

IMPORTANCE OF THE LOADING FACTOR IN TRANSPORT CO₂ EMISSIONS

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1. INTRODUCTION

Just after the worldwide Copenhagen Conference and the "Grenelle de l'Environnement" in France, global warming caused by CO₂ emissions seems to be the most visible - even if not the most costly - problem of a non-sustainable transport system. This paper is focusing on the influence of the loading factor on CO₂ emissions, from freight and passengers. A common approach in economics to relate greenhouse gas (GHG) emissions to economic activity is the ASIF model (Unander & Schipper 2000). However, this model has been elaborated for all economic sectors, and it doesn't take into account the vehicle load factor for the calculation of transport emissions. The objective of this paper is to include the loading factor into the ASIF approach. First, we will include this loading factor into the ASIF equation, aggregating step by step from trip level to macro level; loading will appear as a result of empty running, vehicle capacity and occupancy rate (section 2). Then section 3 will analyse the relationship between loading factor and energy consumption, per type of vehicle. Section 4 will focus on issues concerning freight, as well as section 5 for passengers. The examples will be mainly taken from road transport, which causes most of transport CO₂ emissions. Then our conclusion will draw attention on data needs and policy implications.

2. AN APPLICATION OF ASIF MODEL TO TRANSPORT HIGHLIGHTING LOADING FACTORS.

Denoting volumes in capital letters contrary to ratios, the conventional Asif approach [Fulton and Eads, 2004; Cuenot 2009] relates CO₂ emissions at macro level to:

- A for Activities: Transport activity is measured in tonne*kilometres (TKM), person*kilometres (PKM) or vehicle kilometres (VKM);
- s for modal Share (expressed as road transport in % of total transport activity A);
- i for energy Intensity (expressed in litres fuel/km);
- f for CO₂ emission Factor (in kg CO₂/litre fuel); 1 litre diesel = 2.62 kg CO₂ and 1 litre gasoline = 2.32 kg CO₂.

The emission factor of the "fuel mix" can be lower than those for diesel or gasoline, for example when biodiesel is mixed with diesel at the level of 5% or 10%, or, in case of electricity/hydrogen motors, if the generation of electricity was performed using renewable or nuclear, rather than by fossil fuels.

Following this approach, the calculation for CO₂ emissions in transportation is expressed first in absolute terms in tonnes (or kg) of CO₂ emitted:

$$\text{(Equation 1) } CO_2 = A * s * i * f$$

Let us include a step I (for loading factor), which is the ratio of:

- D for Demand (in TKM or PKM), which is a sub-sector indicator of "Activities";
- to VKM for traffic.

2.1 At micro level

In order to define the load factor, we will start from the micro-level of the vehicle utilisation, but not consider the instantaneous most disaggregate level, with the influence of speed, acceleration and slope, which explains all the interest in eco-driving. At the vehicle trip (or stage) level and for a short term analysis (i.e. with a given vehicle, using a given type of fuel, with a given load), thus with f, i, I and D fixed:

$$CO_2 = f * i / I * D$$

Where the units are: CO₂ = (CO₂ / litres) * (litres / VKM) * (VKM/ TKM) * TKM

The problem is that these factors are inter-related, e.g. fuel intensity depends on the weight moved W (thus on the load) of the vehicle as a function i(W). For cars, the range of vehicle weight between single occupancy and full occupancy is quite narrow, which is not the case for trucks.

Let: $i = i(W) = i(We + Wt) = i(We + Wt_{max} * (Wt / Wt_{max}))$

with

- W: Gross Weight moved (vehicle + passengers or freight);
- We: Weight of the empty vehicle;
- Wt: Weight transported (freight or passengers, assuming an average weight per passenger –i.e. 70 kg);
- Wt_{max}: Maximal Weight transported (or capacity)

Thus $i = i(We + o * Wt_{max})$

with: $o = Wt / Wt_{max}$: rate of Occupancy

This ratio can also be used to derive traffic expressed in vehicle*km (VK), from transport demand (D) expressed in tonnes*km or passenger*kms transported:

$$D = VK * Wt$$

$$VK = D / Wt = D / (Wt_{max} * o)$$

Thus $CO_2 = f * i(We + Wt) * D / Wt$

$$CO_2 = f * i(We + o * Wt_{max}) * D / (Wt_{max} * o)$$

This formulation allows distinguishing between capacity (Wt_{max}) and rate of occupancy (o) in the loading factor.

2.2 Empty Running

Although we could consider that a solo driver's trip back from escorting (e.g. children to school) is "empty running", this concerns essentially freight transport. Let us consider a given vehicle during a given period. The traffic generated is VKL when it is loaded and VKE when it is empty:

$$VKM = VKL + VKE;$$

Let us denote e , as the proportion of empty running ($e = VKE/VK$).

Then $VKE = VK * e$

and define VKL as the sum of the distances of j , the loaded journeys:

$$VKL = VKM - VKE = VKM * (1-e)$$

Let WTK be the average load of the vehicle, weighted by the loaded distance:

$$WTK = (\sum_j Wt_j * KM_j) / VKL = D / VKL$$

$$o = WTK / Wt_{max} = (D / VKL) / Wt_{max}$$

Therefore, in order to calculate the GHG emissions including load factors at the stage level, total CO_2 is the sum of CO_2 emitted during loaded stages (CO_{2l}) and CO_2 emitted during empty stages (CO_{2e}):

$$CO_2 = CO_{2l} + CO_{2e} = f * [i (We + Wt_{max} * o) * VKL + i (We) * VK * e]$$
$$= f * VK * [i (We + Wt_{max} * o) * (1-e) + i (We) * e];$$

The expression between brackets is the average consumption as a function of capacity, of the rate of occupancy o and of the proportion of empty running e . These parameters o and e seem to play the same role.

2.3 From micro to macro level

Total CO_2 emissions are obtained by summing up the expressions above for:

- all trips made by the same vehicle during a given time period (e.g. loaded or empty),
- all vehicles with the same type of fuel (fuel mix),
- all vehicles for the same mode of transport (modal share).

Let us also consider that economic activity (GDP) and population (POP) are major determinants of the demand for transport, with the crucial question in a long term perspective of decoupling the growth of CO_2 emissions from economic and demographic growth:

$$\text{Equation (2)} \quad CO_2 = (CO_2 / \text{litres}) * (\text{litres} / VKM) * (VKM / D) * D/GDP * GDP/POP * POP$$
$$= f * i / I * (D/GDP) * (GDP/POP) * POP$$

This calculation method for total carbon dioxide is inspired from the Kaya's equation (1989) and from Jancovici (2007), with:

- D/GDP is the transport intensity of the country or world Economy;
- GDP/POP is the wealth produced per person (important also for person trips)
- and POP is the population.

3 LOAD AND FUEL INTENSITY

We have seen that the loading factor, or average load weighted by the distances, is the result of vehicle capacity, load rate for loaded trips and empty running.

For freight, the maximum load is the difference between maximum authorized vehicle weight and the weight of empty vehicle. The maximum authorized vehicle weight is currently 40

tonnes in many European countries, which gives a maximum capacity around 25 t. per Heavy Duty Vehicle. In the UK, this maximum weight has grown from 32 to 38 t. in 1983 and progressively up to 44 t. in 2001 (McKinnon, 2005); in some countries the possibility to follow such a trend is being analysed and, furthermore, the empty weight might slightly decrease. For a fleet, the average maximum load also results from the distribution of vehicles according to these characteristics; in UK most of the growth in good vehicles comes from vans, which means that the average maximum load capacity of the total goods fleet (heavy duty vehicles + light duty vehicles) is increasing at a slower pace than the fleet.

Average load rate for loaded trips is linked to the density of the products transported and to the shipment size; the density might decrease as the wealth is growing but logistics can improve this, either by a better adaptation of vehicles or a better conception of the products, like flat packed furniture.

The rate of empty running mainly results from the imbalance in transport demand and this imbalance is clearly more important for freight than for passengers. As the flow of goods imported from Asia to Europe is more important than from Europe to Asia, the average rate of loading is low for containerships in this last direction. Homogeneity of the products transported in each direction and the share of own account transport (which is generally less loaded) are also important factors. According to Eurostat in 2006, trucks are empty for 13% of the distance travelled in Latvia and 17% in Denmark, while this proportion seems to be much higher in Greece (35%) and in islands (38% in Ireland and up to 45% in Cyprus).

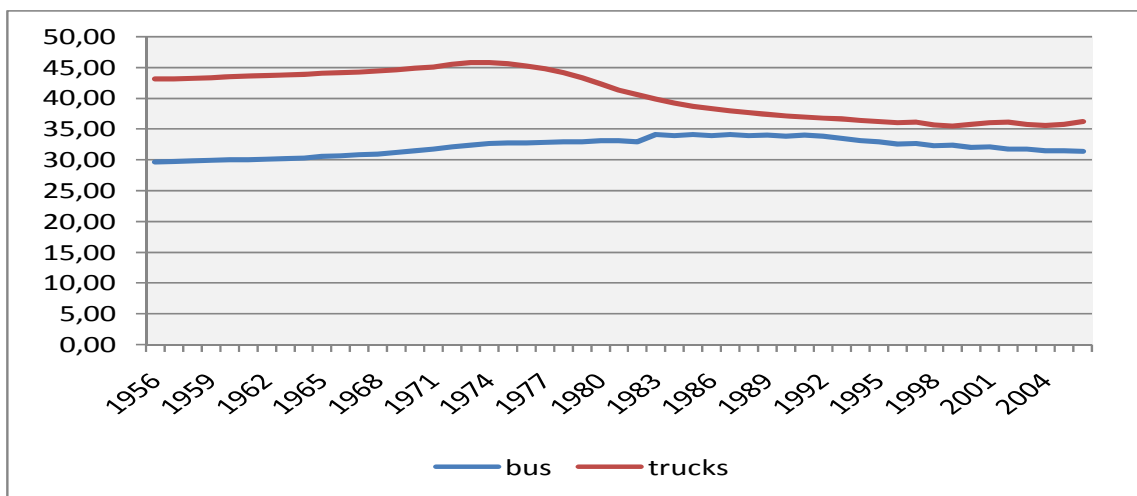


Figure 1: Real fuel consumption (litres per 100 kilometres) of bus and trucks in France
Source: MEEDDAT-SESP (2008)

For heavy duty vehicles, fuel consumption has been estimated using ARTEMIS / COPERT4 models (Boulter et al. 2007). Consumption curves have been computed, according to vehicle type and weight, for loading factor of 50 and 100%, and for selected speed (cf. Hugrel, 2006). Here we only consider Euro4 vehicles but the results are not so different for older vehicles. From the consumption, in litres per 100 vehicle km estimated by ARTEMIS for several speeds, we derived the consumptions per 100 tkm, for 50 and 100 % loading factor.

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Overconsumption per supplementary tonne loaded, expressed in litre per 100 veh*km, is between 0.9 and 1.0 l/100km for an average speed of 20 km/h (urban transport), between 0.6 and 0.7 l/100km at 60 km/h (rural) and between 0.3 and 0.4 l/100km at 80 km/h (highways). A supplementary tonne loaded induces more fuel overconsumption at low speeds (urban transport) than at high speeds (highways and motorways); this overconsumption varies relatively few between rigid and articulated trucks.

Max load (t.)	vehicle type	Loading ratio (%)	consumption (l./100 vkm)			consumption (l./100 tkm)		
			speed (km/h)			speed (km/h)		
			20	60	80	20	60	80
5	Rigid trucks >7.5-12t	a) 50	23.7	15.2	16.2	9,5	6,1	6,5
5	Rigid trucks >7.5-12t	b) 100	26.1	16.9	17.2	5,2	3,4	3,4
<i>RT >7.5-12t</i> : supplementary consumption (l/100 km) per supplementary tonne loaded			<i>1,0</i>	<i>0,7</i>	<i>0,4</i>			
8.4	Rigid trucks >14-20t	c) 50	33.6	19.3	18.9	8,0	4,6	4,5
8.4	Rigid trucks >14-20t	d) 100	37.4	21.7	20.3	4,5	2,6	2,4
<i>RT >14-20t</i> : supplementary consumption (l/100 km) per supplementary tonne loaded			<i>0,9</i>	<i>0,6</i>	<i>0,3</i>			
24.7	Articulated >34-40t	e) 50	51.1	28.9	25.6	4,1	2,3	2,1
24.7	Articulated >34-40t	f) 100	62.6	35.9	30.3	2,5	1,5	1,2
<i>Artic >34-40t</i> : supplementary consumption (l/100 km) per supplementary tonne loaded			<i>0,9</i>	<i>0,6</i>	<i>0,4</i>			

Table 1 : fuel consumption according to the loading ratio for different Heavy Duty Vehicles

Source: computed from Artemis model

Energy consumption per tonne kilometre (in litres per 100 tkm, at 80 km/h) varies from 6.5 for small rigid trucks (5 t. payload, half loaded), down to 1.2 l/100tkm for fully loaded large tractors and trailers (24.7 t. payload). This energy consumption per tkm would rise much higher if we would have considered smaller loading ratios: consumption per tkm is infinite for empty vehicles. These results from ARTEMIS are coherent with Coyle (2007) who quantified the impact of load weight on fuel consumption for two types of trucks. He measured energy consumption *i* (in litres per 100 km) according to total vehicle weight (TVW in tonnes). These consumption measures can be expressed as linear functions of total vehicle weight: $i = a * TVW + b$ where parameter *a*, which indicates the rise of energy consumption per supplementary tonne of load, is comprised between 0.47 and 1.05 according to analysed vehicles and service types.

For vans, Joumard et al. (2001) have quantified the impact of representative loads on light duty vehicles consumption. For 2.5 - 3.5 tonnes, Euro 1 and 2 vans, they found supplementary consumption per 100 kg of incremental load in the range of 0.1 to 0.9 l/100 vkm in urban transport, and 0.2 to 0.6 on highways and motorways. Not surprisingly, we notice that overconsumption induced per additional tonne loaded is higher for vans than for HDV.

For cars, Zallinger et al (2004) have estimated the supplementary consumption for an incremental load of 100 kg, using ARTEMIS / COPERT4. Applying these to estimates of consumption per car for representative speeds, enables to compute a consumption per 'full'

car (assuming the driver plus 4 passengers of 70 kg each) and per car with the driver alone in the car.

		Load influence on fuel consumption (% increase of l per extra 100kg)	Consumption (l/100 pkm) according to the number of passengers in the car				
			1	2	3	4	5
Diesel	Urban	1.4	8.3	4.2	2.8	2.1	1.7
	Rural	0.6	4.4	2.2	1.5	1.1	0.9
	Motorway	-0.7	4.7	2.3	1.6	1.2	0.9
Gasoline	Urban	2.6	13.8	7.0	4.8	3.6	3.0
	Rural	1.0	5.8	2.9	2.0	1.5	1.2
	Motorway	3.9	5.7	2.9	2.0	1.5	1.3

Table 2 : fuel consumption according to the loading ratio for cars

Source: using Hugrel 2006 for average consumption and Zallinger 2004 for overconsumption

There again we notice that supplementary consumption induced per additional tonne loaded is higher for cars than for vans. Fuel consumption per person*km (expressed in litres per 100 person*km, or l/100 pkm) varies, between a car where the driver is alone and a car with 5 persons (driver plus 4 passengers):

- for urban traffic, from 8.3 down to 1.7 l/100 pkm for a diesel car and from 13.8 to 3.0 l/100 pkm for a gasoline car;
- in the countryside, from 4.4 to 0.9 for a diesel car and from 5.8 to 1.2 l/100 pkm for a gasoline car ;
- on a motorway from 4.7 to 0.9 for a diesel car and from 5.7 à 1.3 l/100 pkm for a gasoline car.

Fuel consumption per person*km is divided by a factor of at least 4.5 when moving from a car in which the driver is alone to a car with 4 passengers.

4 FREIGHT CO₂ EMISSIONS AND LOADING FACTOR

4.1 Transport demand

Changes in freight transport demand are linked to economic growth, measured as GDP. Landwher et Marie-Lilliu [2002] estimated this link in large OECD zones on the 1986-97 period: the elasticity values of freight transport to GDP was estimated from -0.1 for Central Europe up to more than 1.2 for western Europe, with values between 0.7 and 0.8 for other OECD zones. In fact two main drivers induce the evolution of freight transport intensity of GDP (TKM/GDP ratio): tonnes per € of output and the average distance per tonne. These quantities are difficult to measure since, when a shipment is transhipped to another vehicle, its tonnage is counted twice in the transport statistics and its distance is separated in two legs.

- Nevertheless, tonnes per € ratio should decline in rich countries when, beyond a certain level of development, the new economic growth mainly results from service activities which generate less tonnes per €. Furthermore, the richer the people, the

lower the weight per purchased euro spent, as consumers shift to more expensive items.

- The average distance per tonne has increased, in relation with the decreasing cost of transport, the development of subcontracting, a wider sourcing and offshoring manufactures to lower cost countries. According to Hemery (2009), the intercontinental transport should continue to increase in the next decades and only a dramatic rise in transport cost might significantly reduce inland transport.

There is a link between distance and loading factor, mainly for parcels and small shipments: In order to improve the loading factor the carrier has to organise hubs and these hubs not only multiply the number of legs: they also increase the whole crow-fly distance from shipper to consignee, since the shipment has to deviate from the straight line in order to reach the hub. Rizet & Keita [2005] estimated that consolidation (i.e. grouping) of road freight in France increases the overall distance of the shipment of around 10 % as compared to the 'one truck' solution.

4.2 Modal share

For freight, the share of road transport in total land freight transport, expressed as a percentage of tkm, increased during the last decade in most European countries, especially in Poland, Hungary and Czech Republic, where it used to be much lower than in other countries (Figure 2). On average for the member states of the European Union (25 before 2007 = EU25) it grew steadily from 72% in 1995 to 77% in 2006. The main counter example is UK where road share decreased steadily from 92% in 1996 to 88% in 2006.

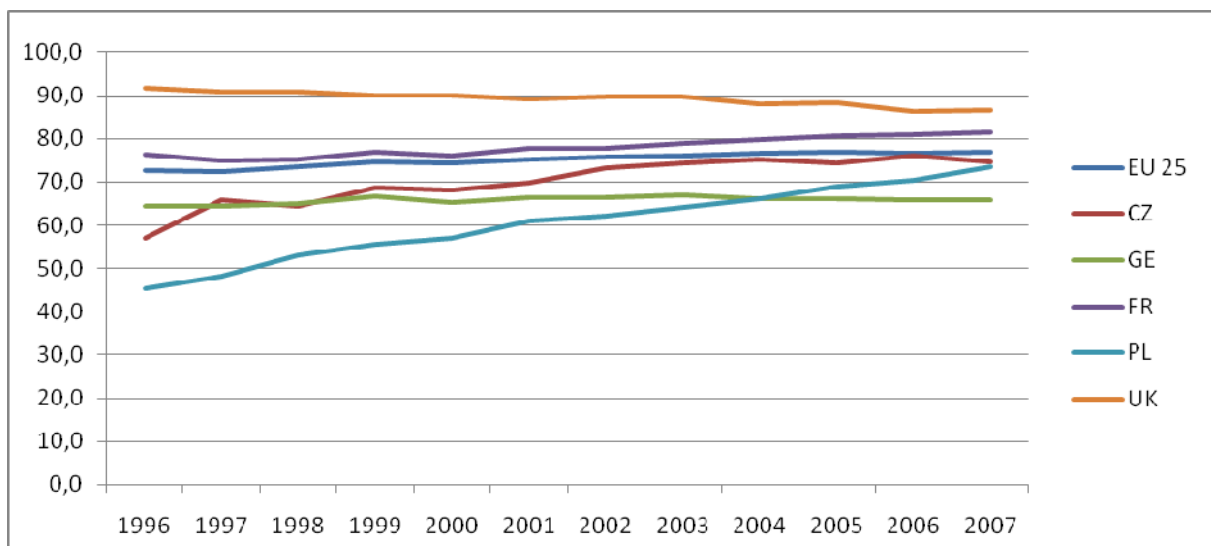


Figure 2: Road share in freight transport (% tkm) in selected countries and in EU25

Source: Eurostat 2009

4.3 Loading factor

The loading factor, or average load of road freight transport weighted by the distance, has been expressed as the result of maximum load, load rate for loaded trips and empty running. Figure 3 here under indicates the evolution of empty running for Heavy Duty Vehicles according to Eurostat in several European countries. This rate is between 15 and 30 %; it is slightly decreasing in Germany and increasing in UK.

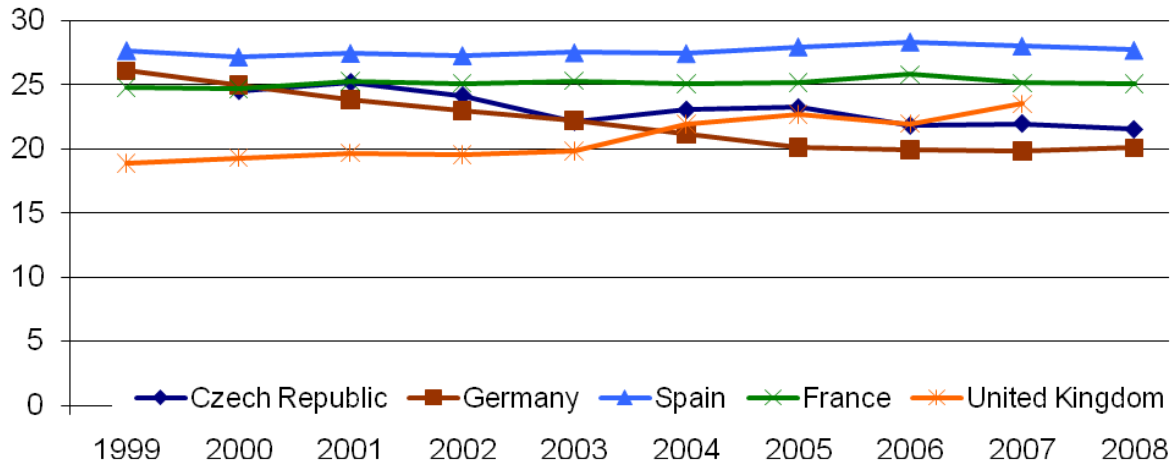


Figure 3: Rate of empty running for HDV (empty km / total km)

Source: Eurostat 2009

Figure 4 shows the evolution of the loading ratio (average load weighted by the distances) in several European countries. This ratio is rising in all the countries analysed: Very slightly in Spain where it was already high at the beginning of the period (from 15.6 tonnes in 1999 to 16.3 in 2008; and more strongly in Czech Republic where it was low (from 7.9 t. in 2000 up to 12.1 in 2008).

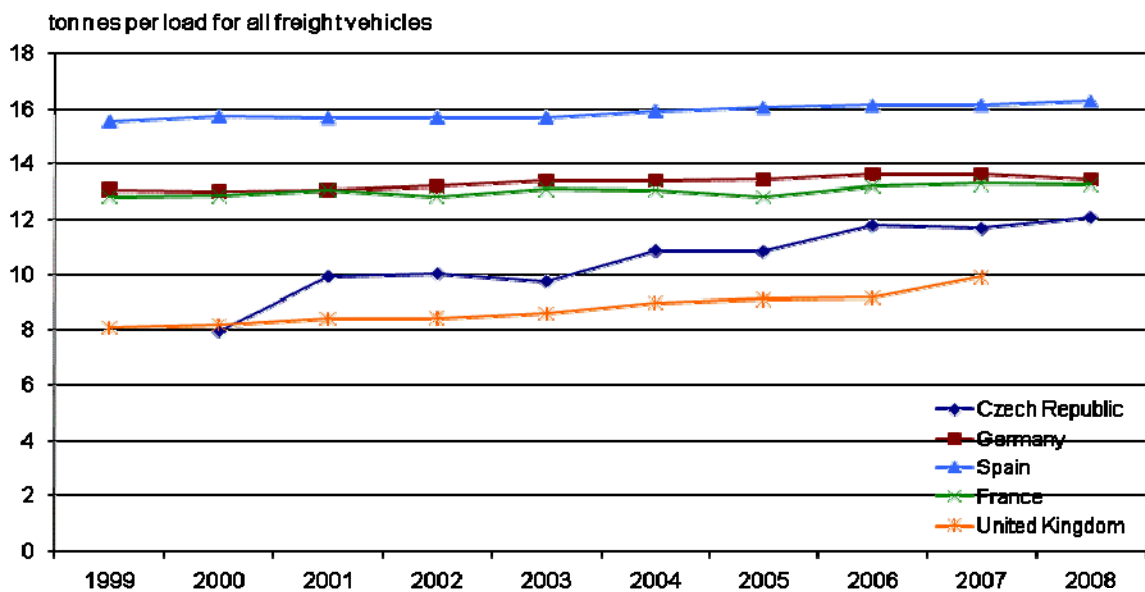


Figure 4: Average tonnes per load for HDV loaded trips (tkm/km)

Source: Eurostat 2009

4.4 Fuel intensity

For heavy goods vehicles in France (figure 7), after rapid gains between mid-70's and mid-80's, corresponding to two oil crisis, average fuel consumption per 100 km has been nearly stable since the 90's. For vans, either gasoline or diesel, the average consumption is almost stable, due probably to larger and more powerful vehicles.

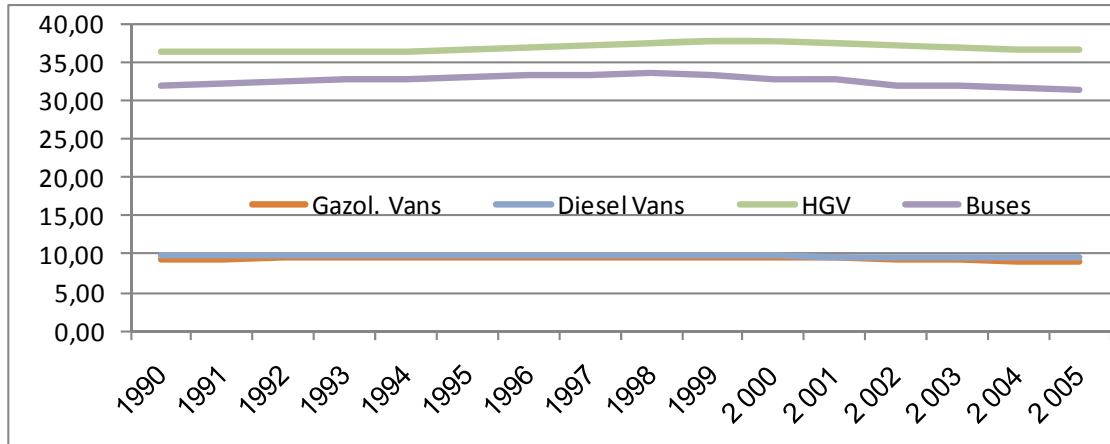


Figure 5: Average fuel consumption (litres / 100 km) in France for goods vehicles and buses
Source : MTETM/SESP 2008

4.5 Evolution of CO₂ emissions from road freight transport in France

Using the equation (2) for road freight transport, the evolution for the period 1990 to 2005 have been computed for carbon dioxide, showing trends for load factor and the ASIF model. CO₂ emissions from road freight traffic has increased 20% in France between 1990 and 2007 (Figure 6). This results mainly from a much more important increase in demand (tkm: +40%), compensated by an increase in loading factor (TKM/VKM: +18%); the fuel intensity has been nearly stable on this period, between 36.2 and 37.7 l/100 km.

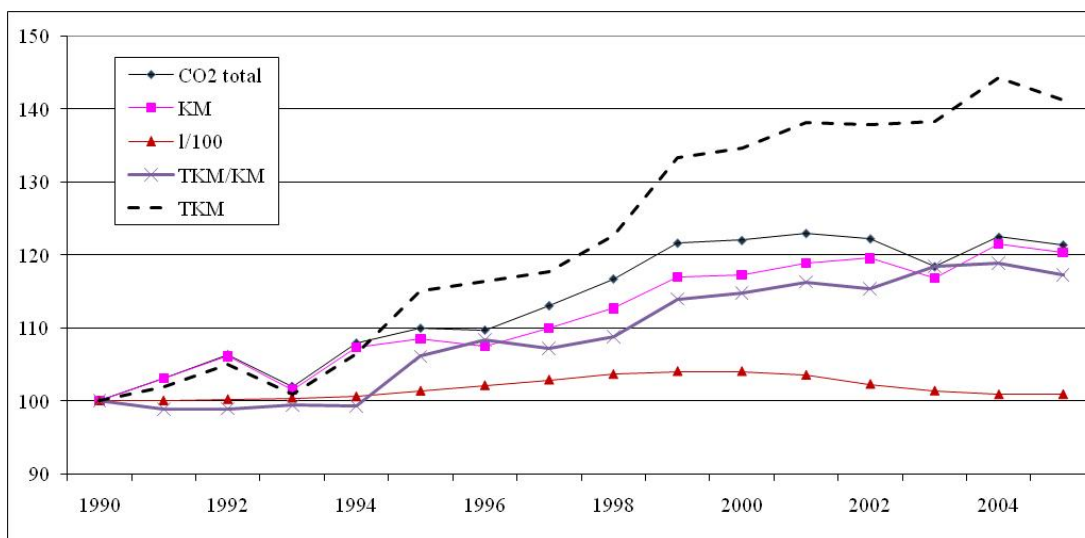


Figure 6 : CO₂, ASIF and load factor: Evolution of CO₂ emissions, traffic, fuel consumption and loading factor for HDV in France
Source : computed from MTETM/SESP 2008 data

4.6 IMPROVING THE LOADING FACTOR

Loading factors are generally far below the theoretical maximum but, in some market segments, this maximum is not reachable: certain goods (chemical products, milk) requires specialized vehicles that makes it impossible to find return loads. For some commodities, the available volume or surface is reached before the maximum weight. Few countries have directly tackled this issue and the loading factor is generally indirectly tackled, through logistics optimization, fleet or supply chain management systems, and information and communication technologies. We will mention here only a few examples of measures used to improve the load factor for trucks.

In cases where deck space is the constraining factor, the use of double-deckers is a way to improve loading factor. After the UK, Europe is considering the possibility of increasing the maximum vehicle weight, in order to increase the average load. In Europe, cabotage has been liberalised in order to increase loading factors by enabling international road hauliers to pick-up and deliver goods outside their own country of origin, mainly on their way back; cabotage is still having a small market share in Europe, at around 1% of total transport, and could be increased by sharing more information on freight transport demand (Jensen et al 2007).

Generally, one thinks that there is more to be gained by objectives more directly related to environmental pressures, like internalizing external costs of transport: increasing transport costs is often considered as the best incentive to improve loading factors as well as to mitigate other inefficiencies. Many logistic improvement programs, like freight best practice program in UK, or the “Voluntary commitment to reduce CO₂ emissions for road carrier » in France (“charte d'engagements volontaires de réduction des émissions de CO₂ des transporteurs routiers de marchandises”) define the loading factor as one of the performance indicators that helps to monitor the CO₂ emitted.

5. PASSENGER TRANSPORT, CO₂ EMISSIONS AND LOADING FACTOR

Passenger transport experienced steady growth in the decades after WW II, but while this is still the case for some new member states of the EU, other Central European countries have been experiencing stagnation in at least some segments of passenger travel demand lately (See Zumkeller et al 2006 for Germany or Hubert 2009 for France).

However, loading factors in passenger transport play a role both in regions with growing demand and with declining demand: While in regions with growing demand, reduction of congestion and emissions is an important issue, regions with declining transport demand face the question of how public transport can still keep up service in an efficient way, and how a minimum occupancy of vehicles even in areas with low population density can be achieved.

Therefore, depending on spatial structure and travel mode, there are varying issues of loading factors. In the first part of this section, this question of loading factors related to mode choice shall be addressed, in the second part of this section shall then be analyzed what factors affect occupancy for the car mode, and where potentials for increasing loading factors

can be identified. The analysis focuses on France, Germany and the UK, three countries that are comparable in size and economic significance for the European Union.

5.1 Modal Share

Loading factors play a different role depending on the observed mode. Figure 7 depicts the modal split in Germany based on the number of trips. Here, non motorized modes account for about a third of all trips independent of their length, which implies that loading factors only play a role for the remaining two thirds of the trips. However, when considering mileage, which is obviously more relevant to emissions and energy consumption, non motorized modes almost disappear, while by far the most important mode is the car, as can be seen in Figure 8 for several European countries.

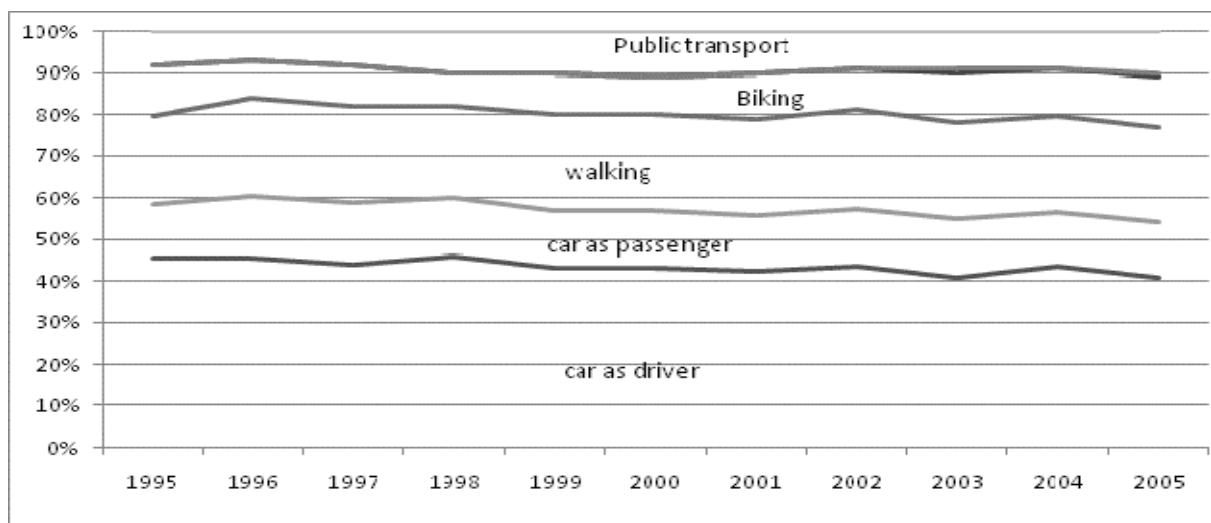


Figure 7: Modal Split in Germany based on Number of Trips

Source: German Mobility Panel 1995-2005

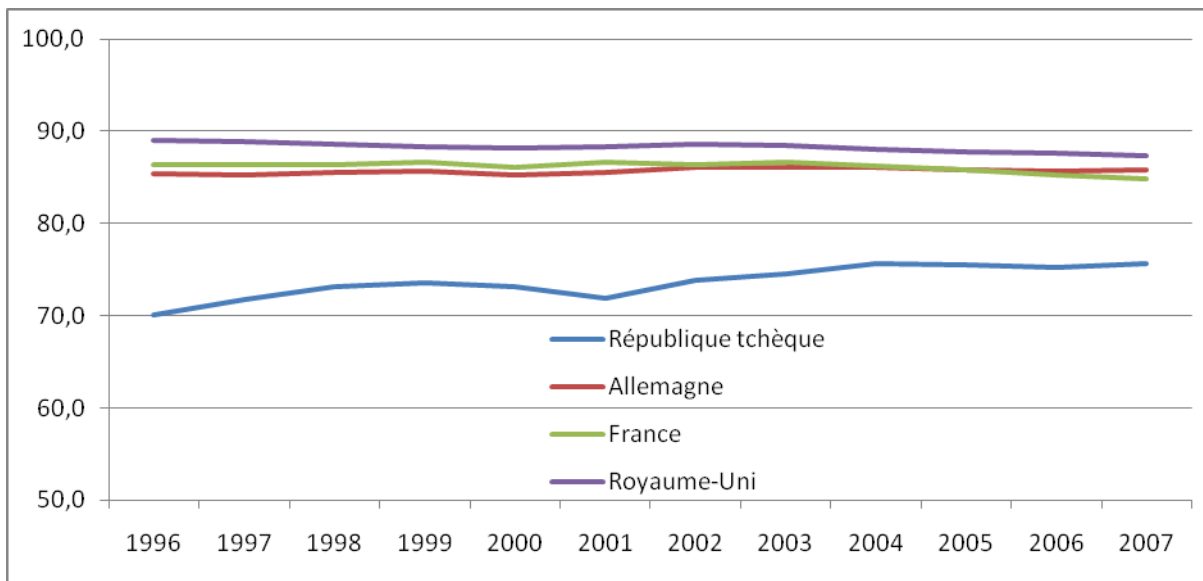


Figure 8: Share of cars in passenger transport in several European countries (% of passkm, 1996-2007)

Sources Eurostat 2009

While loading factors do not matter for non motorized modes, they do for public transport. Vehicle kilometers are by far the most expensive for airlines, so efficiency and thus high loading factors are of vital importance for carriers, particularly in the recent past when international competition and operational costs increased. One possibility for airlines to increase occupancy is a network design with only few hubs and many feeder flights serving as spokes. This increases occupancy and frequency particularly on the long distance flights, while it also increases travel time and travel burden for the passenger.

The trade-off between cost reduction by high loading factors and flexibility of the system can also be illustrated by the comparison of French and German long distance trains, where different philosophies seem to prevail: French has a rather demand-based system with a strong focus towards Paris, and with timetables that are particularly busy during peak hours. Germany on the other hand has a polycentric network with no single hub, and trains usually run continuously every hour or every other hour, even in off-peak hours. This makes train mode more attractive for more passenger groups as it increases flexibility, but at the same time leads to lower loading factors: Average occupancy is about 75% for French long distance trains where reservation is compulsory (TGV, TEOZ rapid trains and LUNEA night trains), while it is only about 43% for Intercity-Express and Intercity trains in Germany (Ilgmann 2007). Considering the objective of reducing emissions and energy consumption, it is far from clear which approach is preferable, as the German approach yields a lower efficiency due to lower occupancy, but it may at the same time attract passengers that would otherwise use modes with higher emissions and energy consumption.

Similar problems arise for local and regional public transport: Maximum occupancy rates would be established by jam-packed buses and trains running only in peak hours, a system, that is for example in place in several rural regions in France or Germany where public transport clientele is mostly limited to pupils and students. However, such a system would be far from sustainable: Public transport customers are not keen on trains and buses that only run in peak hours. Their actual demand for off-peak-hour connections may be low, but may be still prerequisite for them to consider public transport as a mode option.

The situation seems to be clearer for car mode, where higher occupancy on average also implies a higher efficiency of the whole system. The issue of car occupancy in France, Germany and the UK shall thus be addressed in the following sub-section.

5.2 Loading factors for car trips

Loading factors for car mode can be defined in different ways: Either as the ratio of passenger kilometres over seat kilometres, this yields a value between zero and one, or as the ratio Passenger kilometres over vehicle kilometres, which yields a factor larger or at least equal one. As the vehicle kilometres have a direct relationship with emissions and energy consumption, the latter definition seems more straightforward for the purpose of this paper and shall thus be used in the following.

The French National Travel Surveys (NTS) includes in some waves a car diary that enables an exact calculation of loading factors according to the definition above:

- Passenger kilometres / vehicle kilometres

In Germany, there is no such car diary, but the distinction between car mode as driver and as passenger in the German Mobility Panel (MOP) and in the NTS makes it possible to estimate a loading factor per car trip that is consistent with the definition above:

- Mileage of all car trips / mileage of car trips only as driver.

This definition is also applied to France in those data sets where no information can be derived from a car diary. The British NTS does not offer mileage, but mode choice classified by different distance bands, which should therefore yield similar results. The calculation of loading factors is thus:

- (average of Number of all car trips) / (number of car trips only as driver), weighted by trip distance

According to MOP (Zumkeller et al. 2005), the occupancy rate in Germany has oscillated around 1.4 persons per vehicle over the last ten years: a clear development cannot be observed. In France according to the car diary from the NTS, the occupancy rate of cars amounts to about 1.6 and thus seems to be higher than in Germany; but to some extent, these differences can be explained by the exclusion of children under 10 in the German Mobility Panel.

In France, there are more persons per car for longer trips, and there were almost no significant changes between 1981-82 and 1993-94, but car occupancy has significantly dropped between 1993-94 and 2007-08 (Table 3). Larger cars are used for longer trips, but there is not much difference in the average number of seats per car according to trip distance. The resulting proportion of occupied seats varies from 31% for trips under 8 km to 44% for trips over 200 km.

Table 4 provides loading factors for car trips in the UK, and Table 5 for Germany. There are some issues of comparability among the countries: The French data were collected through a 7 day car diary, while in Germany since 1994 and in Great Britain it is a 7-days personal trip diary; thus it is a 7-days diary in all three countries and journeys with more than one week away from home (that tend to have a high occupancy of cars) are excluded. In Germany, only individuals over 10 years old are taken into account, which explains why car occupancy is lower in this country. In the UK, there is no information on mileage, just on the number of trips within one distance class, which may distort the British results slightly. However, since the indicator has been weighted by trip length, it should still be comparable with the other countries.

Trip Distance	Persons/Car			Seats/Car	Persons/Seat (%)
	1981-82	1993-94	2007-08	1993-94	1993-94
0-7 km	1.51	1.52	1.45	4.94	30.8 %
8-19 km	1.57	1.60	1.46	4.94	32.6 %
20-49 km	1.73	1.67	1.50	4.95	33.9 %
50-199 km	1.93	1.98	1.69	4.98	40.7 %
+ 200 km	2.15	2.16	2.00	5.01	44.1 %
All	1.56	1.57	1.47	4.94	35.5 %

Table 3: Loading Factor of Private Cars in France according to Trip Distance
Sources: National Travel Surveys 1981-82, 1993-94 and 2007-08.

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Trip Distance	Persons/Car 2006
0-7 km	1.56
8-16 km	1.49
17-40 km	1.47
41-80 km	1.50
81-160 km	1.65
+161 km	1.76
All	1.53

Table 4: Loading factors of private cars in the UK according to trip distance
Source: UK NTS 2006

Trip Distance	Persons/Car		
	1976	1996-1998	2005-2007
0-7 km	1.31	1.32	1.31
8-19 km	1.32	1.34	1.31
20-49 km	1.34	1.35	1.31
50-199 km	1.49	1.56	1.41
+ 200 km	1.80	1.71	1.66
All	1.43	1.44	1.38

Table 5: Loading factor of cars in Germany according to trip distance
Sources: German Mobility Panel (MOP), KONTIV 1976

Methodological issues aside, the synopsis shows three important findings: Firstly, capacity in cars is nowhere used efficiently –factors are not even close to half load, assuming an average of about five seats per car, as can be verified in the French example. Secondly, loading factors have not increased over the past few decades, they have stagnated at best, probably even slightly decreased. Finally, efficiency of private cars tends to be particularly low on short trips, while loading factors are higher on longer trips. This poses another question: Are there specific circumstances that are related to low or high loading factors? In order to choose adequate explanatory factors for a comparative analysis over time and countries, a logit model has been estimated on the car-diary of 1993 French NTS (79.4% of concordant observations):

The binary dependant variable is single occupant vehicle (SOV), which is 1 if only the driver is present in the car for the particular trip, 0 otherwise. Several explanatory variables are tested: Purpose and trip distance are the best explanatory variables, as well as the type of household (mainly the number of persons). Geographical variables (home location or origin/destination) seem to have almost no significant effect, and income effects seem to be resulting from the main determinants described above. While distance has already been analyzed above, purpose and income shall thus be used for the following analyses.

The German Mobility Panel distinguishes between different trip purposes, this enables an estimation of loading factors according to trip purpose in Germany (table 6):

Trip Purpose	Work	Education	Shopping	Leisure	All
Vehicle Occupancy	1.11	1.54	1.38	1.74	1.38

Table 6: Loading factors for different trip purposes in Germany
Source: German Mobility Panel (MOP)

The results show that loading factors are highest for leisure activities and lowest for work trips. It is particularly interesting that even trips to educational institutions have much higher factors than trips to the work place. It seems likely that when people can carpool to schools and universities, they could in principle do this as well en route to their workplace, but students may have a larger affinity to carpooling as their financial means tend to be lower. On the flipside, it could be argued that carpooling would also be an option for more employees in case there are suitable incentives.

The issue of monetary incentives leads to the question if car occupancy is indeed related to financial means and thus income. Table 7 calculates loading factors for the five income quintiles of the population in the UK. Occupancy is there in fact inverse to income: People with a low income carpool more often, while people with a high income tend to use their financial means in favor of a more flexible mobility. However in France, there is no relationship between income level and car occupancy.

Lowest income quintile	2nd quintile	3rd quintile	4th quintile	Highest income quintile
1.90	1.80	1.63	1.51	1.38

Table 7: Loading factors in Great Britain for car trips according to different income quintiles
Source: British NTS 2006

Table 8 compares car occupancy related to income and different household types in Germany. The table distinguishes between single households, two person households with no kids, and family households. Families are here defined as households with at least three members, the special case of single parents with one or more kids is also included. Each of the three household types is further distinguished between two income classes, the definition of high and low incomes vary across classes as it depends on the household composition and the number of household members.

Household Type	Distance Class	Vehicle Occupancy
Single Household with income < €1500	0-99km	1.39
Single Household with income < €1500	+ 100km	2.22
Single Household with income > €1500	0-99km	1.14
Single Household with income > €1500	+ 100km	1.35
Two person household with income < €2000	0-99km	1.44
Two person household with income < €2000	+ 100km	1.86
Two person household with income > €2000	0-99km	1.34
Two person household with income > €2000	+ 100km	1.63
Family household with income < €2500	0-99km	1.39
Family household with income < €2500	+ 100km	1.57
Family household with income > €2500	0-99km	1.29
Family household with income > €2500	+ 100km	1.50

Table 8: Loading factors in Germany for different household types
Source: German Mobility Panel (MOP) 1994 – 2007

In every type of household, vehicle occupation is lower when incomes are higher, and occupancy is higher for long trips. It may seem surprising that single households with a low

income have quite high vehicle occupancy for long distances. Single people with a low income, often not owning a car, apparently can rarely afford long distance trips, and are thus dependant on a ride in another person's car.

Car occupancy is lowest for single persons with a high income, as this group of the population has both the personal freedom and the financial means for an extended flexible mobility. Occupancy is also quite low for family households with a high income. This is at first surprising, as family members should also increase the potential for sharing a ride. On the other hand, high incomes allow extra vehicles for each individual, which decreases the need for carpooling.

The French NTS car diary provides some more insights on further explanatory factors:

- SOV more often occur in secondary cars in the household, and even more in the third one
- SOV are less common on Saturdays and Sundays, but also on Wednesdays. This may seem a little astonishing, but can be well explained by the fact that there is often no school in France on Wednesdays, which may cause parents to escort their children to other activities.

This observation is also consistent with the insight from above that SOV occur more often on work trips, but less likely on trips to other activities. Therefore, the largest potential to increase car occupancy seems to be on work trips.

6 CONCLUSIONS AND OUTLOOK

The findings suggest that there is still a lot of idle capacity left on European roads, both in the freight and the passenger sector. To some extent, this is unavoidable: In the case of freight, for example, some commodities such as liquids or food need special vehicles, which often causes empty runs on the return trips, while other commodities are so light that the limiting factor is not maximum weight, but maximum volume or surface of the vehicle.

It is also straightforward to think of situations where nearly empty passenger vehicles are unavoidable, for example business trips en route to a client or a parent that takes a carload full of children to a leisure facility and returns home alone. Besides, different economic and sociological trends may favour low loading factors, such as an increasing complexity of goods and logistic chains, more flexible working hours, or smaller household sizes.

However, the analysis also identified areas where there is still potential to increase loading factors. For the freight sector, cabotage is now legally possible in a unifying Europe, but local resentments and missing cooperation on authority and enterprise level are still obstacles to a notable increase and thus higher loading factor here. Optimization of the logistic chain as well as improved data exchange are further ways to increase loading factors.

In the passenger sector, idle capacity seems to be left on almost all kinds of trips, although vehicle occupancy is particularly low on trips to work as well as on short trips. While the United States have already gained experience with incentives to increase carpooling, these do hardly exist around Europe. High Occupancy Vehicle Lanes can almost nowhere be found in Europe and would definitely be worth a try in areas with congestion problems.

Still, the most straightforward approach to increase loading factors would probably be to internalize external costs of transport. After a continuous increase of fuel prices from 2004 to

mid-2008, the subprime crisis has led to a temporary stagnation. In the midst of another financial crisis affecting Europe it is difficult to look into the future, but with limited resources it is likely that fuel prices will increase on the long run again.

Hautzinger et al. (2004) have computed German fuel price elasticities and cross price elasticities for different passenger modes on the macro and micro level. People react on increasing fuel prices by cutting their demand: The elasticity for car as passenger is about -0.16, while it is about -0.38 for car as driver. This implies that with increasing fuel prices, loading factors increase as well.

Comparable results have been found for road freight transport. For freight on the road in terms of tkm, fuel price elasticity is about -0.14 for Own Account transport (OA), while for Hire and Reward (H&R) it is only -0.05 (Hemery and Rizet, 2007). Indeed it is easier to promote efficient logistics for transport firms, mainly by optimising the loading factor, than for firms from other sectors implementing their own transport. The loading factor is 11.4 tonnes/veh for H&R and only 5.8 tonnes/veh for OA in 2007 for Heavy Duty Vehicles registered in France.

Thus, when fuel price is increasing, the market share of H&R is also increasing within road transport: Between 1998 and 2007, from 71.7% to 74.8% in terms of TKM and from 83.4% to 85.4% in terms of VKM. The elasticity of traffic (in VKM) to fuel price is -0.24 (almost the same for H&R and for OA) in France; its sensitivity is increasing over time, because fuel represents a growing share of transport cost (up to 25%) and because hauliers are more and more aware that fuel prices will continue to rise. Between 1994 and 2005, fuel efficiency of French trucks has increased less (by only 2%) than the loading factor (+7% for tonnes/vehicle). Thus by optimising logistics, it seems possible to moderate road traffic without reducing transport demand, which would play against economic growth.

The analysis conducted for this paper shows that for several variables data exist in most of European countries, and that some of them are harmonised by EUROSTAT rules for data collection. But white spots still exist, both at national and European level. Surveys on Road freight Transport are a good example of data harmonised by EUROSTAT, but they don't always provide information on energy consumption, because it is difficult to obtain an accurate estimate through a mail-back questionnaire. Time series are generally split by mode, but there is a lack of information on inter-modality (e.g. the Shipment Surveys conducted in 1988 and 2004 in France). A different strategy has been adopted in the US: the vehicle-based Road Freight Transport survey has been stopped, while the Commodity Flow Survey is conducted every 5 years.

For passengers, most European countries have conducted a National Travel Survey. But these surveys are not harmonised; a first attempt has been made on long distance travel with the DATELINE FP5 project (DATELINE 2003). It is only in U.K., Sweden, Denmark, the Netherlands, Germany and Italy, that National Travel Surveys are conducted on continuous basis, although this information would everywhere be necessary for analysing the relationship between changes in fuel price and in the rate of occupancy of private cars. Besides, on the international and intermodal level, there is still a strong need for more detailed data sources.

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