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# Analysis of the load factor and the empty running rate for road transport. Artemis - assessment and reliability of transport emission models and inventory systems

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*Nadine ADRA  
Jean-Luc MICHAUX  
Michel ANDRÉ*

# **Analysis of the load factor and the empty running rate for road transport**

*ARTEMIS - Assessment and reliability of transport  
emission models and inventory systems*

**Report INRETS-LTE 0419  
November 2004**

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13 Résumé <p>Dans le cadre du projet européen ARTEMIS, une analyse des paramètres ayant un effet sur les émissions est réalisée.</p> <p>Dans ce rapport, nous étudions l'importance du chargement des véhicules à travers deux paramètres : le facteur de charge et le parcours à vide. Une synthèse et une analyse des statistiques européennes, françaises, anglaises, etc et de données de différentes institutions internationales ont permis de souligner les différents aspects et les difficultés liés à ces paramètres. Le rapport présente également une série de recommandations à prendre en compte lors de l'estimation des émissions. Ces recommandations comprennent des fonctions de correction en fonction du temps et du type et du poids des véhicules pour le transport de marchandises.</p>				
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13 Summary  <p>In the frame of the ARTEMIS European research project, an analysis of different parameters influencing the emission is made.</p> <p>In this report, we study the importance of the vehicle load through the study of the load factor and the empty running rate. The synthesis and the analysis of statistics from Europe, France, Great Britain, etc, and data from international institutions enabled to highlight various aspects and difficulties. The report has also developed a set of recommendations to consider when estimating pollutant emissions. Such recommendations include correction functions for freight transport in term of variation of the parameters with time for different vehicles types and sizes.</p>					
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# Summary

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# 1.Introduction

Different variables have effects on the emission of vehicles. For these variables, in general, corrections are applied to the emission factors to accommodate variation of emissions according to the various effects.

Because of well known fact that emissions and fuel consumption are linked to the engine power, the calculations have to take into account, in principle, vehicle load (Meet, 1999). In fact, the driving resistance of a vehicle is influenced by vehicle mass, i.e. higher mass requires higher power from the engine during driving, especially in acceleration modes.

In this report, we highlight the importance of the vehicle load through the study of the load factor and the empty running rate. For each factor, we present and analyse available statistics and data from different countries and we discuss the variation of the factor with various parameters (e.g. vehicle size, vehicle weight, time, travel purpose). A set of recommendations are then presented in order to better take into account the load factor in the emission calculation.





## **2. Vehicle load factors**

### **2.1. Introduction**

The total weight of vehicles is required as an input of emission modelling and is one of the main parameters that determine energy and emission efficiency. The most important determinant is load factor i.e. how much of the capacity of the truck is used.

For cars, buses and coaches, we use the term ‘occupancy’ while for vans and trucks we use ‘load factor’.

A high occupancy rate in passenger cars, buses and coaches has relatively little impact on overall vehicle weight. For freight, the relationship is more complex, as a higher load factor is likely to result in a significant increase in vehicle weight and therefore in more energy use and emissions.

### **2.2. Passenger vehicles occupancy**

#### ***Definition***

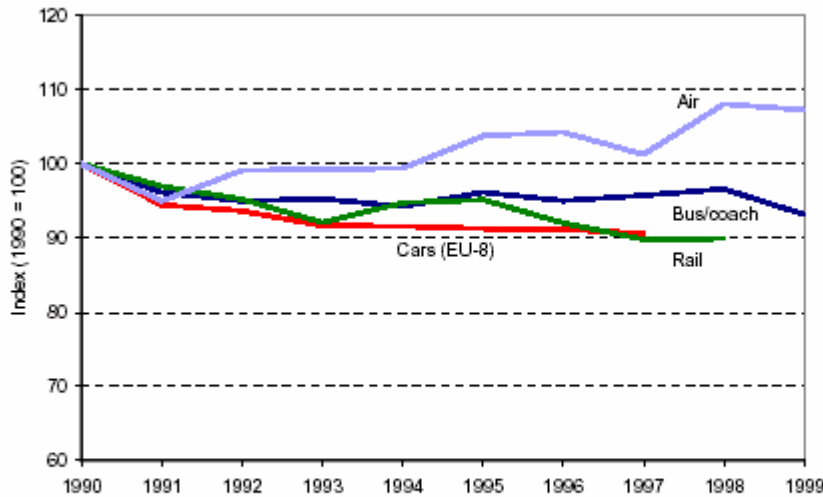
The occupancy of cars, buses and coaches can be indicated by the absolute values of passengers being transported by each vehicle type (e.g. average number of passengers) or the occupancy rate.

The use of occupancy rates has the advantage of providing information on the efficiency of the specific vehicle types, whereas the adoption of absolute value fails to provide such kind of assessment. Information on the maximum capacity of each vehicle type (number of seats available) is required (TRENDS, 2001).

Occupancy rates are often calculated by dividing passenger-kilometres by the vehicle-kilometres.

**European context**

Occupancy rate for passenger cars is falling in most countries, despite EU efforts to increase utilisation efficiency, for example through its citizens' network strategy. Occupancy rates for other passenger transport modes (buses, trains) have also not improved during the last decade, except for air transport (see Figure 1). The occupancy rates of trains and buses are expected to improve in future, as budget cuts eliminate unprofitable lines and congestion is pushing people towards public transport (TERM, 2002).



NB: EU-8 (cars) refers to Denmark, Germany, France, the Netherlands, Portugal, Finland, Sweden and the UK. Buses/coaches occupancy rates exclude Greece. Air refers to principal airline carriers only. All series but aviation are based on passenger-kilometres/vehicle-kilometres. Air is based on the percentage of seats occupied.

Figure 1: Evolution of occupancy rates, 1990-1998

The cost-effectiveness study of Auto Oil II program gives transport base case for different European countries (AOPII, 1999). The main macro-economic assumptions used to construct this base case are historical values up to 1995 of the main macroeconomic indicators from national statistics. The values used from 1996 to 2020, are consistently taken from the Energy 2020 forecast prepared by DGXVII (i.e. the pre-Kyoto reference scenario), throughout the AOPII transport base case. Throughout the study, a discount rate of 4% has been used, corresponding to the long-term real interest rate. Load factors have usually been computed for each transport mode as the ratio of traffic in passenger kilometre to traffic in vehicle-kilometre (Table 1).

Load factors for passenger cars and public transport are also differentiated between peak and off-peak. When no information was available on this split, the ratio of the peak load factor to the total load factor was assumed to be the same than in the UK. Off-peak load factors were then computed as a residual. We give hereafter the example of Italian load factors.

Region	Mode/Year	1990	1995	2000	2005	2010	2015	2020
Italy	Cars	1.74	1.71	1.71	1.71	1.71	1.70	1.70
Italy	Buses & coaches	23.36	24.34	26.26	26.40	25.66	24.92	24.20
Milan	Cars	1.59	1.56	1.56	1.56	1.56	1.56	1.56
Milan	Buses & coaches	16.23	13.54	13.75	13.53	13.80	14.08	14.36

Table 1: Average load factors for cars and buses/coaches in Italy (in passenger per vehicle)

### Environmental context

Efficient usage of passenger vehicles results in less vehicle-kilometres needed to transport the same amount of passengers. Car sharing might even lead to fewer cars on the roads, which can attribute to averting congestion. Utilisation efficiency is one of the main parameters that determine energy and emissions efficiency. A high occupancy rate in passenger cars and buses has relatively little impact on overall vehicle weight, and therefore on energy consumption.

Hence, less vehicle-kilometres results in less environmental damage occurring for transporting the same number of passengers.

## 2.2.1. Cars

### 2.2.1.1. European context

Data on trends in occupancy rates is limited. According to the IEA, occupancy rates of passenger cars in Europe fell from 2.0-2.1 in the early 1970s to 1.5-1.6 in the early 1990s. The decrease is a result of increasing car ownership, extended use of cars for commuting and a continued decline in household size. Table 2 shows car occupancy rates in Member States. It is calculated by dividing passenger-kilometres by the vehicle-kilometres.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Belgium	1.5	1.4	1.4	N/A	1.1	N/A	N/A	N/A	N/A	N/A
Austria	2.0	2.2	2.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Denmark	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	N/A
Finland	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
France	1.9	1.8	1.9	1.9	1.9	1.8	1.9	1.8	1.8	N/A
Germany	1.6	1.4	1.4	1.4	1.4	1.4	1.4	1.4	N/A	N/A
Greece	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ireland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Italy	1.9	1.9	1.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Luxembourg	1.3	1.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Netherlands	1.8	1.8	1.7	1.6	1.6	1.6	1.6	1.6	N/A	N/A
Portugal	2.5	2.5	2.4	2.5	2.5	2.6	2.5	2.5	2.4	N/A
Spain	N/A	2.9	N/A	3.0	3.0	N/A	N/A	N/A	N/A	N/A
Sweden	1.6	1.7	1.6	1.7	1.5	1.5	1.6	1.7	1.7	1.4
United Kingdom	1.8	1.7	1.7	1.5	1.5	1.5	1.5	1.5	1.5	N/A

Table 2: Passenger car occupancy in Member States (TERM, 2002)

The TREMOVE<sup>1</sup> model gives a baseline average (EU 15) value of 2.0 passengers/car from 1995 to 2007 and 2.1 passengers/car from 2009 to 2020 (Tremove, 2004).

TRENDS project has produced a set of occupancy values for EU-15 countries for the period 1970-2020 based on TERM and TRAP values (Figure 2). These data were used for calculating the default occupancy rates to be incorporated into the road transport module. The user, however, has the option to input manually different than the default values (Samaras Z. & al., 2002).

	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK
1970	1,95	1,75	1,84	2,13	2,80	1,85	1,94	1,57	1,61	1,85	1,82	2,44	1,71	1,77	1,91
1971	1,95	1,76	1,82	2,12	2,79	1,85	1,90	1,57	1,61	1,86	1,80	2,42	1,69	1,76	1,88
1972	1,95	1,77	1,80	2,10	2,78	1,84	1,86	1,58	1,61	1,86	1,78	2,41	1,67	1,74	1,85
1973	1,95	1,78	1,78	2,09	2,78	1,84	1,82	1,58	1,60	1,87	1,76	2,40	1,65	1,72	1,83
1974	1,95	1,79	1,76	2,08	2,77	1,83	1,78	1,59	1,60	1,87	1,74	2,39	1,63	1,70	1,80
1975	1,95	1,80	1,74	2,07	2,76	1,83	1,74	1,60	1,60	1,88	1,71	2,37	1,61	1,69	1,77
1976	1,91	1,83	1,70	2,06	2,76	1,83	1,70	1,59	1,56	1,85	1,69	2,37	1,59	1,67	1,78
1977	1,87	1,87	1,67	2,05	2,77	1,84	1,66	1,59	1,52	1,83	1,67	2,36	1,57	1,64	1,78
1978	1,83	1,90	1,63	2,04	2,77	1,84	1,62	1,58	1,48	1,80	1,65	2,36	1,55	1,62	1,79
1979	1,80	1,94	1,60	2,03	2,78	1,85	1,58	1,58	1,44	1,78	1,63	2,35	1,53	1,60	1,79
1980	1,77	1,97	1,57	2,01	2,78	1,85	1,53	1,57	1,40	1,75	1,62	2,35	1,52	1,57	1,80
1981	1,74	1,94	1,56	2,00	2,80	1,85	1,52	1,57	1,42	1,77	1,61	2,34	1,52	1,57	1,79
1982	1,71	1,91	1,56	1,98	2,83	1,85	1,50	1,57	1,44	1,78	1,60	2,34	1,52	1,57	1,77
1983	1,68	1,88	1,55	1,97	2,85	1,85	1,49	1,57	1,46	1,79	1,58	2,32	1,51	1,56	1,76
1984	1,65	1,82	1,55	1,95	2,88	1,85	1,48	1,57	1,48	1,80	1,57	2,32	1,51	1,56	1,75
1985	1,61	1,84	1,54	1,94	2,90	1,85	1,47	1,57	1,50	1,82	1,56	2,33	1,51	1,56	1,74
1986	1,58	1,83	1,50	1,93	2,84	1,86	1,46	1,59	1,46	1,81	1,55	2,33	1,50	1,57	1,74
1987	1,55	1,82	1,47	1,92	2,77	1,86	1,44	1,60	1,42	1,80	1,54	2,34	1,49	1,58	1,74
1988	1,53	1,81	1,44	1,90	2,71	1,87	1,43	1,62	1,38	1,79	1,52	2,34	1,48	1,58	1,73
1989	1,50	1,80	1,41	1,89	2,65	1,87	1,42	1,64	1,34	1,78	1,51	2,35	1,47	1,59	1,73
1990	1,47	1,78	1,37	1,88	2,58	1,88	1,41	1,65	1,30	1,77	1,50	2,35	1,46	1,60	1,73
1991	1,44	1,77	1,41	1,87	2,54	1,84	1,43	1,65	1,30	1,76	1,53	2,34	1,45	1,64	1,68
1992	1,44	1,77	1,41	1,86	2,54	1,85	1,42	1,65	1,29	1,66	1,53	2,30	1,40	1,55	1,72
1993	1,29	1,77	1,41	1,85	2,54	1,87	1,41	1,65	1,27	1,65	1,52	2,33	1,40	1,57	1,62
1994	1,13	1,77	1,43	1,83	2,53	1,85	1,41	1,65	1,26	1,65	1,52	2,33	1,40	1,50	1,61
1995	1,00	1,77	1,42	1,82	2,52	1,85	1,41	1,65	1,24	1,63	1,52	2,38	1,40	1,51	1,61
1996	1,00	1,76	1,41	1,81	2,52	1,85	1,41	1,65	1,24	1,63	1,52	2,33	1,40	1,57	1,61
1997	1,00	1,76	1,40	1,80	2,52	1,85	1,41	1,65	1,24	1,62	1,52	2,33	1,40	1,61	1,61
1998-2020	1,00	1,76	1,40	1,80	2,52	1,85	1,41	1,65	1,24	1,62	1,52	2,28	1,40	1,61	1,61

Figure 2: Proposed occupancy timeseries for passengers cars for EU-15 countries from TRENDS

### 2.2.1.2. Statistics

- In Switzerland, the association of transport engineers shows that the occupancy rate is less than the average (1.5 persons) for study and work travels (Taux d'occupation des véhicules privés, 2001).
- An inquiry realised by ILReS in Luxembourg on the fastening of seatbelt gives a value of 1.35 person/car (Enquête Ilres, 2003).
- The 'ménages et déplacements' survey (CERTU, 2003) conducted by CERTU in France, gives the car occupancy rate for different regions and years. For year 2000, the values range from 1.28 to 1.40 persons/car.

<sup>1</sup> TREMOVE is a policy assessment model to study the effects of different transport and environment policies on the emissions of the transport sector.

- The national occupancy rate for cars in the UK is 1.5 passengers/car (CPT, 2003).
- The Local mobility and passenger transport survey conducted in Oslo (Environment and Sustainability Profile for Oslo, 2003) shows that 70% of the cars have zero passenger (it means one person/car who is the driver). This gives an average of 1.4 person/car.

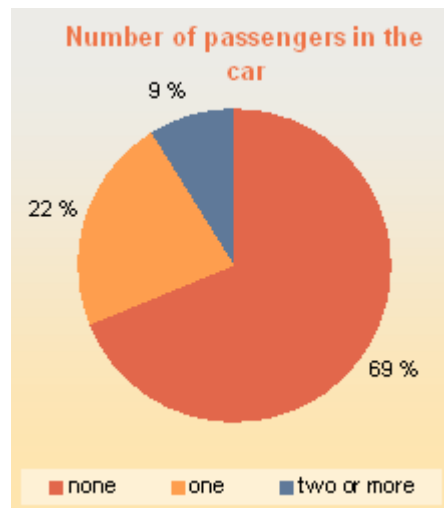


Figure 3: Number of passengers in a car in Oslo, 2003.

- A Canadian Vehicle Survey (CVS, 2001) gives a value of 1.67 persons/car (2.00 passenger/van and 1.43 passenger/pickup truck)<sup>2</sup>.

### ***Variation with time***

In Switzerland, a study conducted by the association of transport engineers on the analysis of the occupancy rate for private cars (Taux d'occupation des véhicules privés, 2001) has shown that this rate is decreasing (from 2.0 to 1.5 passengers in 2001).

In France, the 'ménages et déplacements' survey (CERTU, 2003) shows a general tendency to decrease (see Anne I). For Paris, the car occupancy rate seems to be stable (1.31-1.32) from 1978-1998.

For Great Britain, Figure 4 shows the steady decline in car occupancy of about 5% since the mid-1980s. Occupancy averaged 1.63 people in 1985/1996, falling to 1.56 in 1998/2000. In 2002, 61% of cars on the road had only one occupant. This has contributed to vehicle kilometres increasing more than passenger kilometres over the same period, and reflects smaller average size of households and increasing car ownership (Transport trends, 2004).

<sup>2</sup> Passenger/vehicle=passenger-km/vehicle-km

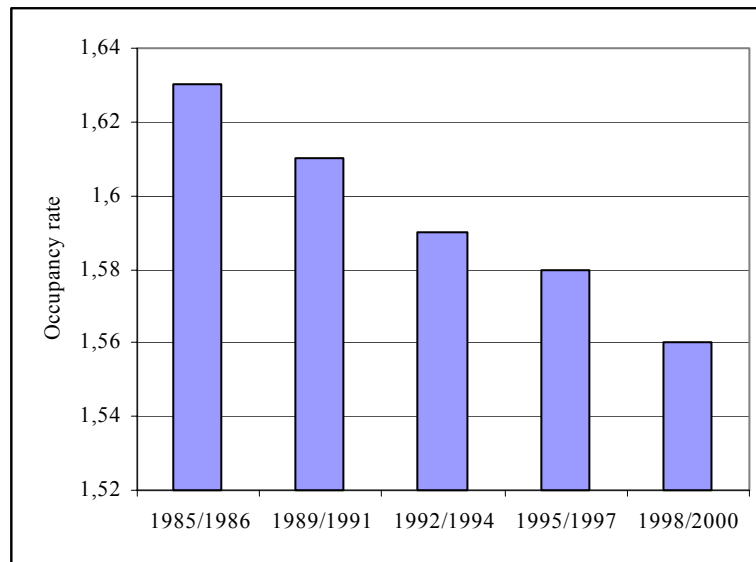


Figure 4: Car occupancy in GB: 1985/1986 to 1998/2000

Figure 5 shows that the occupancy rate tends to increase in Belgium, Flanders, Wallonia and Brussels. It also shows that Brussels has the lowest car occupancy rate (Labeeuw, 2002).

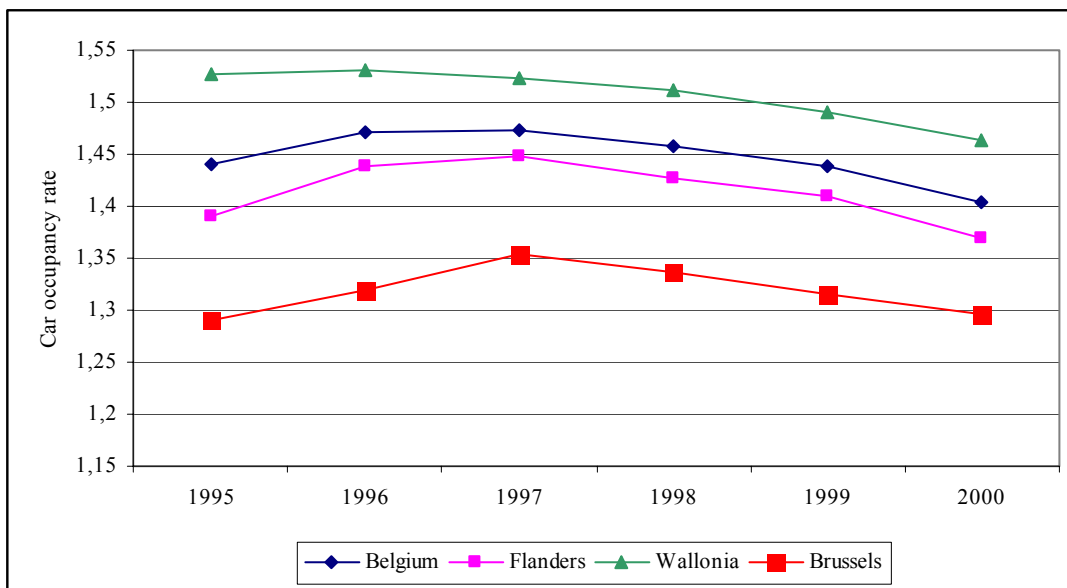


Figure 5: Variation of car occupancy rate in Belgium

### Variation with trip purpose and type

Car occupancy rates vary with travel purpose (see Table 3). Family trips and leisure trips are generally much better occupied than commuting trips (TERM, 2002).

Travel purpose	Car occupancy rate (passengers per vehicle)
Commuting to/from work	1.1-1.2
Family trip	1.4-1.7
Travel and leisure	1.6-2.0

Table 3: Car occupancy rates by travel purpose in Europe

A car use study in Great Britain (Personal travel factsheet, 2003) shows that occupancy rate for cars varies by trip purpose (Figure 6), with high occupancies for holiday trips (2.2), education trips (2.0), and leisure trips (1.8). Occupancy is lowest for business trips (1.2) and commuting trips (1.2), where the single occupancy rate is 84%.

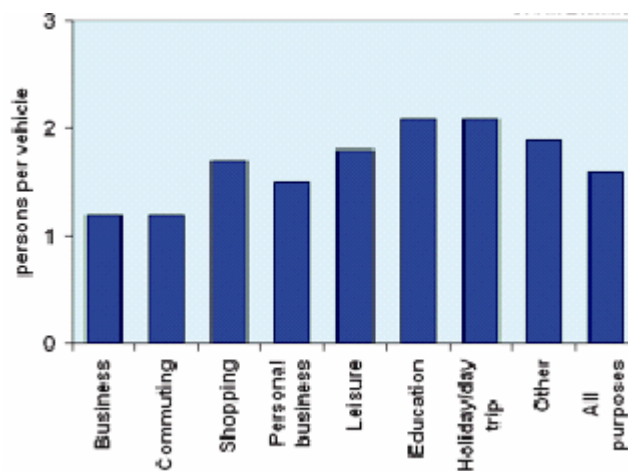


Figure 6: Average car occupancy by trip purpose in GB, 2002 (Transport trends, 2004)

### ***Variation with trip purpose and day of the week***

The travel behaviour microcensus by the Swiss Federal office for Spatial Development (ARE) and the Swiss Federal Statistical Office (SFSO) gives data on the car occupancy rate by trip purpose and day of the week (OFS, 2002). In Figure 7, we note an occupancy rate of 1.14 for business trips and this is due to the fact that for 90% of this kind of trips there is one person in the car. For leisure trips, this rate is of 1.92. For all purposes, the maximum occupancy rate is for Sunday.



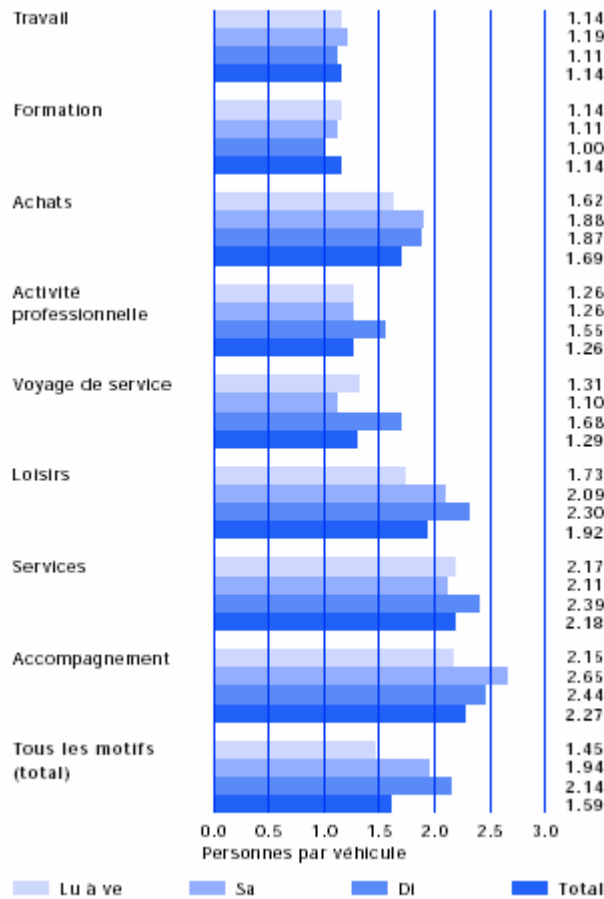


Figure 7: Car occupancy rate in Switzerland by trip purpose and day of the week

### Variation with type of road

Car occupancy rates also vary for urban and long-distance trips (1.3 and 1.8 passengers per car, respectively) (TERM, 2002).

The STREAMS<sup>3</sup> model include data on vehicle occupancy for local and long distance. Table 4 shows a slow but steady decrease in occupancy from 1994 to 2020 (ASTRA, 2000).

Travel purpose/year	Local			Long distance		
	1986	1994	2020	1986	1994	2020
Commuting & business	1.21	1.18	1.08	1.23	1.20	1.10
Personal	1.85	1.80	1.64	1.85	1.80	1.64
Tourism	-	-	-	2.79	2.71	2.47

Table 4: passenger car occupancy rate (persons/car)

For Sweden, trips on rural roads have a greater occupancy rate (2.0 passengers per vehicle) than trips on urban roads (1.70 passengers per vehicle) (TERM, 2000).

In Belgium (Labeeuw, 2002), the car occupancy rate is higher on highways than on roads (Figure 8).

<sup>3</sup> Strategic Transport Research for European Member States

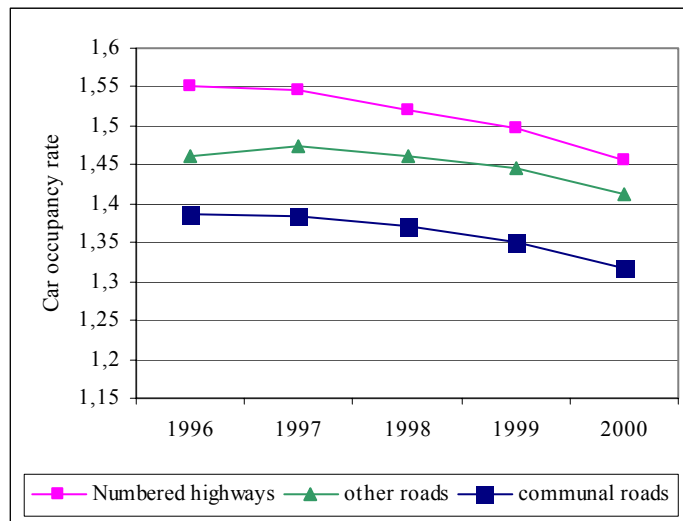


Figure 8: Variation of car occupancy rate with road type in Belgium

### Variation with income

A car use study in Great Britain (Personal travel factsheet, 2003) shows that people with low income groups are more likely to travel in larger parties, with an average occupancy of 1.9 for those trips made by individuals living in households in the lowest income quintile; 46% of these car trips are made by one person alone. Occupancy decreases steadily through each successive income quintile, with those individuals living in households in the highest income quintile making trips with an average occupancy of 1.5; 66% of trips made by these individuals are made alone (see Figure 9).

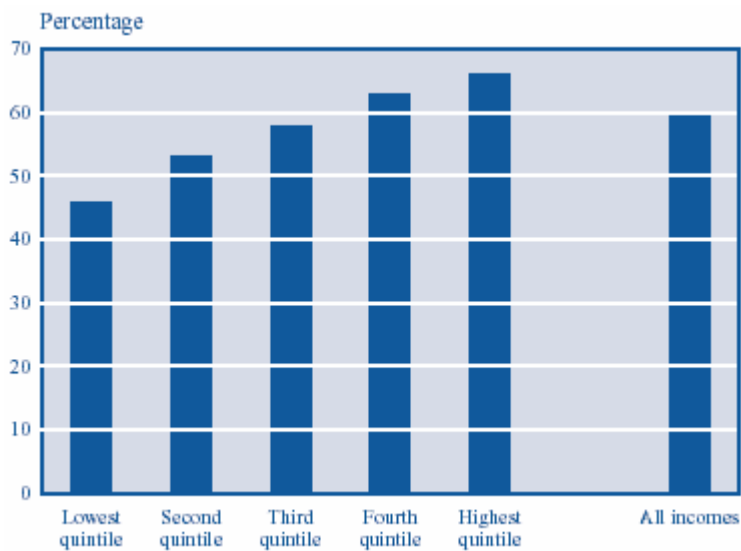


Figure 9: Single occupancy rate by income quintile: 1999/2001 in GB

### **2.2.1.3. Recommendations**

Occupancy rate for passenger cars ranges from 1.1 to 2.2 passengers/car. However this value can differ, depending on:

- the length and purpose of the trip. Breakdowns by purpose (work/education, business, shopping and leisure) are therefore needed.
- the road type

The method for calculating the occupancy rates (using calculated passenger-kilometres and the calculated vehicle-kilometres) has to be improved. In fact, passenger-kilometre and vehicle-kilometre data are often estimated. The possible error is the error in passenger-kilometres times the error in vehicle-kilometres. Furthermore, some passenger-kilometre data are calculated by using an estimation of the average number of vehicle-kilometres and the average occupancy rates.

## **2.2.2. Buses and coaches**

### **2.2.2.1. Definition**

We made a difference between buses (>10 seats, with the possibilities for people to stand up) and coaches (>10 seats, no possibility of standing up).

### **2.2.2.2. European context**

Occupancy rate for buses and coaches vary widely between Member States (see Table 5). It is calculated by dividing passenger-kilometres by the vehicle-kilometres. For example, in the United Kingdom a bus carries, on average, around 9 persons while in France this figure is around 25. The differences between Member States can be explained by different organisation of public transport (fares, frequency, accessibility, etc.).

In most Member States there is a tendency to privatise bus companies and/or cut back subsidy levels. Hence, unprofitable bus routes are being closed down. This results in higher occupancy rates and corresponding improvements in usage efficiency (TERM, 2002).

Country	Bus/coach occupancy rate (passenger/vehicle)
Austria	25
Belgium	32
Denmark	19
Finland	13
France	18
Germany	18
Greece	N.A.
Ireland	15
Italy	17
Luxembourg	23
Netherlands	25
Portugal	16
Spain	28
Sweden	9
United Kingdom	9
EU-14	17

Table 5: Bus/coach occupancy rates in 1999

The TREMOVE<sup>4</sup> model gives a decreasing average value (EU 15) for bus/coach (Tremove, 2004) as shown in Figure 10.

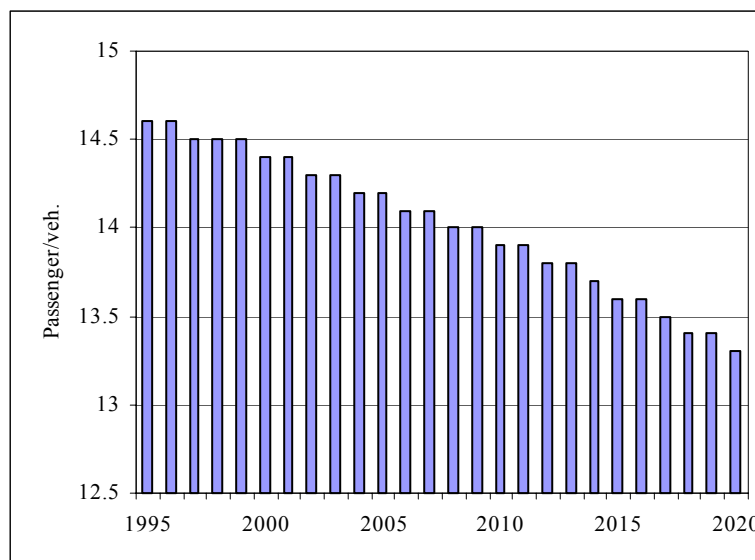


Figure 10: TREMOVE occupancy rates for bus/coach

TRENDS project has produced a set of occupancy values for EU-15 countries for the period 1970-2020 based on TERM and TRAP (LAT) values (Figure 11). There are significant fluctuations between the two datasets. In order to compensate for missing data and differences

<sup>4</sup> TREMOVE is a policy assessment model to study the effects of different transport and environment policies on the emissions of the transport sector.

between TERM and LAT results, a common set of values was produced for each country for the period 1970-2020 (Samaras Z. & al., 2002).

	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK
1970	25,34	15,33	19,70	12,77	25,78	28,60	12,56	23,52	9,82	24,67	27,24	21,79	12,25	9,74	12,88
1971	25,12	16,10	19,66	12,90	25,79	28,60	12,56	23,86	9,82	24,08	26,94	21,76	12,27	9,88	13,15
1972	24,90	16,83	19,62	13,03	25,80	28,60	12,56	24,12	9,82	23,52	26,63	21,73	12,29	10,02	13,42
1973	24,68	17,56	19,59	13,16	25,81	28,60	12,56	24,46	9,82	22,96	26,32	21,70	12,31	10,16	13,69
1974	24,45	18,28	19,55	13,28	25,82	28,60	12,56	24,80	9,82	22,40	26,01	21,67	12,34	10,30	13,96
1975	24,23	19,00	19,43	13,40	25,83	28,60	12,56	25,20	9,82	21,85	25,70	23,63	12,36	10,44	14,23
1976	24,04	18,82	19,30	14,80	25,78	28,30	12,56	24,10	9,82	22,35	25,45	22,60	12,44	10,65	14,00
1977	23,85	18,64	19,18	16,20	25,73	28,00	12,56	23,00	9,82	22,85	25,20	21,58	12,52	10,86	13,76
1978	23,65	18,46	19,06	17,60	25,68	27,70	12,56	21,90	9,82	23,35	24,95	20,56	12,60	11,07	13,51
1979	23,46	18,29	18,98	19,10	25,63	27,40	12,56	20,80	9,82	23,85	24,70	19,53	12,67	11,27	13,27
1980	23,27	18,11	18,90	20,65	25,59	27,12	12,56	19,63	9,82	24,31	24,46	18,49	12,75	11,47	13,02
1981	23,25	18,20	18,49	22,00	25,57	26,89	12,57	19,33	9,82	24,00	24,24	18,36	12,80	11,64	12,67
1982	23,23	18,28	18,08	23,40	25,55	26,66	12,58	19,04	9,82	23,69	24,02	18,23	12,84	11,80	12,31
1983	23,21	18,37	17,66	24,80	25,53	26,43	12,59	18,75	9,82	23,38	23,80	18,10	12,89	11,97	11,95
1984	23,19	18,45	17,25	26,20	25,51	26,20	12,60	18,46	9,82	23,07	23,58	17,97	12,94	12,16	11,65
1985	23,17	18,53	16,83	27,90	25,49	25,96	12,61	18,18	9,82	22,77	23,35	17,83	12,98	12,30	11,24
1986	23,65	18,59	16,90	29,30	25,48	26,25	12,62	17,85	9,82	22,54	23,13	17,70	12,92	12,01	10,88
1987	24,11	18,65	16,97	30,70	25,47	26,55	12,63	17,52	9,82	22,31	22,89	17,57	12,86	11,72	10,52
1988	24,58	18,71	17,04	32,10	25,47	26,84	12,63	17,19	9,82	22,08	22,67	17,44	12,80	11,43	10,16
1989	25,15	18,77	17,14	33,50	25,46	27,14	12,64	16,86	9,82	21,85	22,45	17,30	12,72	11,14	9,80
1990	25,52	18,82	17,20	35,15	25,45	27,43	12,65	16,54	9,82	21,63	22,24	17,17	12,67	10,85	9,44
1991	27,86	19,29	18,31	36,45	25,45	26,91	13,46	16,34	9,43	23,14	22,47	17,40	12,48	10,79	9,32
1992	28,76	19,66	18,46	36,88	25,44	25,03	12,57	16,33	9,43	22,58	22,70	17,95	12,48	10,73	9,16
1993	28,76	20,09	18,85	37,27	25,79	25,16	12,46	16,33	9,43	22,06	22,71	17,88	12,50	10,97	9,00
1994	28,76	20,30	18,91	37,65	25,40	25,61	12,36	16,33	9,43	22,35	22,70	18,46	12,60	9,95	8,81
1995	28,76	20,08	18,86	38,15	25,40	25,33	11,83	16,33	9,43	22,52	22,72	18,25	12,80	9,71	8,85
1996	28,76	19,79	18,84	38,15	25,40	25,52	11,20	16,33	9,43	22,29	22,70	17,68	12,80	9,90	8,70
1997	28,76	19,55	18,71	38,15	25,40	25,61	11,20	16,33	9,43	23,35	22,72	17,11	12,80	9,85	8,71
1998-2020	28,76	19,34	18,71	38,15	25,40	25,57	11,20	16,33	9,43	23,35	22,72	17,11	12,85	9,84	8,72

Figure 11: Proposed occupancy timeseries for buses for EU-15 countries from TRENDS

### 2.2.2.3. Statistics

- For France, SES<sup>5</sup> (DAEI-SES, 2002) gives the following values: 27.7 passengers for coaches in 1999 (28.6 in 2002), and 27.8 for buses (without RATP<sup>6</sup>).
- For UK, the national trade association for bus, coach and light rail operators shows that the national average occupancy for buses and coaches is 11<sup>7</sup> (CPT, 2003).
- The Canadian Vehicle Survey (CVS, 2001) gives a value of 16 passenger/bus.

### Variation with travel purpose

The French statistics (DAEI-SES, 2002) gives the average number of passengers per trip for different types of coach travel (regular, occasional) and for different purposes (see Table 6). It can vary from 22.4 passengers for coaches driving employees, to 40.3 passengers for travels of more than 1 day.

<sup>5</sup> Service Economique et Statistique, Ministère de l'équipement, des Transports et du Logement

<sup>6</sup> Paris public transport system

<sup>7</sup> Public service vehicles only

<b>Travel type and purpose</b>	<b>Average number of passengers per trip</b>
Regular	28.1
ordinary	25.7
School transport	33.2
Personal transport	22.4
Occasional	30.5
Interurban	33.9
Excursions (1 day)	32.9
Travel (> 1day)	40.3
Other	26.1
<b>TOTAL</b>	<b>28.6</b>

Table 6: Average number of passengers per trip for coaches in France

Table 7 presents bus activity by the type of operation for Canada (CVS, 2001). As can be seen, bus occupancy rates averaged about 16 passengers per bus with the highest occupancies found in charter activity at 33 persons per bus. Intercity and school buses averaged about 20 passengers per bus.

<b>Type of operation</b>	<b>Persons/bus</b>
Scheduled urban	<i>n.a.</i>
Scheduled intercity	19.3
School	20.7
Charter	33.4
Other	16.3

Table 7: Bus occupancy rate by type of operation in 10 provinces in Canada for year 2000

### ***Variation with road type and time of the day***

In the UK, the CPT (CPT, 2003) shows that much higher bus loading is achieved in urban areas during peak times. In central London, the average bus loading is 37.5 at peak times. In Birmingham the average bus loading in the morning peak entering the city centre is 28. High loadings are also found during peak times on inter-urban routes and on many private hire and tour and excursion coach services.

#### **2.2.2.4. Recommendations**

As a first approximation, we can take an average value for the bus/coach occupancy rate in Europe, i.e. 17 passengers. However, this value can vary with:

- the country
- the vehicle type: bus/coach
- the travel types and purposes
- the road type and time of the day

The method for calculating the occupancy rates (using calculated passenger-kilometres and the calculated vehicle-kilometres) has to be improved.

## 2.3. Load factor for goods transport

### 2.3.1. Definition

The load factor is the ratio of the average load to total freight capacity in tonnes. A difference should be made between load factor for loaded trips (excluding empty running) and load factor for all trips (including empty running).

The load factor is often defined as the number of tonne-km divided by the number of vehicle-km.

### 2.3.2. European context

It seems that no EU-wide data is available on freight load factors. The country figures used in this assessment may not be representative for the whole EU, but indicate the type of data that is relevant.

The load factors of road transport in the EU are gradually increasing. However, this finding is based on six Member States only and might not be valid for the whole EU (EEA, 2001):

- Load factors in Denmark, Germany, Spain and Portugal increased between 1980 and 1995.
- Load factors in the Netherlands, Finland and Sweden dropped significantly (by 10-17 %) between 1980 and 1995.

In the frame of the European project REDEFINE<sup>8</sup>, an overview of changes in economic activity and road freight transport 1985-1995 was made for some countries. Table 8 gives the ratios of changes of load factor calculated for these countries (Redefine summary report, 1999).

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<sup>8</sup> Relationship between Demand for Freight-transport and Industrial Effects



Country	% of changes of the load factor
France	+7%
Netherlands	-3%
Sweden	-4%
United kingdom	-4%

Table 8: Ratios of changes of load factor for 4 European countries for the period 1985-1995

In the cost-effectiveness study of Auto Oil II program (AOPII, 1999), load factors have usually been computed for each transport mode as the ratio of traffic in tonne-kilometre to traffic in vehicle-kilometre. In the case of trucks, thus, load factors represent an average over all sizes of trucks, from 3.5T.

Region	Mode/Year	1990	1995	2000	2005	2010	2015	2020
Italy	Trucks	2.41	3.03	3.04	3.05	3.05	3.06	3.07

Table 9: Average load factor for trucks in Italy (in tonne per vehicle)

In TRENDS project, we can find data on load factors for goods vehicles based on TERM data (obtained from the Eurostat NewCronos database). These data provide load factors for road freight transport without distinguishing however, between light and heavy duty vehicles or on the basis of the loading capacity / gross vehicle weight (Table 10). In addition, there are several gaps in this dataset, whereas some values are beyond the tolerated limits, which in this case are set to 1.0 and 6.5 (data marked in red in Table 10). Several values in Belgium and France exceed the tolerated limits, while inconsistencies are observed in Luxembourg, Denmark, Spain, Ireland, Portugal and UK (Samaras Z. & al., 2002).

Load factors for road freight transport (tkm/vkm)

	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK
1970	4.3	2.3	3.4	4.7	2.7			2.6			1.7	3.4		3.6	2.2
1975	4.7	2.6	4.2	4.7	2.9	6.7		2.6			1.2	2.6	4.0	4.3	2.2
1980	5.1	2.1	4.3		2.9	7.2	4.0	3.6	1.9	2.8	1.7	2.4	4.7	3.9	2.2
1985	5.5	2.2	4.3		3.1	8.7	4.4	3.6	1.6	2.7	1.7	1.7	4.5	3.6	2.1
1990	8.7	2.2	4.5		3.1	12.5		3.7	3.0	2.5	1.6	5.4	4.7	3.2	2.0
1991	8.7	1.5	4.6		6.0	9.0		3.7	0.7	1.7	1.6	4.5	4.6	3.0	2.0
1992		2.3	4.4		3.2	12.5	2.5	3.7	7.0	2.5	1.5	6.4	4.4	2.9	1.9
1993		2.1	4.3		3.1	12.6	2.5		6.5	2.3			4.4	3.2	4.5
1994		2.3	4.4		3.2	13.1	2.3			2.4			4.5	3.3	4.6
1995		2.3	4.3			14.2	2.8			2.3			4.0	3.6	4.8
1996		2.2	4.5			12.7	2.7			2.3		4.7	4.1	3.8	4.7
1997		2.2	4.6			11.3				2.3		4.6	4.2	3.9	4.6
1998		2.2				11.5						4.8	4.3	3.8	5.0

Tolerated limits: greater than 1 and less than 6.5

Table 10: Load factors for goods vehicles produced in tkm/vkm by TERM for the EU-15 countries

### 2.3.3. Statistics

UK statistics show that load factors (excluding empty running) remained fairly stable at around 63 % between 1986 and 1996.

In Denmark, load factors for loaded trips fell from over 70 % in 1984 to 47 % in 1996, and for all trips (including empty running) from 45 % to 38 % (see Figure 12). This smaller reduction is caused by reductions in the share of vehicle-km running empty, which fell from 29 % in 1984 to 17 % in 1996. The decrease in load factors is the result of the combined effect of increases in the loading capacity per truck and reductions in the weight transported per trip probably due to declining densities of modern high-quality goods. Increasing demand for just-in-time deliveries of high-value goods, together with relatively low transport costs, gives companies an economic incentive to prioritise fast deliveries above a more efficient capacity utilisation (TERM, 2000).

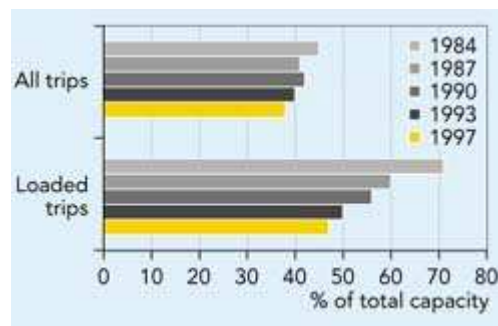


Figure 12: Load factor for trucks over 6 tonnes 1984-1996 in Denmark

The institute for road transport in Belgium gives the trends for the professional transport of goods in Belgium. The Figure 13 shows the evolution of the load factor for trucks calculated as the ratio of the km for loaded trips to the total running km. The load factor varies from 73% to 76.1%. The 2002 average (75.3%) is higher than the 2003 average (74.9%).

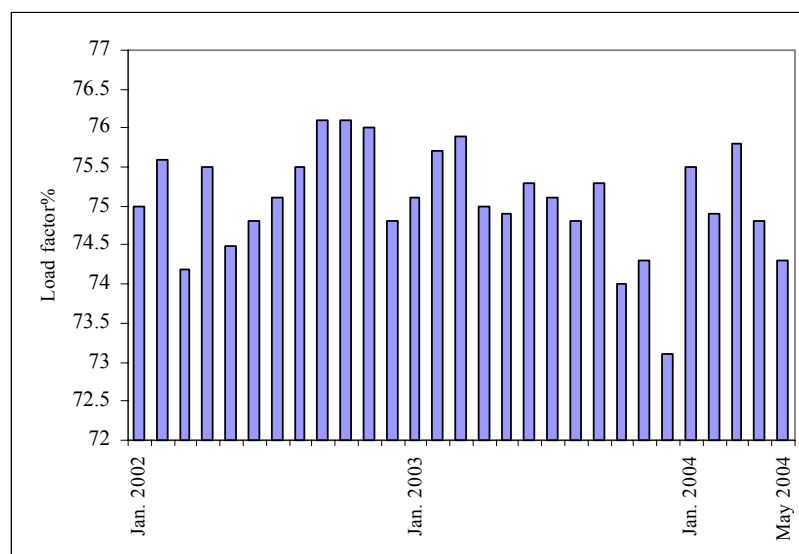


Figure 13: Load factors for trucks in Belgium

In Canada, good data on the overall load factors of Canadian trucks appear to be unavailable, although it is believed that trucks on average operate well below capacity, with possible recent improvements. U.S. data are equally sparse. They suggest a declining load factor, at least in the 1980s (Sustainable Transportation Monitor, 2001).

### **2.3.4. Statistics from Austria**

The ministry of transport in Austria gives the load factor for the HDV (Table 11). These values include the empty running. Data on share of empty running is not available (Rexeis M. & al., 2004).

<b>Vehicle type</b>	<b>Vehicle size</b>	<b>Load factor % (including empty running)</b>
Solo-Truck	≤ 7.5 t	44
	over 7.5 t -12 t	30
	12-14 t	31
	14-20 t	22
	20-26 t	33
	26-28 t	32
	28-32 t	33
	>32 t	33
Semi trailers and truck trailers	< 28 t	53
	28-34 t	73
	34-40 t	68
Coaches	< 18 t	65
	> 18 t	65

*Table 11: Load factor for HDV in Austria*

### **2.3.5. Statistics from Germany**

The statistics of Germany (KBA, 2002) gives the percentage load factor of HDV vehicles for loaded trips by vehicle weight (see Figure 14). The load factor ranges from 53% (for the < 7.5 t weight class) to 62% (for the 7.5-10 t weight class).

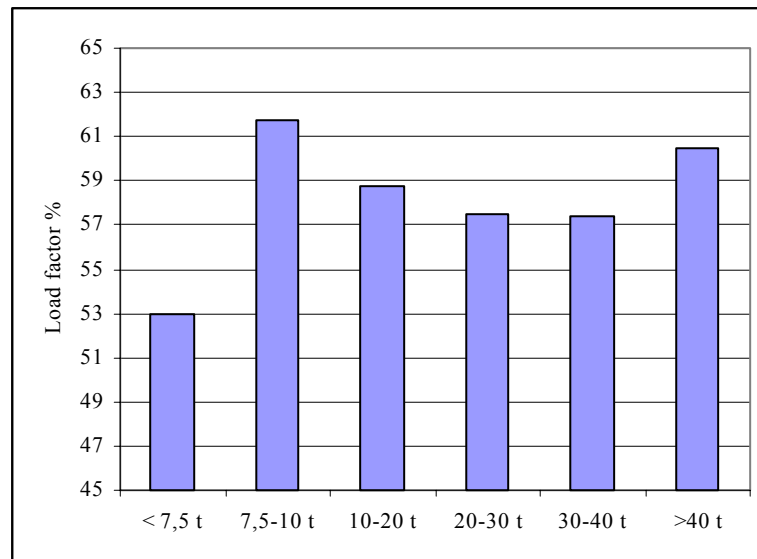


Figure 14: Load factor for HDV in Germany

### 2.3.6. Statistics from Great Britain

Detailed information on the usage conditions for goods transport in Great Britain is available in (HMSO 2003, 2002 and 1996). This information includes in particular average loading factors as function of the vehicle categories. It also includes vehicle kilometres (loaded, empty, total) by vehicle type and size and by mode of working.

Loading factor ranges between 40 and 65%. It is calculated as the ratio of the actual goods moved to the maximum tonne-kms achievable if the vehicles, whenever loaded, were loaded to their maximum carrying capacity. The statistics are presented in Annex 2.

#### *Variation with vehicle type and size*

The load factor varies with the vehicle type from 58% for the whole articulated vehicles to 52% for the whole rigid vehicles (see Table 12). It also depends on the size of vehicle for each type. For example, for rigid vehicles, load factor is equal to 42% for vehicles with gross vehicle weight over 3.5 to 7.5 tonnes and 65% for vehicles with gross vehicle weight over 25 tonnes.

<b>Vehicle type</b>	<b>Vehicle size (gvw<sup>9</sup> tonnes)</b>	<b>% of load factor</b>
Rigid vehicles	Over 3.5 to 7.5	42
	Over 7.5 to 17	40
	Over 17 to 25	46
	Over 25	65
	All rigids	52
Articulated vehicles	Over 3.5 to 33	43
	Over 33	60
	All artics	58
All vehicles	-	57

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*Table 12: Percentage of load factor by vehicle type in 2003 for Great Britain.*

### ***Variation with day of week***

There is very few variation of the load factor with day of week, except on Sunday, with a decrease of 5% for rigid vehicles, compared to other days.

### ***Decrease with time***

From 1985 to 2003, the load factor decreased by 0,7%/year for rigid vehicles and 0,8%/year for articulated vehicles (see Figure 15).

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<sup>9</sup> gross vehicle weight

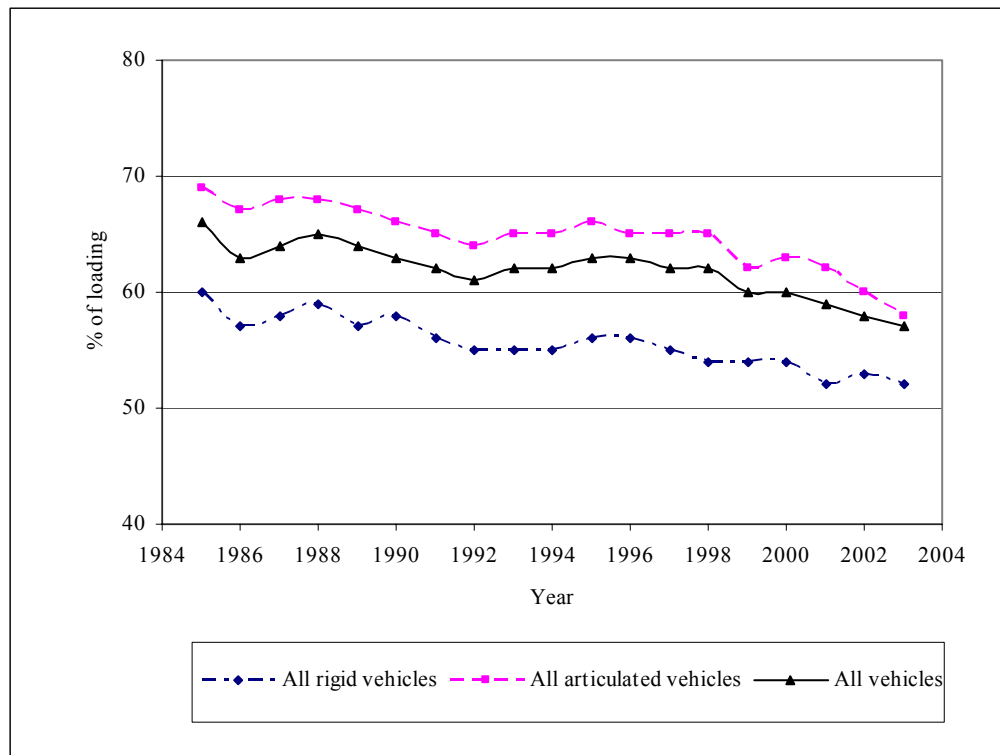


Figure 15: Time variation of the average load factor in Great Britain

This decrease depends on the vehicle type and size (see Figure 16 and Figure 17). Example: 2,7%/year for rigid vehicles with a gross vehicle weight of 17 to 25t.

### ***Determination of correction functions***

Based on the available data, we have determined correction functions for the time variation of load factor for rigid and articulated vehicles.

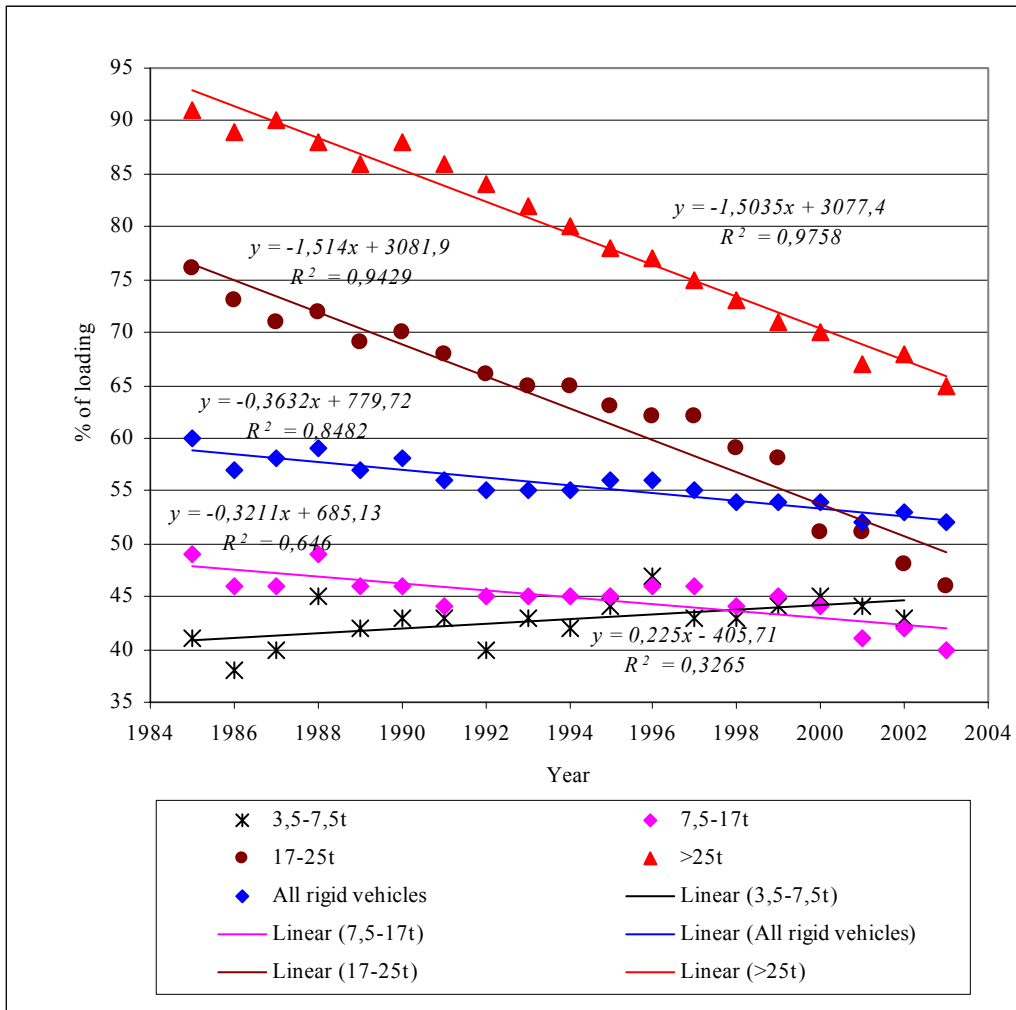


Figure 16: Time variation of load factor for goods transport in Great Britain, for rigid vehicles

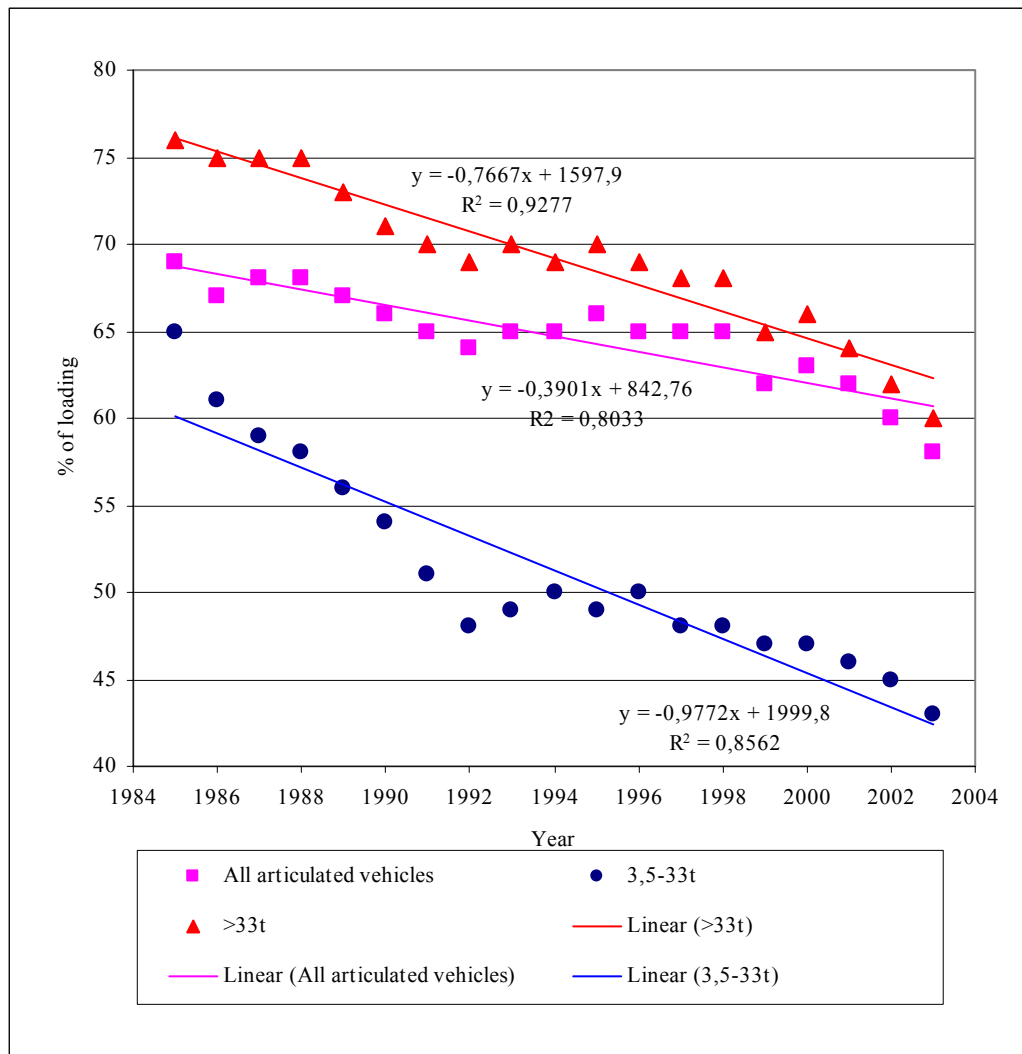


Figure 17: Time variation of load factor for goods transport in Great Britain, for articulated vehicles

Thanks to these functions, we can determine relation between the load factor at a given year  $n_0$  and the load factor at a year  $n$ , as followed:

First, we have the relation for different types of vehicles for Great Britain:

$$LF_{GB}^i(n) = P \cdot n + B \quad (\text{Equation 1})$$

Where,

$LF_{GB}^i(n)$  is the load factor at year  $n$  in Great Britain, for a vehicle type  $i$ .

$P$  is the slope of the linear tendency.

$B$  is a coefficient.

For years before 1985, we assumed that in Great Britain, the load factor is equal to the load factor in 1985:  $LF_{GB}(n < 1985) = LF_{GB}(1985)$ .



Moreover, for years after 2003, we assumed that in Great Britain, the load factor is equal to the load factor in 2003:  $LF_{GB}(n>2003)=LF_{GB}(2003)$ . (This hypothesis is strong and could be performed in the future).

We considered that the decrease of the load factor is the same all around Europe, and is equal to the decrease in Great Britain, i.e. the slope P. We have therefore the load factor in Europe at a year n for a vehicle type i:

$$LF^i(n)=P*(n-n_0)+LF^i(n_0) \quad (\text{Equation 2})$$

Where  $LF(n_0)$  is the load factor at a year  $n_0$ .

This function, obtained for the vehicle types used in Great Britain, was adapted to the vehicle types used in Artemis thanks to the relations given in Annex 3.

We also make the hypothesis that the load factor all over Europe cannot be higher than the load factor in 1985 in Great Britain, and cannot be lower than the load factor in 2003 in Great Britain.

We obtained therefore the functions given in Table 13 for the different vehicle types and sizes. We propose to apply the evolution observed for UK for a given country for which the load factor at year  $n_0$ ,  $LF(n_0)$  is known.

Vehicle type	gvw(t)	Calculated load factor $LF(n)=p*(n-n_0)+LF(n_0)$ where $n_0 = \text{given year}$ ; $p = \text{slope}$ ; $n = \text{year of the study}$	R <sup>2</sup>
Rigid Vehicles	<7.5	If $n < n_0$ , $LF(n)=\min(0.225*(n-n_0)+LF(n_0);LF_{GB}(1985))$ If $n > n_0$ , $LF(n)=\max(0.225*(n-n_0)+LF(n_0);LF_{GB}(2003))$	0.33
	7.5-12	If $n < n_0$ , $LF(n)=\min(-0.324*(n-n_0)+LF(n_0);LF_{GB}(1985))$ If $n > n_0$ , $LF(n)=\max(-0.324*(n-n_0)+LF(n_0);LF_{GB}(2003))$	0.65
	12-14		
	14-20	If $n < n_0$ , $LF(n)=\min(-0.9175*(n-n_0)+LF(n_0);LF_{GB}(1985))$ If $n > n_0$ , $LF(n)=\max(-0.9175*(n-n_0)+LF(n_0);LF_{GB}(2003))$	0.79
	20-26	If $n < n_0$ , $LF(n)=\min(-1.512*(n-n_0)+LF(n_0);LF_{GB}(1985))$ If $n > n_0$ , $LF(n)=\max(-1.514*(n-n_0)+LF(n_0);LF_{GB}(2003))$	0,95
	26-28	If $n < n_0$ , $LF(n)=\min(-1.5035*(n-n_0)+LF(n_0);LF_{GB}(1985))$ If $n > n_0$ , $LF(n)=\max(-1.5035*(n-n_0)+LF(n_0);LF_{GB}(2003))$	0,97
	28-32		
>32			
Articulated vehicles	<7.5	If $n < n_0$ , $LF(n)=\min(-0.9772*(n-n_0)+LF(n_0);LF_{GB}(1985))$ If $n > n_0$ , $LF(n)=\max(-0.9772*(n-n_0)+LF(n_0);LF_{GB}(2003))$	0.86
	7.5-28	If $n < n_0$ , $LF(n)=\min(-0.9414*(n-n_0)+LF(n_0);LF_{GB}(1985))$ If $n > n_0$ , $LF(n)=\max(-0.9414*(n-n_0)+LF(n_0);LF_{GB}(2003))$	0.87
	28-34		
	34-40	If $n < n_0$ , $LF(n)=\min(-0.7667*(n-n_0)+LF(n_0);LF_{GB}(1985))$ If $n > n_0$ , $LF(n)=\max(-0.7667*(n-n_0)+LF(n_0);LF_{GB}(2003))$	0.93

Table 13: Functions for the determination of a load factor at a year from a load factor at a given year

### 2.3.7. Statistics from France

We have determined the load factor in France for different categories of rigid vehicle with the following method:

- We first calculated the ‘real load’ transported as the ratio of the tonne-kilometres to vehicle-kilometres, where these two parameters are function of the payload.
- Then we calculated a maximum and a minimum load factor for each category of rigid vehicle as the ratio of the real load to the minimum or the maximum payload. The difference between these two values is important, around 20%.
- We also determined an average load factor by the use of an average value for the payload (see Table 14). Detailed data are presented in Annex 4.

A distinction is made between different modes of working:

- “hire or reward” which correspond to goods vehicle operators who carry goods for other people for hire or reward
- “own account” which are goods vehicle operators who only carry goods in the course of their own trade or business.

Payload (t)	Load Factor for rigid vehicles								
	Maximum load factor (%)			Minimum load factor (%)			Average load factor (%)		
	Hire or reward	Own account	Both	Hire or reward	Own account	Both	Hire or reward	Own account	Both
3,0-4,5	68	59	62	45	39	41	54	47	50
4,6-6,5	63	52	59	45	37	42	52	43	49
6,6-8,9	78	62	72	58	46	53	67	53	61
9,0-12,9	81	70	76	56	49	53	67	58	62
13,0-16,9	80	77	78	62	59	60	70	67	68
>17,0	63	80	73	36	46	41	46	58	53

Table 14: Calculated load factor for rigid vehicles in France (2001, from data of (SES, 2002)).

#### **Errors on this method**

According to (HMSO, 2003), we can have errors up to  $\pm 10\%$  on the measurement of the tonne-kilometres. If we assume the same errors for French data, and an error of  $\pm 10\%$  on the vehicle-kilometres, we obtain an error of  $\pm 20\%$  on the measurement of the real transported load. Therefore, we obtain an error on the load factor, which is also important: more than  $\pm 20\%$ , since we have also taken an average payload.

Moreover, there is only one type of vehicles with a payload  $>17t$  whereas data from Great Britain show a strong difference between 17-25t and  $>25t$ .

### **2.3.8. Recommendations**

A common definition of load factor excluding empty running rate must be used within Artemis.

The value of the load factor for goods transport ranges from 35% to 80%. It depends on the following parameters:

- vehicle type and weight: Based on the GB data, we have determined the variation of the load factor:
  - o with vehicle type: average values: 0.9 for rigids and 1.05 for artics
  - o With vehicle weight: 0.7-1.15 for rigids, 0.75-1.05 for artics
- mode of working: Based on the French data, we have calculated an average factor for the variation of the load factor:
  - o 1.04 for hire or reward mode
  - o 0.95 for own account mode
- time: it tends to decrease with time. When data at year  $n_0$  are available for a country, defined correction functions can be used for time correction. We note that this trend is related to the incentive system.

More work is needed to provide reliable and comparable data for load factors in particular in the calculation including/excluding empty running.

## **3. Empty running rate**

### **3.1. Introduction**

#### *Definition*

The rate of empty running vehicles is the rate of vehicle-kilometres without goods or passengers.

#### *European context*

It seems that EU-wide data on empty hauling is not available, but a few country examples indicate that there are large differences. Empty hauling makes up only 25 % of total truck vehicle-km in Germany (German Federal Ministry of Environment and Nuclear Safety, 2000) and more than 40 % in the Netherlands. In the United Kingdom, empty hauling fell from about 33 % to 29 % of total truck vehicle-km between 1980 and 1996. This may be explained by longer journeys, more drops per trip, more load-matching services, a growth in the reverse flow of packaging material / handling equipment, and greater efforts by shippers to obtain return loads (EEA, 2001).

### **3.2. Buses and coaches**

#### **3.2.1. Statistics**

According to French data (SES, 1999 and 2002) the empty running rate for buses and coaches is not varying a lot with time. This empty rate was of 19% in 1999 for coaches (20.6% in 2002), and 10.6% for buses (RATP not included).

According to the data given by the RATP the proportion of empty running km is equal to:

- 6.96% (of the total running km)
- 7.48% (of running km with passengers)

### ***Variation with the age of vehicle***

However this rate is increasing with the age of vehicles, in particular for coaches (see Table 15).

<b>Vehicle age (years)</b>	<b>% empty running</b>
0-4	18.1
5-9	19.3
10-14	22.8
15-25	27

*Table 15: Percentage of empty running by vehicle age in 2002 for coaches in France.*

### **3.2.2. Recommendations**

In order to better take into account the empty running rate for buses/coaches, the following points must be considered:

- When data are available, distinction between buses and coaches must be made.
- The use of a value of 25% for the empty rate seems to be not pertinent since we find values of 19% for coaches and 10.6% for buses in France in 1999.
- The empty running rate increases with the vehicle age. This parameter could have an impact if the age distribution is spread.

### 3.3. Transport of goods

A half-loaded truck uses more than 90% of the fuel used per kilometre by a fully loaded truck. Thus the fuel use per t-km is almost twice as high for a half-loaded truck (The Centre for Sustainable Transportation, 2001).

#### 3.3.1. European context

In the frame of the European project REDEFINE, an overview of changes in the rate of empty running was made for some countries (Redefine summary report, 1999). We can notice a decrease in the rate of empty running (see Table 16).

Country	% of changes of the empty running rate
France	-21%
Netherlands	-7
Sweden	-7%
United kingdom	-5%

Table 16: Ratios of changes of empty running for 4 European countries for the period 1985-1995

#### 3.3.2. Statistics

The Swedish Statistics from SIK10 include the description of trip lengths (passengers and freight) and the proportion of empty journeys. This proportion varies greatly between the different commodity categories – general consignment showed an empty running proportion of 7%, while, for instance, round timber had an empty-journey proportion of 46%. The proportion of empty journeys for Swedish lorries with a maximum load of at least 3.5 tonnes in domestic traffic is given in Table 17.

<sup>10</sup> The Swedish Institute for Transport and Communications Analysis

Year	% empty running
1993	28
1994	26
1995	25
1996	23
1997	24
1998	24
1999	24
2000	24
2001	24

Table 17: Example of percentage of empty running in Sweden

The empty running rate is available for France and Great Britain and concerns an important part of travels: 26.5% in 2002 in Great Britain for heavy duty vehicles (HMSO, 2003), and 25.2% in 2001 in France (SES, 2002).

### 3.3.3. Statistics from Germany

The statistics of Germany (KBA, 2002) gives the percentage load factor of empty running for HDV vehicles by vehicle weight (see Figure 18). The empty running rate ranges from 21% (for the 30-40 t weight class) to 32% (for the < 7.5 t weight class) with an average value of 23%.

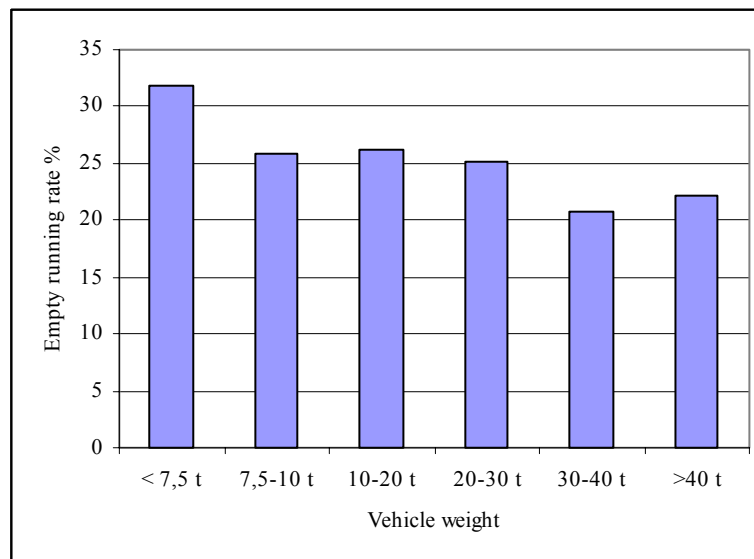


Figure 18: Empty running rate for HDV in Germany

### 3.3.4. Statistics from Great Britain

#### *Variation with the vehicle type and size*

As we can see in Table 18, this rate depends on the vehicle type and size. For both rigid and articulated vehicles, the heavier the vehicles are the higher is the empty rate.

Vehicle type	Vehicle size (gvw tonnes)	% of empty running
Rigid vehicles	Over 3.5 to 7.5	26.3
	Over 7.5 to 17	24.2
	Over 17 to 25	25.4
	Over 25	35.7
	All rigids	27.9
Articulated vehicles	Over 3.5 to 33	21.0
	Over 33	25.9
	All artics	25.2
All vehicles	-	26.5

Table 18: Percentage of empty running by vehicle type in 2003 for Great Britain.

#### *Variation with day of week*

There is very few variation of the empty rate with day of week.

#### *Decrease with time*

We can also notice that the empty rate is decreasing with time in Great Britain (see Figure 19), from 31% in 1985 to 26.5% in 2002 (-0.9%/year) in average and with important decrease for certain types of vehicles (-3%/year from 1985 to 2002 for rigid 17-25t). The statistics are presented in Annex 5.

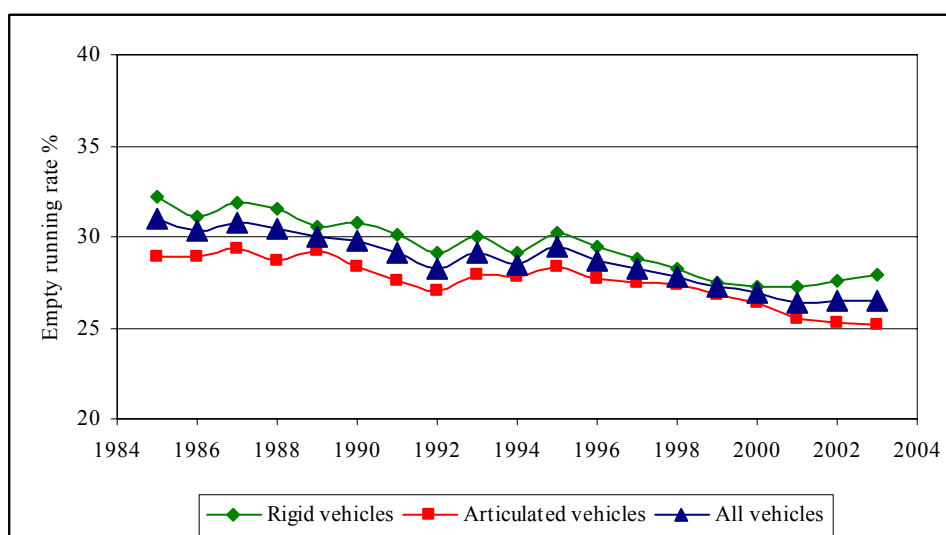


Figure 19: Time variation of rate of empty running for goods transport in Great Britain



This decrease seems to be European since Savin (Savin, SES 2000) points out a decrease of –12% in Netherlands from 1980 to 1995, -10% in United Kingdom, -15% in Sweden and –23% in France. This decrease is supposed to be reduced with time, since it does not exist any more in France after 1997 (SES, 1998, 2001 and 2002). This decrease could be explained by an improvement of the management of vehicles use.

### Determination of correction functions

Based on the available data, we have determined corrections functions for the time variation of empty running rate for rigid and articulated vehicles (see Figure 20 and Figure 21).

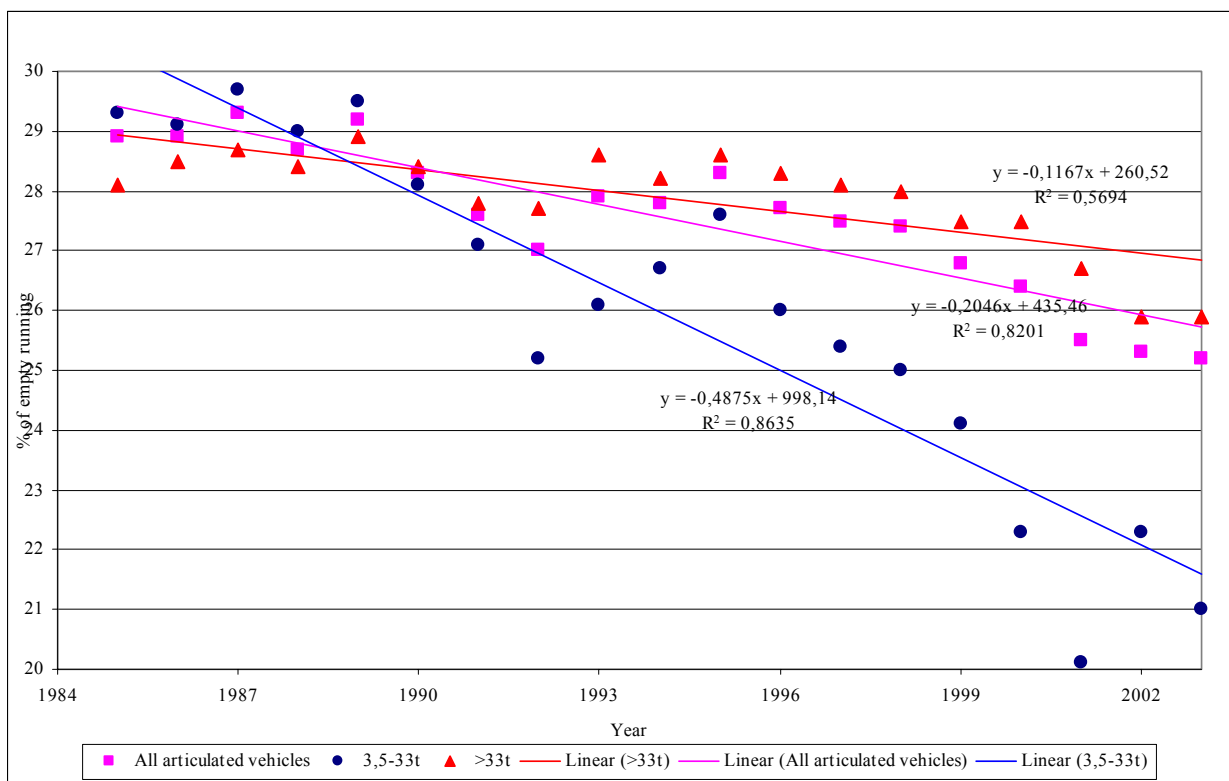


Figure 20: Time variation of rate of empty running for goods transport in Great Britain, case of articulated vehicles.

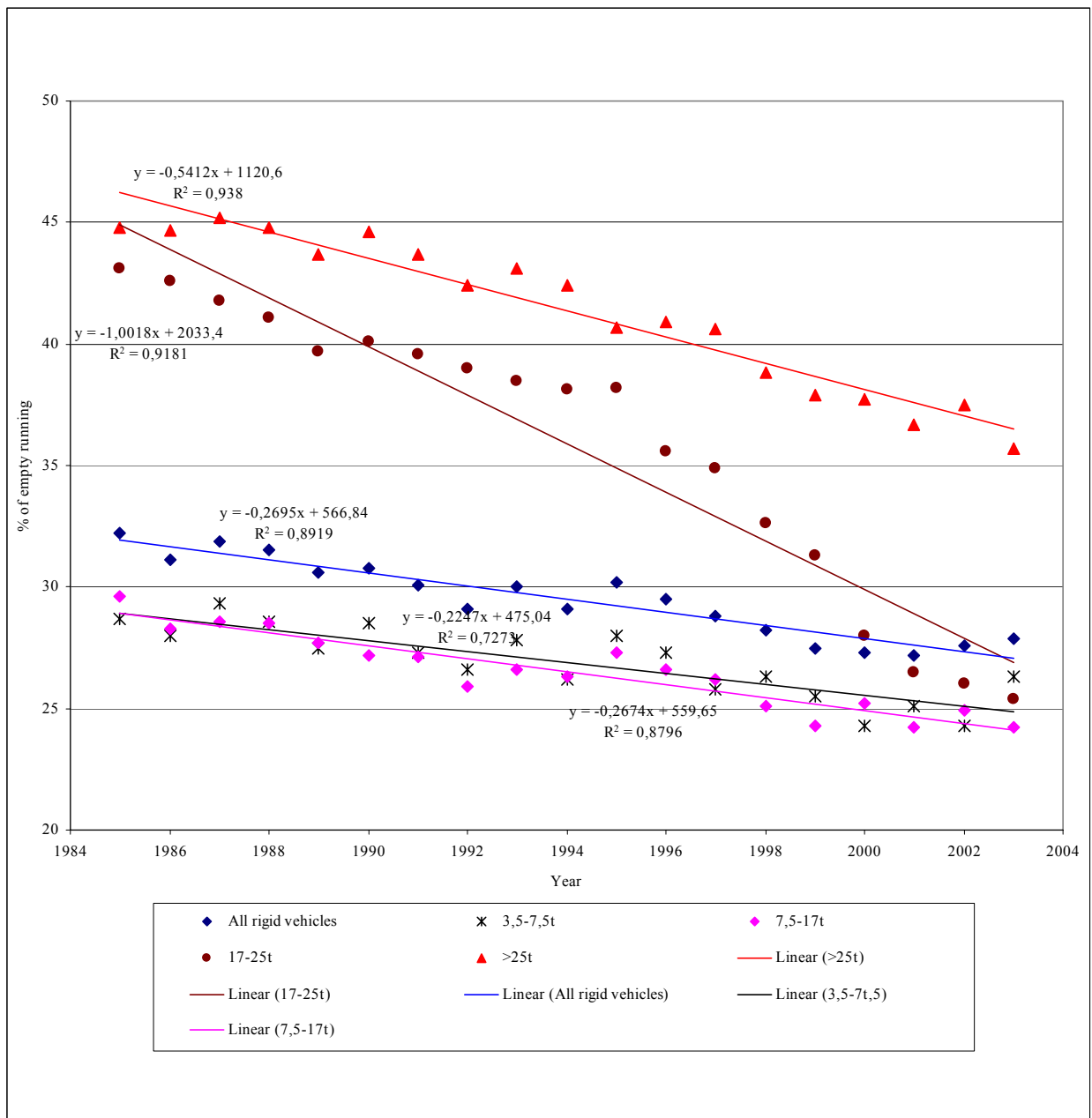


Figure 21: Time variation of rate of empty running for goods transport in Great Britain, case of rigid vehicles.

Thanks to these functions, we determined relation between the empty rate at a given year  $n_0$  and the empty rate at a year  $n$ , as followed:

First, we have the relation for different types of vehicles for Great Britain between 1985 and 2003:

$$ER_{GB}^i(n) = P \cdot n + B, \quad (\text{Equation 3})$$

Where,

$ER_{GB}^i(n)$  is the empty rate at year  $n$  in Great Britain, for a vehicle type  $i$ .

$P$  is the slope of the linear tendency.

$B$  is a coefficient.

For years before 1985, we assumed that in Great Britain, the empty rate is equal to the empty rate in 1985:  $ER_{GB}(n<1985)=ER_{GB}(1985)$ .

Moreover, for years after 2003, we assumed that in Great Britain, the empty rate is equal to the empty rate in 2003:  $ER_{GB}(n>2003)=ER_{GB}(2003)$ .

We considered that the decrease of the empty rate is the same all around Europe, and is equal to the decrease in Great Britain, i.e. the slope P. We have therefore the empty rate in Europe at a year n for a vehicle type i:

$$ER^i(n)=P*(n-n_0)+ER^i(n_0) \quad (\text{Equation 4})$$

Where  $ER(n_0)$  is the empty rate at a year  $n_0$ .

This relation, obtained for the vehicle types used in Great Britain, was adapted to the vehicle types used in Artemis thanks to the relations given in Annex 3.

We also make the hypothesis that the empty rate all over Europe cannot be higher than the empty rate in 1985 in Great Britain, and cannot be lower than the empty rate in 2003 in Great Britain.

We obtained therefore the functions given in Table 19 for the different vehicle types and sizes. We propose to apply the evolution observed for UK for a given country for which the empty running rate at year  $n_0$ ,  $ER(n_0)$  is known.

Vehicle type	gvw (t)	Empty rate (ER%) $ER(n)=p*(n-n_0)+ER(n_0)$ <b>p= slope; n=year; n<sub>0</sub>=year of reference</b>	R <sup>2</sup>
Rigid Vehicles	<7.5	If $n < n_0$ , $ER(n)=\min(-0.2247*(n-n_0)+ER(n_0);ER_{GB}(1985))$ If $n > n_0$ , $ER(n)=\max(-0.2247*(n-n_0)+ER(n_0);ER_{GB}(2003))$	0.73
	7.5-12	If $n < n_0$ , $ER(n)=\min(-0.2674*(n-n_0)+ER(n_0);ER_{GB}(1985))$ If $n > n_0$ , $ER(n)=\max(-0.2674*(n-n_0)+ER(n_0);ER_{GB}(2003))$	0.88
	12-14	If $n < n_0$ , $ER(n)=\min(-0.6346*(n-n_0)+ER(n_0);ER_{GB}(1985))$ If $n > n_0$ , $ER(n)=\max(-0.6346*(n-n_0)+ER(n_0);ER_{GB}(2003))$	
	14-20	If $n < n_0$ , $ER(n)=\min(-0.987*(n-n_0)+ER(n_0);ER_{GB}(1985))$ If $n > n_0$ , $ER(n)=\max(-0.987*(n-n_0)+ER(n_0);ER_{GB}(2003))$	0.89
	20-26	If $n < n_0$ , $ER(n)=\min(-0.5412*(n-n_0)+ER(n_0);ER_{GB}(1985))$ If $n > n_0$ , $ER(n)=\max(-0.5412*(n-n_0)+ER(n_0);ER_{GB}(2003))$	0.93
	26-28	If $n < n_0$ , $ER(n)=\min(-0.4875*(n-n_0)+ER(n_0);ER_{GB}(1985))$ If $n > n_0$ , $ER(n)=\max(-0.4875*(n-n_0)+ER(n_0);ER_{GB}(2003))$	
	28-32	If $n < n_0$ , $ER(n)=\min(-0.4245*(n-n_0)+ER(n_0);ER_{GB}(1985))$ If $n > n_0$ , $ER(n)=\max(-0.4245*(n-n_0)+ER(n_0);ER_{GB}(2003))$	0.94
	>32		
Articulated vehicles	<7.5	If $n < n_0$ , $ER(n)=\min(-0.1167*(n-n_0)+ER(n_0);ER_{GB}(1985))$ If $n > n_0$ , $ER(n)=\max(-0.1167*(n-n_0)+ER(n_0);ER_{GB}(2003))$	0.86
	7.,5-28	If $n < n_0$ , $ER(n)=\min(-0.4875*(n-n_0)+ER(n_0);ER_{GB}(1985))$ If $n > n_0$ , $ER(n)=\max(-0.4875*(n-n_0)+ER(n_0);ER_{GB}(2003))$	
	28-34	If $n < n_0$ , $ER(n)=\min(-0.4245*(n-n_0)+ER(n_0);ER_{GB}(1985))$ If $n > n_0$ , $ER(n)=\max(-0.4245*(n-n_0)+ER(n_0);ER_{GB}(2003))$	0.82
	34-40	If $n < n_0$ , $ER(n)=\min(-0.1167*(n-n_0)+ER(n_0);ER_{GB}(1985))$ If $n > n_0$ , $ER(n)=\max(-0.1167*(n-n_0)+ER(n_0);ER_{GB}(2003))$	0.60

Table 19: Functions for the determination of an empty rate at a given year from an empty rate at another year.

### 3.3.5. Statistics from France

#### *Variation with the vehicle size*

For the French case, the empty running rate increases with the vehicle size (Table 20) with an average value of 27.9% for all vehicles.

Vehicle type	Payload (tonnes)	% of empty running
Hire or reward	3.0-4.5	18.1
	4.6-6.5	16.8
	6.6-8.9	20.8
	9.0-12.9	21.0
	13.0-16.9	31.0
	>17	40.0
Own account	3.0-4.5	29.5
	4.6-6.5	26.9
	6.6-8.9	33.0
	9.0-12.9	35.1
	13.0-16.9	42.1
	>17	41.9
All vehicles		27.9

Table 20: Percentage of empty running by vehicle type in 2001 for France for rigid vehicles.

#### *Variation with the owner of the vehicle*

We have difference of 13.2% in 2001 between the two categories (21.8% for “hire or reward” and 35.0% for “own account”), for a distribution of vehicles of nearly 50% in each category for rigid vehicles, and 86,8% of hire or reward and 13,2% of own account concerning articulated vehicles (SES, 2002).

#### *Increase with the vehicle age*

The empty rate increases with the vehicle age. Concerning France, we have determined the correction of this rate in comparison with the average empty rate for different categories of vehicles. Results are presented in Table 21 and Table 22.

<b>Rigid vehicles</b>						
	<b>Hire or reward</b>		<b>Own account</b>		<b>Both</b>	
<b>Age (year)</b>	<b>Empty rate (%)</b>	<b>Correction coefficient/Average</b>	<b>Empty rate (%)</b>	<b>Correction coefficient/Average</b>	<b>Empty rate (%)</b>	<b>Correction coefficient/Average</b>
0-1	20.3	0.95	33,9	0,99	26,6	0,95
2-4	19.9	0,93	33.0	0.96	25.8	0.92
5-7	20.2	0.94	32.8	0.96	26.4	0.95
8-10	23.8	1.11	33.4	0.97	29.0	1.04
11-13	29.5	1.38	38.7	1.13	35.9	1.29
>13	30.8	1.44	35.9	1.05	34.4	1.23

Table 21: Rate of empty vehicle-kilometres as a function of the vehicle age for rigid vehicles in France (2001), and correction coefficient  $C$  relative to the average empty rate ( $ER=C*(average\ ER)$ ).

<b>Articulated vehicles</b>						
	<b>Hire or reward</b>		<b>Own account</b>		<b>Both</b>	
<b>Age (year)</b>	<b>Empty rate (%)</b>	<b>Correction coefficient/Average</b>	<b>Empty rate (%)</b>	<b>Correction coefficient/Average</b>	<b>Empty rate (%)</b>	<b>Correction coefficient/Average</b>
0-1	19.6	0.89	34.6	0.95	21.0	0.88
2-4	19.8	0.90	32.8	0.90	21.3	0.89
5-7	24.9	1.14	38.4	1.05	26.9	1.13
8-10	30.2	1.38	38.4	1.05	32.1	1.35
11-13	32.8	1.50	44.2	1.21	36.1	1.52
>13	30.8	1.41	41.3	1.13	34.0	1.43

Table 22: Rate of empty vehicle-kilometres as a function of the vehicle age for articulated vehicles in France (2001), and correction coefficient  $C$  relative to the average empty rate ( $ER=C*(average\ ER)$ ).

### **3.3.6. Recommendations**

In order to better take into account the empty running rate for goods transport, we can notice that:

- The empty running rate is decreasing with time. We have defined relations between an empty rate at year  $n_0$  where data are available, and an empty rate at year  $n$ , for Artemis. We note that this trend is related to the incentive system.
- The empty running rate depends also on the age of the vehicle. Correction factors are given for different ages based on the French data. This parameter could have an impact if the age distribution is spread.
- The use of an empty running rate of 25% as sometimes adopted is a good approximation which corresponds to the average empty rate in Great Britain (26.5% in 2002) and in France (25.2% in 2001).
- If data are available in European countries, the distinction between the two categories of vehicles: “hire or reward”, (average empty running rate of 22% in France in 2001), and “own account” (35% in France in 2001) should be done.
- The distinction between “rigid vehicles” and “articulated vehicles” could also be done if data are available. The average rate of empty vehicles is the same in France for these two categories, but important differences exist, depending on the payload of vehicles.
- The distinction between payload categories of vehicle should be done.



## 4. Load patterns in ARTEMIS fleet model

The fleet model in Artemis takes into account the load pattern for heavy duty vehicles on different road classes as a function of age. The veh-km is split in 3 load classes (empty/half loaded/fully loaded). Sum must be equal 100% per age class. This split can be defined as a function of age. If no data available, we use the same split for all age classes.

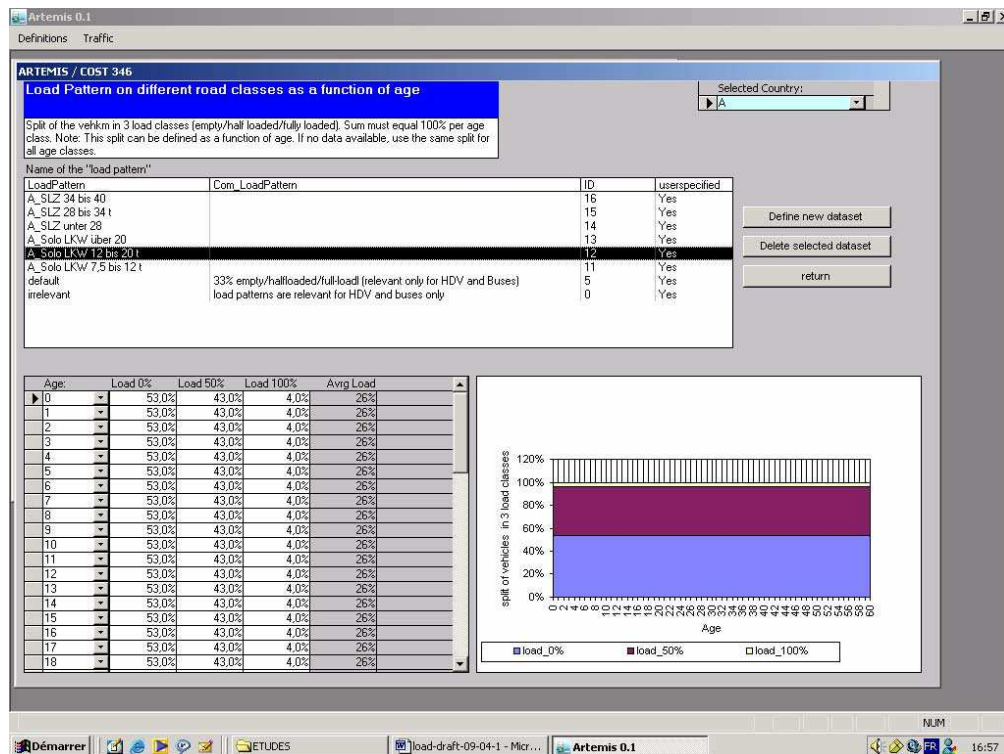


Figure 22: Example of load pattern input screen in Artemis

Intermediate load classes (over 50%) can be expressed as function of half and fully loaded classes as follows:

$$X + Y = 100$$

With

X : % of distance travelled with 0% of load (empty running)

Y : % of distance travelled with LF

LF : Load Factor (%)



$$X + Y_{50} + Y_{100} = 100$$

With

$Y_{50}$  : % of distance travelled with 50% of load

$Y_{100}$  : % of distance travelled with 100% of load

We obtain the following system:

$$Y_{50} * 50 + Y_{100} * 100 = Y * LF$$

$$Y_{50} + Y_{100} = Y$$

$$\Rightarrow Y_{50} = Y * (2 - LF/50)$$

$$Y_{100} = Y * (LF/50 - 1)$$

## **5. Conclusions**

This report has provided a review of the available data and definitions of the load factor and the empty running rate for vehicles. This has highlighted the numerous factors affecting these parameters. The synthesis and analysis of statistics from Europe, France, Great Britain, etc, and from international institutions enabled to highlight various aspects and difficulties. The report has also developed a set of recommendations to consider when estimating pollutant emissions. Such recommendations include correction functions for freight transport in term of variation of the parameters with time for different vehicles types and sizes.



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# **Annexes**





## Car occupancy rate in France

Populations, taux de motorisation et taux d'occupation des voitures situation Septembre 2003				
Enquête	Année	Population	Taux de motorisation ramené à la population totale	Taux d'occupation des voitures
Aix	1989	227 000	0,48	1,34
Aix	1997	290 000	0,53	1,31
Amiens	1979	158 000	0,29	1,40
Amiens	1991	153 000	0,38	1,34
Angers	1989	199 000	0,43	1,29
Avignon	1980	131 000	0,36	1,32
Belfort	1983	106 000	0,36	1,37
Belfort	1992	127 000	0,45	1,36
Bordeaux	1978	604 000	0,37	1,30
Bordeaux	1990	762 000	0,48	1,30
Bordeaux	1998	801 000	0,52	1,28
Cherbourg	1994	87 000	0,42	1,38
Clermont	1992	323 000	0,50	1,31
Côte Basque	1999	223 000	0,59	1,28
Côte d'azur	1998	1 030 000	0,48	1,33
Dijon	1988	221 000	0,39	1,30
Douai	1996	174 000	0,36	1,46
Dunkerque	1991	202 000	0,35	1,40
Elbeuf	1997	53 000	0,42	1,39
Etang De Berre	1990	326 000	0,44	1,36
Etang De Berre	1997	329 000	0,49	1,33
Enquête	Année	Population	Taux de motorisation ramené à la population totale	Taux d'occupation des voitures
Fort de France	2000	170 000	0,34	1,40
Grenoble	1978	371 000	0,33	1,35
Grenoble	1985	380 000	0,41	1,33
Grenoble	1992	349 000	0,44	1,30
Grenoble agglo	2002	385 000	0,51	1,31
Grenoble Total	2002	712 000	0,55	1,31
Le Havre	1992	238 000	0,37	1,39
Lille	1976	889 000	0,25	1,37
Lille	1987	1 093 000	0,34	1,41
Lille	1998	1 177 000	0,41	1,37
Lorient	1982	171 000	0,34	1,35
Lyon	1976	1 029 000	0,30	1,32
Lyon	1985	1 088 000	0,40	1,31
Lyon	1995	1 220 000	0,45	1,29
Marseille	1976	930 000	0,25	1,43
Marseille	1988	1 137 000	0,37	1,34
Marseille	1997	1 068 000	0,44	1,31
Metz	1992	177 000	0,42	1,32
Mulhouse	1990	214 000	0,42	1,31
Nancy	1976	230 000	0,29	1,34
Nancy	1991	295 000	0,41	1,32

Nantes	1980	466 000	0,32	1,33
Nantes	1990	518 000	0,43	1,30
Enquête	Année	Population	Taux de motorisation ramené à la population totale	Taux d'occupation des voitures
Orleans	1976	201 000	0,33	1,37
Paris	1976	9 691 000	0,29	1,31
Paris	1983	9 939 000	0,35	1,32
Paris	1991	10 464 000	0,39	1,31
Paris	1998	10 751 000	0,40	1,32
Perpignan	1984	117 000	0,34	1,36
Reims	1987	200 000	0,38	1,33
Reims	1996	221 000	0,43	1,32
Rennes	1991	309 000	0,47	1,31
Rennes	2000	352 000	0,50	1,28
Rouen	1996	382 000	0,43	1,33
Saint Etienne	1991	435 000	0,42	1,33
Saint Etienne	2001	510 000	0,45	1,32
Saint Nazaire	1996	187 000	0,50	1,35
Strasbourg	1988	386 000	0,38	1,34
Strasbourg	1997	508 000	0,45	1,29
Toulon	1985	289 000	0,36	1,33
Toulon	1998	357 000	0,48	1,35
Toulouse	1978	542 000	0,37	1,33
Toulouse	1990	681 000	0,49	1,30
Toulouse	1996	723 000	0,52	1,28
Troyes	1998	120 000	0,46	1,34
Valence	1981	130 000	0,38	1,33
Valence (Rovaltain)	1991	228 000	0,47	1,33
Valenciennes	1985	329 000	0,29	1,50
Valenciennes	1997	334 000	0,36	1,43
Source : enquêtes ménages déplacements Cerlu INSEE (population )				

## Load factors in Great Britain

<b>Load factor for rigid vehicles (% of loading)</b>				
<b>Year/gvw (t)</b>	<b>3,5-7,5t</b>	<b>7,5-17t</b>	<b>17-25t</b>	<b>&gt;25t</b>
1985	41	49	76	91
1986	38	46	73	89
1987	40	46	71	90
1988	45	49	72	88
1989	42	46	69	86
1990	43	46	70	88
1991	43	44	68	86
1992	40	45	66	84
1993	43	45	65	82
1994	42	45	65	80
1995	44	45	63	78
1996	47	46	62	77
1997	43	46	62	75
1998	43	44	59	73
1999	44	45	58	71
2000	45	44	51	70
2001	44	41	51	67
2002	43	42	48	68
2003	42	40	46	65

*Load factor in Great Britain for rigid vehicles (HMSO, 1995, 2002 and 2003)*

<b>Load factor for articulated vehicles (% of loading)</b>		
<b>Year/gvw (t)</b>	<b>3,5-33t</b>	<b>&gt;33t</b>
1985	65	76
1986	61	75
1987	59	75
1988	58	75
1989	56	73
1990	54	71
1991	51	70
1992	48	69
1993	49	70
1994	50	69
1995	49	70
1996	50	69
1997	48	68
1998	48	68
1999	47	65
2000	47	66
2001	46	64
2002	45	62
2003	43	60

*Load factor in Great Britain for articulated vehicles*

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<b>Average load factor (% of loading)</b>			
<b>Year</b>	<b>Rigid vehicles</b>	<b>Articulate vehicles</b>	<b>All vehicles</b>
1985	60	69	66
1986	57	67	63
1987	58	68	64
1988	59	68	65
1989	57	67	64
1990	58	66	63
1991	56	65	62
1992	55	64	61
1993	55	65	62
1994	55	65	62
1995	56	66	63
1996	56	65	63
1997	55	65	62
1998	54	65	62
1999	54	62	60
2000	54	63	60
2001	52	62	59
2002	53	60	58
2003	52	58	57

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*Average load factor in Great Britain*

## Classification of vehicles by payload and gross vehicle weight in France and Great Britain, and relation with Artemis.

<b>Payload (t)</b>	<b>gvw (t)</b>
3-4,5	3,5-5
4,5-6,5	5-7,5
6,5-9	7,5-12
9-13	12-16
13-17	16-26
>17	>26

*Classification by payload in France*

<b>Vehicle type</b>	<b>gvw (t)</b>
Rigid vehicles	<7,5
	7,5-12
	12-14
	14-20
	20-26
	26-28
	28-32
Articulated vehicles	>32
	<7,5
	7,5-28
	28-34
	34-40

*Classification in Artemis*

<b>Artemis</b>	<b>Equivalent in France</b>		<b>Equivalent in Great Britain</b>	
	<b>gvw (t)</b>	<b>Payload (t)</b>	<b>gvw (t)</b>	
<b>Vehicle type</b>				
Rigid vehicles	<7,5	37,5% (3-4,5) + 62,5% (4,5-6,5)	37,5% (3,5-5) + 62,5% (5-7,5)	3,5-7,5
	7,5-12	6,5-9	7,5-12	7,5-17
	12-14	9-13	12-16	7,5-17
	14-20	33% (9-13) + 67% (13-17)	33% (12-16) + 67% (16-26)	50% (7,5-17) + 50% (17-25)
	20-26	13-17	16-26	83% (17-25) + 17% (>25)
	26-28	>17	>26	>25
	28-32	>17	>26	>25
	>32	>17	>26	>25
	Articulated vehicles	<7,5	37,5% (3-4,5) + 62,5% (4,5-6,5)	37,5% (3,5-5) + 62,5% (5-7,5)
7,5-28		22% (6,5-9) + 19,5% (9-13) + 49% (13-17) + 9,5% (>17)	22% (7,5-12) + 19,5% (12-16) + 49% (16-26) + 9,5% (>26)	3,5-33
28-34		>17	>26	83% (3,5-33) + 17% (>33)
34-40		>17	>26	>33

*Relation between Artemis, France and Great Britain.*

## Vehicle-kilometres and tonne-kilometres for rigid vehicles in France, 2001

Rigid vehicles	Vehicles-kilometres (million) (without empty running)			tonne-kilometres (million)			
	Payload (t)	Hire or reward	Own account	Both	Hire or reward	Own account	Both
	3,0-4,5	184	283	467	374,1	497,6	871,8
	4,6-6,5	635	431	1066	1847,7	1031,9	2879,6
	6,6-8,9	809	540	1349	4185,7	2215	6400,7
	9,0-12,9	890	761	1652	6483,4	4822,3	11306
	13,0-16,9	300	414	715	3138,3	4135,2	7273,5
	>17,0	38	46	84	409,8	629,4	1039,2
	total	2856	2475	5333	16439	13331,4	29770

*Vehicle-kilometres and tonne-kilometres for rigid vehicles in France, 2001  
(SES, 2002)*



## Rates of empty running in Great Britain

<b>% of empty running for rigid vehicles</b>				
<b>Gross vehicle weight (t)</b>	<b>3,5-7,5t</b>	<b>7,5-17t</b>	<b>17-25t</b>	<b>&gt;25t</b>
Year				
1985	28,7	29,6	43,1	44,8
1986	28	28,3	42,6	44,7
1987	29,3	28,6	41,8	45,2
1988	28,6	28,5	41,1	44,8
1989	27,5	27,7	39,7	43,7
1990	28,5	27,2	40,1	44,6
1991	27,3	27,1	39,6	43,7
1992	26,6	25,9	39	42,4
1993	27,8	26,6	38,5	43,1
1994	26,2	26,3	38,1	42,4
1995	28	27,3	38,2	40,7
1996	27,3	26,6	35,6	40,9
1997	25,8	26,2	34,9	40,6
1998	26,3	25,1	32,6	38,8
1999	25,5	24,3	31,3	37,9
2000	24,3	25,2	28	37,7
2001	25,1	24,2	26,5	36,7
2002	24,3	24,9	26	37,5

*Rate of empty running in Great Britain for rigid vehicles (HMSO 2003)*

<b>% of empty running for articulated vehicles</b>		
<b>Gross vehicle weight (t)</b>	<b>3,5-33t</b>	<b>&gt;33t</b>
Year		
1985	29,3	28,1
1986	29,1	28,5
1987	29,7	28,7
1988	29	28,4
1989	29,5	28,9
1990	28,1	28,4
1991	27,1	27,8
1992	25,2	27,7
1993	26,1	28,6
1994	26,7	28,2
1995	27,6	28,6
1996	26	28,3
1997	25,4	28,1
1998	25	28
1999	24,1	27,5
2000	22,3	27,5
2001	20,1	26,7
2002	22,3	25,9

*Rate of empty running in Great Britain for articulated vehicles.*

<b>% average rate of empty running</b>			
<b>Year</b>	<b>Rigid vehicles</b>	<b>Articulated vehicles</b>	<b>All vehicles</b>
1985	32,2	28,9	31,0
1986	31,1	28,9	30,3
1987	31,9	29,3	30,8
1988	31,5	28,7	30,4
1989	30,6	29,2	30,0
1990	30,8	28,3	29,8
1991	30,1	27,6	29,1
1992	29,1	27,0	28,2
1993	30,0	27,9	29,1
1994	29,1	27,8	28,5
1995	30,2	28,3	29,4
1996	29,5	27,7	28,7
1997	28,8	27,5	28,2
1998	28,2	27,4	27,8
1999	27,5	26,8	27,2
2000	27,3	26,4	26,9
2001	27,2	25,5	26,4
2002	27,6	25,3	26,5

*Average rate of empty running in Great Britain.*