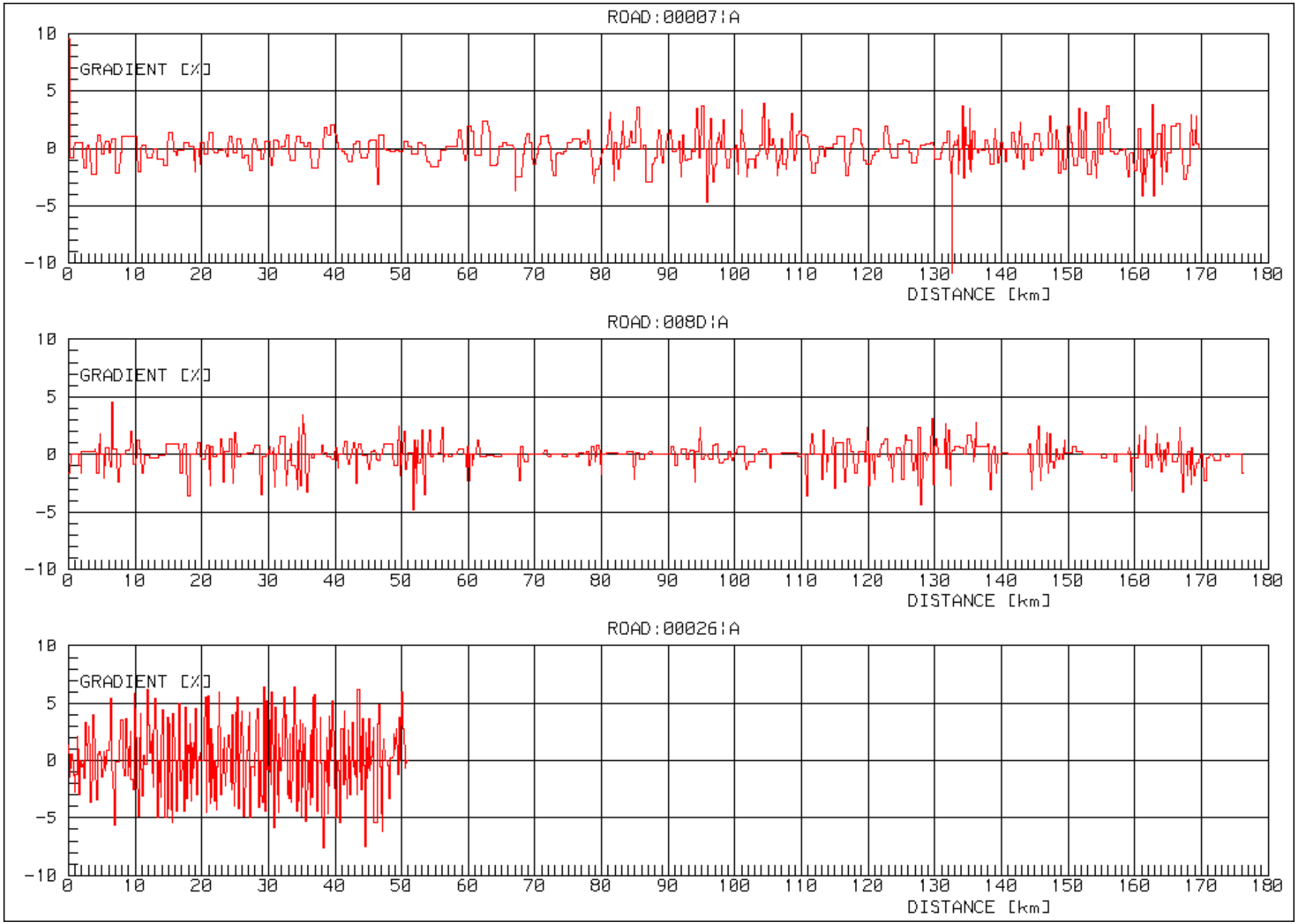


**FIG. 1 TEST ROAD SECTIONS: GRADIENT VS. DISTANCE**

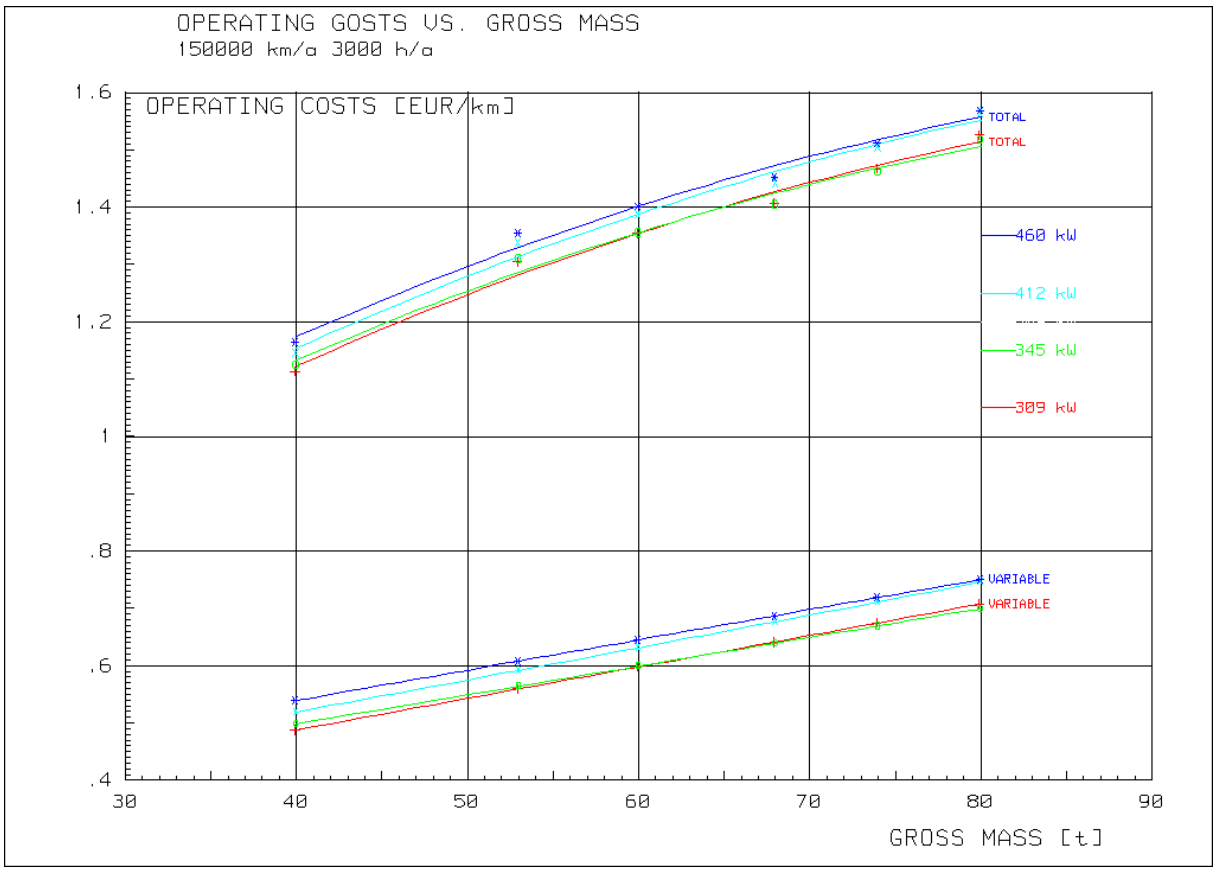


**FIG. 2 VEHICLE OPERATING COSTS VS. GROSS MASS**

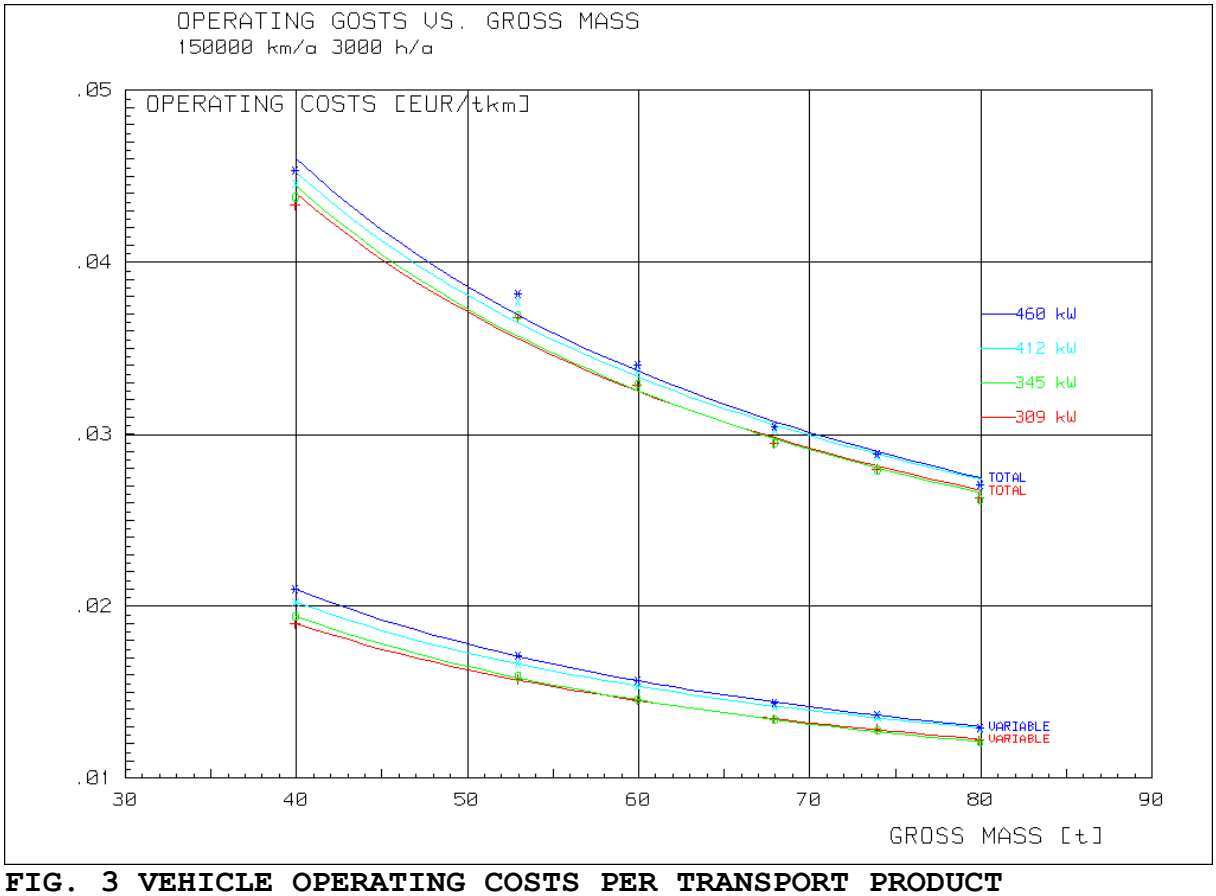


**FIG. 3 VEHICLE OPERATING COSTS PER TRANSPORT PRODUCT UNIT[tkm] VS. GROSS MASS**

**Appendix**

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# V E H I C L E  M O T I O N  S I M U L A T O R

## INTRODUCTION

The vehicle computer simulation system has been developed by Mr. Olavi H. Koskinen in the Ministry of Transport and Communications in Finland in order to simulate the motion of a real vehicle in normal road and traffic conditions. In that simulation process the vehicle can be driven either in undisturbed or disturbed traffic flow according to predefined driving techniques and rules (goal speed, schwung, use of gears etc). The simulation output can be continuous, so also the statistical analysis of the drive containing the elapsed time, proceeded distance, consumed fuel amount, use of gears, engine power, torque, engine load distribution etc.

## SIMULATION SYSTEM IN DETAIL

The technical characteristics of the vehicle and road must be given as input data, before the simulation process can be started. The idea of the simulation is simply based upon the Newton's second law, which is expressed in the following differential equation:

$$m\, dv/dt = F_t - F_r$$

where:

- $v$ = vehicle speed
- $t$ = time
- $m$ = vehicle mass
- $F_t$ = traction force
- $F_r$ = resistance force

The current resistance force ($F_r$) is determined by the drive resistance parameters of the vehicle (rolling and air resistance coefficients) and current longitudinal road gradient. The traction force ($F_t$) is regulated by using the accelerator and brake pedals and various gears.

The geometric data of the road are stored in a very compact mode as distance-altitude or respectively as distance-gradient coordinates. In the former case the rounding curves between them are determined by an effective iterative algorithm.

The vehicle data for the computer simulation are:

- drive resistance coefficients
- description of the power train
- description of the engine
  - maximum torque as a function of the engine speed
  - fuel flow rate as a function of the engine speed and torque (engine map of fuel consumption)
  - emission flow rates by components ($NO_x$, CO, HC, PM, $CO_2$) as functions of the engine speed and torque

The quantities, which are followed continuously in the standard output during the drive, are:

- time
- proceeded distance
- consumed fuel amount
- emission amounts if available and selected
- gear position

- current speed
- current engine speed
- longitudinal road gradient
- position of accelerator pedal
- current engine power
- engine load degree
- traction force
- resistance force
- brake force

In the graphical output it is possible to plot several different quantities. The standard graphical output contains, as a function of the distance, the current speed, the cumulative fuel amount or the current fuel consumption per distance unit [l/100 km] and the longitudinal road gradient. In addition, the locations of the gear changes are plotted in the figure; changes up and down with different symbols.

The drive can be analyzed. There are two options, short and long. The long analysis prints the following information:

- time of drive
- distance of drive
- average speed
- cumulative rotation angle of engine
- average engine speed
- loading distribution of engine
  - time distribution by engine speed and torque categories
  - distance distribution by engine speed and torque categories
- drive at full load (maximum torque): time and distance
- average power, torque and loading degree of engine
- fuel consumption
  - time, distance and fuel amount distribution by specific fuel consumption categories
  - consumed fuel amount
  - average fuel consumption per distance, per time and average specific fuel consumption
- emission amounts if available and selected for survey
- use of brakes: time and distance
- use of gears
  - drive at different gears: time, distance and average speed
  - number of gear changes: down, up, to neutral

- time and distance distribution by different speed and acceleration categories
- drive work: engine work, traction work, resistance work, brake work, acceleration work and average thermal efficiency

**EMISSION SIMULATION**

If emission maps of different pollutants are available, the impact of the environmental pollution can be studied by this simulation system in various road and traffic conditions. However, for the time being there is a lack of emission maps of engines and they are not easily available from the engine manufacturers.