17
TRANSPORTATION STATISTICS

Data reported in this chapter were extracted from institutional documents of ANFIA, ACEA, ISTAT and Eurostat.

ANFIA (Associazione Nazionale Fra le Industrie Automobilistiche), the Italian national association of automotive manufacturers[1], was established in 1912 and is spokesman for its associates, on all issues (from technical, economic, fiscal and legislative to qualitative and statistical) regarding the mobility of people and goods.

Among several objectives, ANFIA has the task of gathering data and information, providing official statistical data for this segment of industry.

ANFIA publishes every year a report called *Autoincifre* (Figures of the Automobile), which is one of the fundamental references for statistical data on motoring in Italy and Europe. Much of the data collected in this report comes also from PRA (Pubblico Registro Automobilistico), the public vehicle register managed by ACI, the Association of Italian Motorists.

ISTAT (Istituto nazionale di STATistica) the Italian government institution for statistics [2]is well known. Established in Italy in 1926, ISTAT is the main producer of official statistics for citizens and public decision takers. It works in full autonomy while maintaining continuous interactions with the academic and scientific world.

This institution is fully involved in gathering European statistics (according to regulation R 322) and gathers data according to the fundamental rules of impartiality, reliability, efficiency, privacy and transparency.

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[1]Web address: www.anfia.it.

[2]Web address: www.istat.it.

G. Genta, L. Morello, *The Automotive Chassis, Volume 2: System Design*, Mechanical Engineering Series,

The role of ACEA (Association des Constucteurs Européen d'Automobile[3]) in the European Union is similar to that of ANFIA in Italy; the 13 major vehicle manufacturers with headquarters in Europe are associated with ACEA.

This association represents European manufacturers in the European Union under a wide spectrum of activities, setting up research groups, supporting manufacturers with objective data and creating new legislative proposals in the fields of mobility, safety and environmental protection.

Eurostat [4] is the statistical office of the European Union. Its job is to supply the Union with statistics from corresponding national services. The European Statistic Service (ESS) adopts similar methods, allowing it to obtain comparable data. This service was established in 1953.

These data, accessible to the public, concern:

- key indicators of Union policies;
- general and national statistics;
- economy and finance;
- population and social conditions;
- industry, commerce and services;
- agriculture and fisheries;
- commerce with foreign nations;
- transportation;
- environment and energy;
- science and technology.

A further source of information within the European Union derives from the public documents of the different General Directions[5]; among these the Environment General Direction has set up a working group, including associations from the automotive and oil industries, that published the interesting report Auto-Oil II, on the impact of oil product combustion.

Since all data become obsolete quickly, we invite readers interested in updated details to consult the mentioned public sites, which allow access to the original archives.

In the interests of consistency, we will usually refer to the European Union as the original 15 countries, including Austria, Belgium, Denmark, Finland, France, Germany, Greece, Holland, Ireland, Italy, Luxemburg, Portugal, Spain, Sweden and United Kingdom.

[3]Web address: www.acea.be.

[4]Web address: epp.eurostat.cec.eu.int.

[5]General Directions are, for the European Union, the equivalent term for Department or Ministry.

17.1 TRAFFIC VOLUME

Traffic volumes are conventionally measured by the product of transported units times the distance covered by such transportation; therefore:

- passenger traffic is measured in passengers per kilometer [pass×km];
- the transportation of goods is measured in metric tons per kilometer [t×km].

It should be pointed out that the metric ton equivalent to 1,000 kg is a unit of mass; in any case what is relevant is the quantity of transported material, therefore mass and not weight. Nevertheless, the habit of considering the kilogram as a unit of weight and not of mass persists and therefore we sometimes see statements that traffic volume has the same dimensions as energy, which is only correct if the kilogram is assumed to be a unit of weight.

It is also true that if we assume a value for the acceleration of gravity and we know the vehicle coefficient of resistance, which will be explained later on, traffic volume is proportional to the energy spent to overcome motion resistance relative to the payload.

What was said could also apply to passenger traffic, if we substitute the number of passengers with the corresponding mass (conventionally 70 kg per passenger).

These considerations do not take into account the altitude difference between origin and destination or speed variations along the route, which are, instead, relevant for determining motion resistance and prime energy consumption.

17.1.1 Passenger transportation

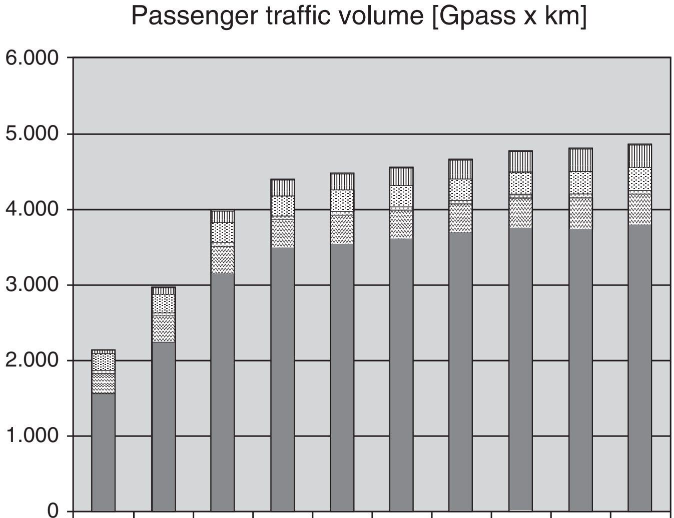
Figure 17.1 reports passenger traffic volume in the European Union from 1970 to 2001, broken down according to the primary passenger transportation vehicles, such as cars, buses, urban railways with subways, trains and airplanes.

Cars definitely predominate over other means of transportation; car traffic represents in 2001 more than 78% of the total, and traffic on tires (cars and buses) is about 87%; this breakdown varies little during these years.

The total volume increased about 4% yearly during the first twenty years considered in this diagram; afterwards the growth slowed down to approximately zero in the last years for which data is available. Air transportation with its continuity of development is an exception.

A similar table is reported for Italy in Fig. 17.2.

The situation for Italy is not so different from that of Europe as a whole; in this case, car traffic represents about 82% of the total and traffic on tires (car and busses) is about 94%. This percentage has slightly increased during most recent years, mainly due to the reduction of railroad traffic.



	1970	1980	1990	1995	1996	1997	1998	1999	2000	2001
Airplanes	33	74	157	202	209	222	241	261	284	286
Railroads	219	248	268	273	282	285	287	295	304	307
Urb. Railrds.	34	35	42	41	42	43	44	44	46	48
Busses	269	348	369	382	391	393	400	404	410	414
Cars	1.562	2.246	3.141	3.481	3.534	3.597	3.673	3.739	3.735	3.779

FIGURE 17.1. Passenger traffic volume in the European Union, from 1970 to 2001 (in billions of pass×km), broken down by main vehicle types: airplanes, railroads, urban railroads, including subways, buses and cars (Source: ANFIA).

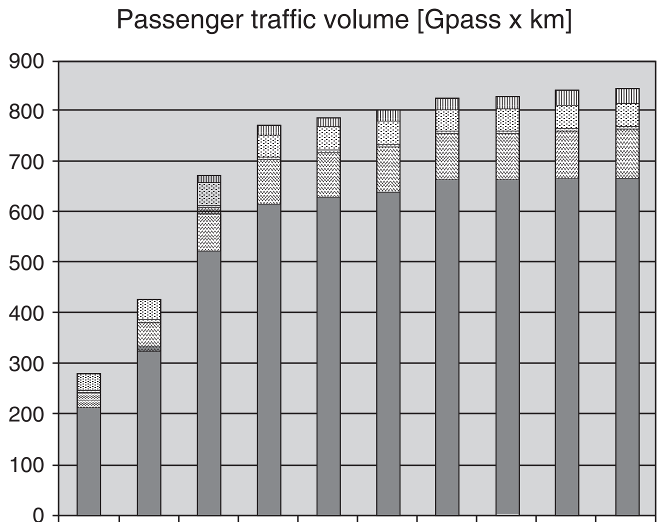
The total traffic volume increased more than the average of the European Union, during the last years considered. Air transportation also increased during this period more than the average.

In Italy (source ISTAT) traffic volume is well correlated with the Gross Domestic Product. The total ground transportation system made use of a network of about 6,500 km of toll motorways, more than 46,000 km of national roads, about 120,000 km of country roads and about 20,000 km of railroads, interconnecting 8,100 communities, 146 harbors, 101 airports and many railroad stations.

On this network about 43 million vehicles were driven. Trains, ships and airplanes served about 57 million residents, whose total yearly distance travelled was about 15,000 km.

17.1.2 Transportation of goods

Figure 17.3 shows the volume of transportation of goods in the European Union from 1970 to 2001, broken down according to the main travel modes; in this case, road, rail, inland and sea navigation, and pipeline transportation are considered.



	1970	1980	1990	1995	1996	1997	1998	1999	2000	2001
Airplanes			14	18	19	21	23	24	27	28
Railroads	33	40	45	44	45	44	41	43	47	47
Urb. Railrds.	2	4	5	5	5	5	5	5	5	5
Busses	32	58	84	87	89	90	91	92	94	96
Cars	212	324	523	615	627	639	663	663	665	666

FIGURE 17.2. Passenger traffic volume in Italy, from 1970 to 2001 (in billions of pass×km), broken down by main vehicle types: airplanes, railroads, urban railroads, including subways, buses and cars (Source: ANFIA).

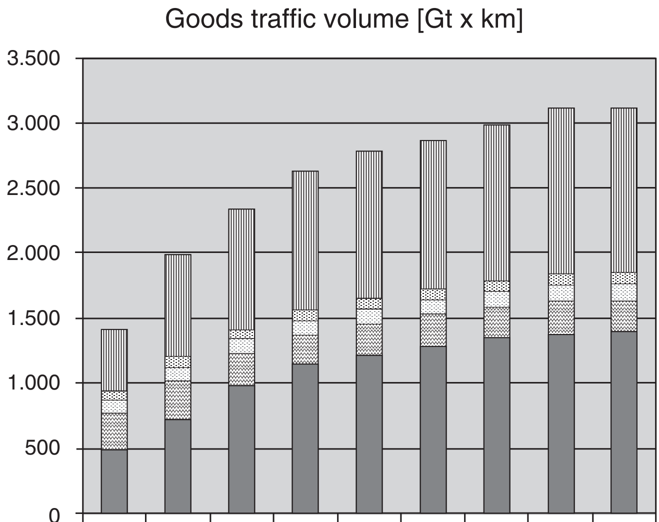
Here again road transportation is predominant: it accounted for 45% of the total in the last year of this period, starting from a percentage of 35% in 1970. The role of railroads has been reduced from 20%, at the beginning, to 8% in 2001. The contribution of sea navigation is relevant, considering the higher average distance travelled.

Figure 17.4 reports a similar table for Italy.

Road transportation plays a more important role in Italy than in the European Union: it carries 89% of the total in the last year considered, starting from 70% in 1970. In a similar way, railroad share has been reduced from an initial 16% to 6% in 2001. The contribution of sea navigation is not relevant, because the data include domestic transportation only.

In the most recent years, all developed countries have recorded continuous growth in transportation demand. Factors stimulating this growth have been many (economical and fiscal integration, market globalization, etc.) and seem likely to last in the medium term.

The most stimulating factor for Italy was the European economic integration process, implying free transfer of goods in the Union. Introduction of the



	1970	1980	1990	1995	1997	1998	1999	2000	2001
See navigation	472	781	923	1.070	1.124	1.142	1.197	1.270	1.254
Oil pipelines	64	85	70	82	82	85	85	85	87
Inland nav.	102	106	107	114	118	120	120	125	125
Railroad	282	290	255	221	237	240	236	250	242
Road	488	720	976	1.144	1.214	1.283	1.344	1.378	1.395

FIGURE 17.3. Transportation of goods volumes in the European Union from 1970 to 2001 (in billions of t×km, broken down according to the different kinds of carrier; road, railroad, inland navigation, oil pipes and sea navigation are considered (ANFIA).

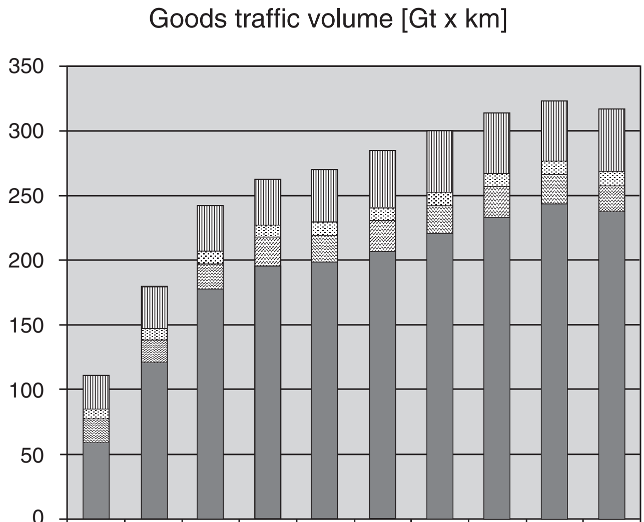
Union currency and the prospect of a further enlargement of the European Union portend a continuation of this trend in the future.

17.1.3 Energy consumption

Energy consumption is usually measured in tons of equivalent petroleum [tep], corresponding conventionally to 41.87 GJ or 11.63 MWh; these values define the equivalent quantity of heat that is delivered by burning a ton of oil of average quality.

This unit is also used to measure energy from sources other than oil, evaluated at the energy cost for their production.

For instance, railroad transportation uses a combination of electric energy and oil refinery products; electric energy itself is produced partly in thermal power stations using oil products or natural gas and partly in hydroelectric power stations. Other contributions can come from geothermal energy or nuclear energy.



	1970	1980	1990	1995	1996	1997	1998	1999	2000	2001
See navigation	26	31	36	35	40	45	47	46	47	49
Oil pipelines	7	9	9	10	10	10	11	10	10	11
Inland nav.	0,4	0,2	0,1	0,1	0,1	0,2	0,1	0,2	0,2	0,2
Railroad	18	18	19	22	21	23	22	23	22	20
Road	59	120	178	195	198	207	220	233	243	237

FIGURE 17.4. Goods transportation volumes in Italy from 1970 to 2001 (in billions of t×km, broken down to the different carrier kinds; road, railroad, inland navigation, oil pipelines and sea navigation are considered (Source: ANFIA).

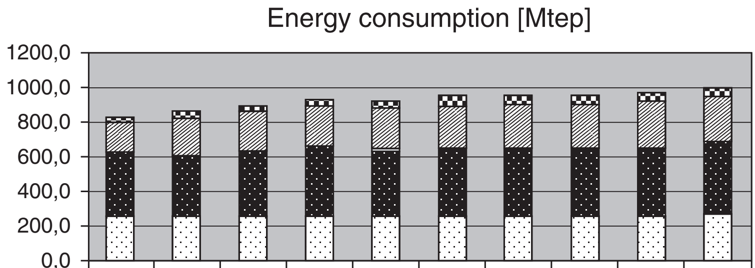
Every contribution is converted to an oil value, considering production losses and thermal equivalence.

Figure 17.5 displays a time series of energy consumption in Europe for most important means of transportation and other final applications.

The energy consumption of the transportation system is about 32% of the total; this share can be broken into:

- 2.4% for railroad transportation;
- 82.4% for road transportation;
- 13.6% for air transportation;
- 1.6% for inland navigation.

This last figure includes not only river, lake and channel navigation, but any maritime navigation in the European Union. The figure therefore includes sea navigation; this correction is particularly important for Italy because of its extensive coastline.



	1985	1990	1995	1996	1997	1998	1999	2000	2001	% in 2001
Inland Nav.	5,1	6,4	6,7	6,9	6,5	6,5	6,1	5,3	4,9	
Aviation	21,1	27,7	32,5	34,2	36,0	39,5	42,1	44,0	42,5	
Road tr.	169,5	211,1	228,6	234,6	238,4	246,3	252,0	253,6	257,0	
Railroad tr.	7,0	7,0	7,4	7,6	7,6	7,7	7,5	7,7	7,5	
Serv. & dom.	356,0	342,3	363,6	393,9	377,6	384,0	381,3	369,7	388,9	
Industry	267,9	265,9	259,1	258,7	261,8	261,2	262,6	270,8	269,5	

FIGURE 17.5. Energy consumption in the European Union for most important transportation systems and final applications; consumption is measured in millions of tep; percentages (for 2001 only) are multiplied by 10 to use the same scale (Source: Eurostat).

The energy used for sea navigation, the so-called bunkered quantity at the sailing harbour, is partially used for transportation to countries outside the European Union; it is conventionally treated as an oil export. In 2001 this quantity was estimated as 43.5 Mtep, about 14% of total transportation consumption.

The transportation system relies mainly on oil products; railroad transportation uses diesel fuel for 30% of its total energy consumption and a notable part of electric energy comes from oil combustion as well.

Road transportation uses primarily oil refinery products; Italy and Holland are an exception, consuming respectively 9% and 7% liquefied petroleum gas for traction (1999); the contribution of coal and natural gas is at this time negligible. Probably this situation will remain unchanged for the near future. Total consumption shows a leveling in recent years.

In Italy, road transportation seems to follow a different trend, as shown in Fig. 17.6, which concerns the consumption of oil products for ground transportation.

The following Fig. 17.7 shows the share between diesel fuel and gasoline.

The growth of diesel fuel over gasoline is evident; this trend is partly justified by the different retail prices of the two fuels and partly by the more efficient combustion of diesel engines. We should also remember that quantities are measured by mass units, but customers are paying by volume; at the same volume, diesel fuel contains 12% more energy than gasoline.

We have tried, using the available data, to compare the energy consumption of different means of transportation; we have defined as *energy efficiency* the

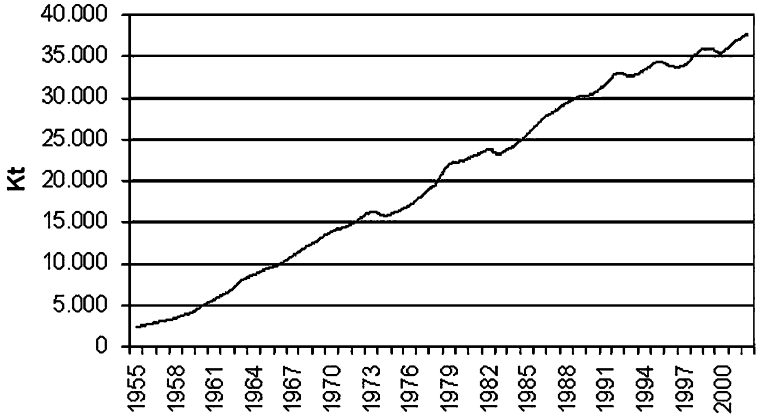


FIGURE 17.6. Total oil product consumption for ground transportation in Italy; the quantity in Ktep includes gasoline, diesel fuel and lubricants, these last accounting for about 1% of the total (Source: ANFIA).

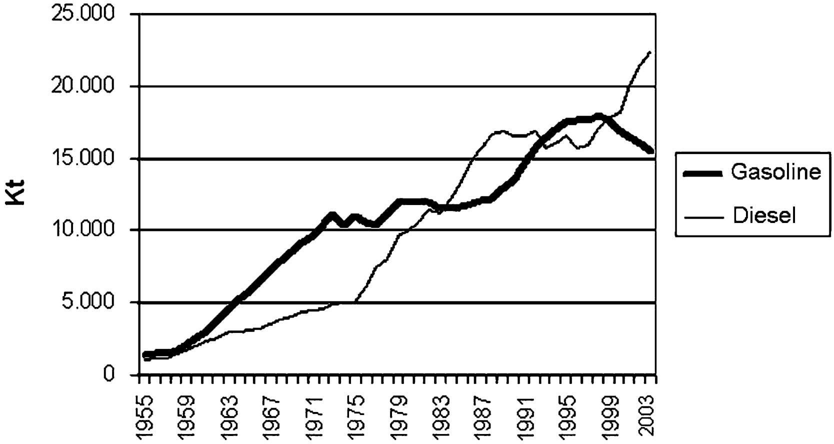
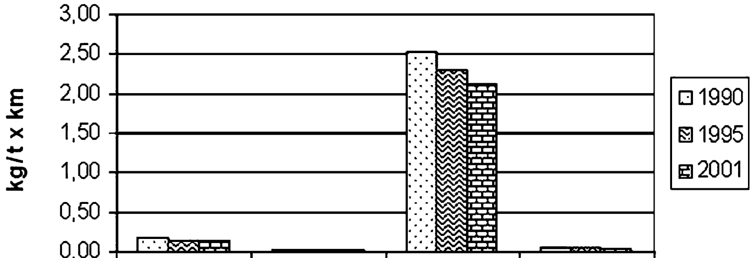


FIGURE 17.7. Gasoline and diesel fuel used in Italy by ground transportation, measured in Ktep (source ANFIA).

amount of energy necessary to perform a unit of traffic volume. We assume, as a common indicator, the goods traffic unit [t×km], which allows us to summarize with a single measurement goods and passengers transportation. We assumed an average mass of 70 kg for each passenger, including the transported baggage.

Accepting this questionable equivalence, we obtain the diagram of Fig. 17.8.

The values shown here display an increase over time of about 12% for road transportation and 16% for air transportation, covering a period of about ten years.



	Road	Railroad	Aviation	Navigation
1990	0,17	0,03	2,52	0,06
1995	0,16	0,03	2,30	0,06
2001	0,15	0,03	2,12	0,04

FIGURE 17.8. Comparison of energy efficiency of different transportation means; data are elaborated from time series of the European Union.

Another relevant parameter for evaluating the energy efficiency of a means of transportation is the *specific traction force*, the non-dimensional ratio:

$$\frac{P_{max}}{mgV_{max}} = \frac{F_t}{mg} = \frac{P_{max}t}{mgd},$$

obtained by dividing the installed maximum power of the propulsion system by the total vehicle weight and by its maximum speed.

The specific traction force may be interpreted, assuming that the vehicle is using its maximum power at its maximum speed with its maximum payload, as the ratio between traction force F_t, which in a steady condition equals the motion resistance, and vehicle weight; this is like an overall friction coefficient. Another interpretation could be the energy supplied by the engine to move a unit of mass for a unit of distance.

Figure 17.9 reports the specific traction force for different kinds of vehicles at different maximum speeds. Each curve has been obtained by considering many vehicles of the same family and charting them on the diagram. Curves on this diagram represent the lower envelope of the points represented.

This methodology may be questioned because only the top speed is taken into account and this may not reflect the most efficient condition for the traction engine; in addition, only the total weight is considered, instead of the payload alone.

All curves are superimposed on an ideal line that on logarithmic scales is straight, defined as the *limit for isolated vehicles.* This line can be interpreted as the optimum use condition for each vehicle, independent of its propulsion system.

The right side of Fig. 17.9 shows an enlargement of the part of this diagram regarding ground vehicles. It will be noticed that all vehicles including trailers are more efficient than isolated vehicles and are set below the limit line.

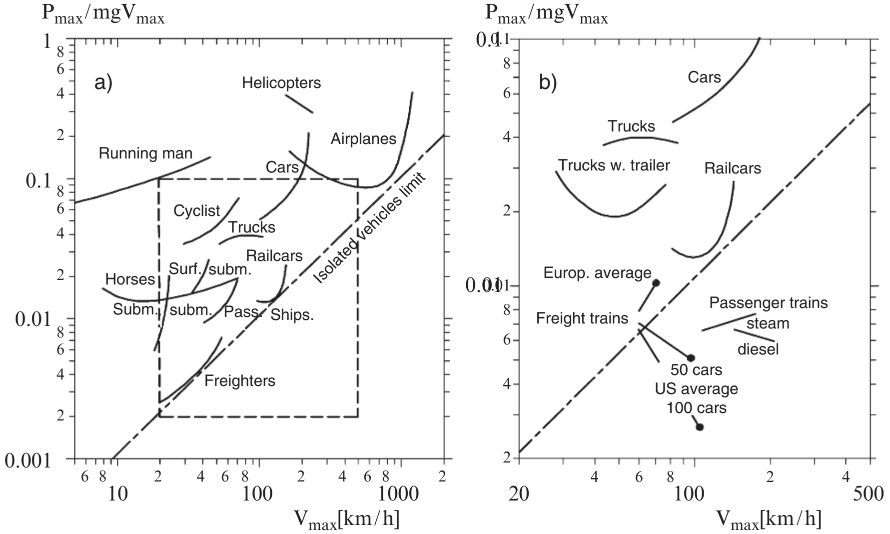


FIGURE 17.9. Specific traction force P_{max}/mgV_{max} as function of top speed. (a) General diagram; (b) enlarged portion concerning ground vehicles.

Although these are approximations, this parameter gives an immediate idea of the energy efficiency of different vehicles, and the distance to the limit lines suggests the amount of room for improvement.

17.2 OPERATING FLEET

17.2.1 Quantity

Vehicles owned by naturalized or legal residents of Europe totalled about 215 millions in 2002; they comprise the so-called vehicle *operating fleet.*

Figure 17.10 shows a time series for private vehicles, mainly cars; while Fig. 17.11 shows public service vehicles, including commercial vehicles, light, medium and heavy duty trucks and busses.

The year 2000 figures on total traffic volume are also available (source Eurostat):

- the railway fleet, included 40,000 engines and rail cars, about 76,000 cars for passenger transportation and about 500,000 freight cars;
- the navigation fleet, included about 15,000 vessels;
- the air fleet, included about 4,900 airplanes.

The private car fleet is predominant; about 469 cars for every 1,000 citizens were available in 2000. The fleet growth in thirty years was about 184%, with a yearly growth rate of about 3.5%; this growth has slowed but not stopped.

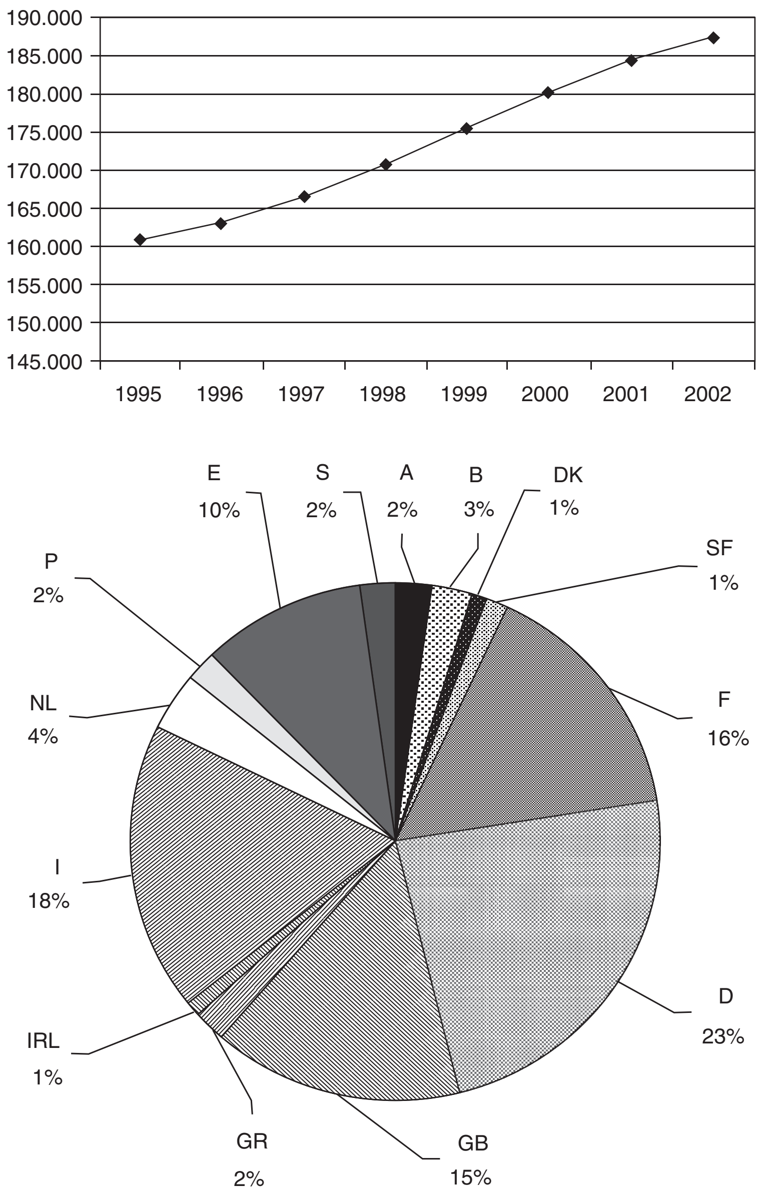


FIGURE 17.10. Time series of private cars in the European Union, in thousands; the lower pie chart shows the breakdown of the 2002 figures into the 15 considered countries, identified according to the international licence plate (Source: ACEA).

In the United States, car density has reached 750 cars per 1,000 citizens and is now steady; statistics show, in fact, that new car sales largely keep pace with written off units.

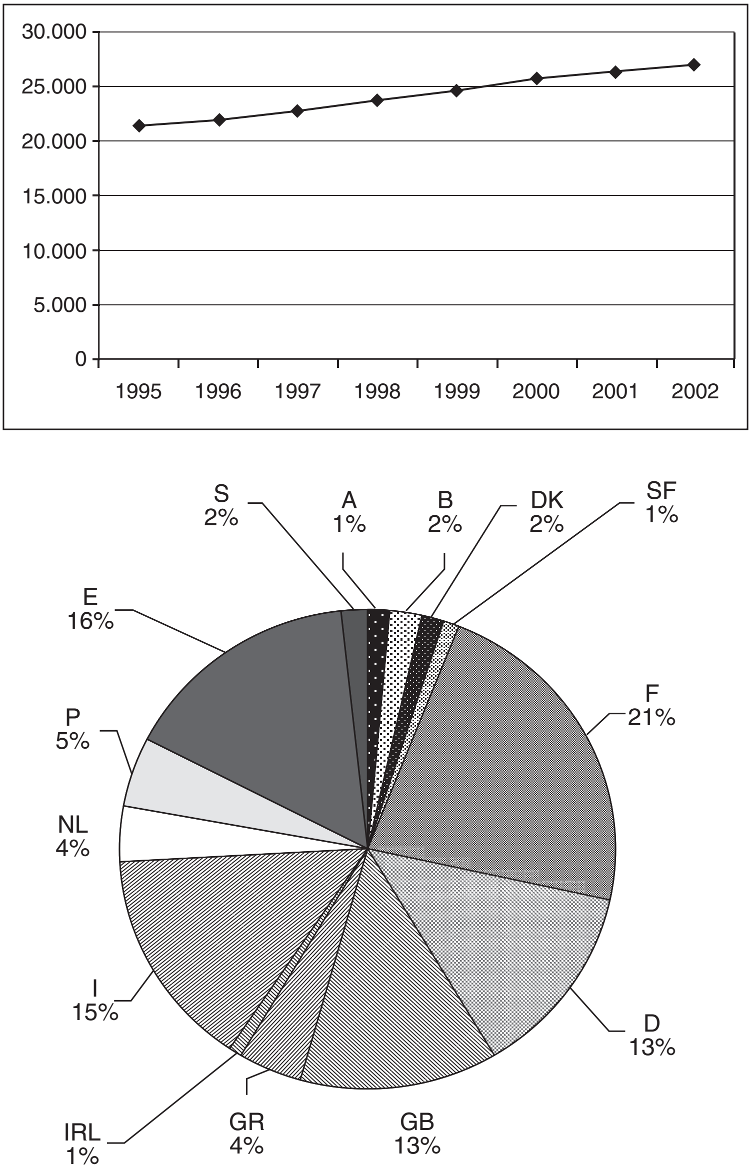


FIGURE 17.11. Time series of public service vehicles in the European Union, in thousands; the lower pie chart shows the breakdown of the 2002 figures into the 15 considered countries, identified according to the international licence plate (Source: ACEA).

Although this density is not inevitable for the European Union, the fleet there is still growing, and countries whose economies are growing fast are showing higher rates, such as Greece, with 9.2%, Portugal, with 7.3%, Spain, with 6.9%,

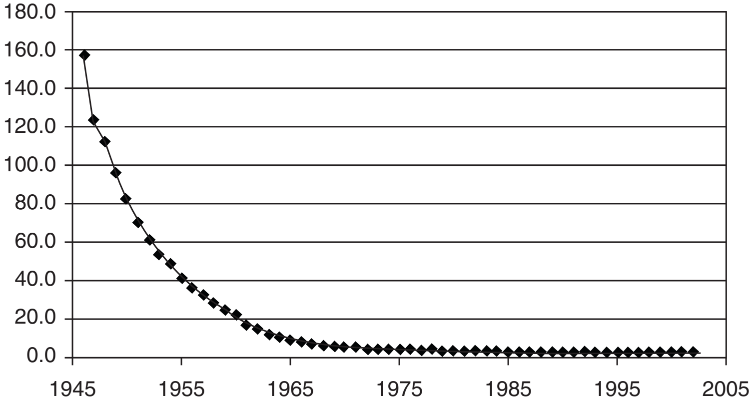


FIGURE 17.12. Citizens per car in Italy; this index has been decreasing continuously over time, with the exception of two discontinuities (not shown) at the time of the two world wars, in 1915-18 and 1939-45 (Source: ANFIA).

while countries with a more mature economy show lower rates, such as Denmark, with 1.8%, and Sweden, with 1.9%.

The highest car density in the year 2000 was reached in Luxemburg with 616 cars/1000 persons (corresponding to 1.62 cars per citizen), Italy with 563 cars/person and Germany with 522 cars/person.

Figure 17.12 shows a time series of the ratio of citizens per car in Italy; this diagram, if compiled from the beginning of the motoring era, would have shown a figure of 300,000 citizens per car in 1899; from that time on the index decrease was continuous, except during the two world wars in 1915 – 18 and 1939 – 45, when the total fleet decreased.

In 2003 this index has decreased to 1.5 citizen/vehicle.

At the same time the transportation infrastructures of the European Union can be described as follows:

- about 160,000 km of railroad network;
- about 3,250,000 km of road network, including 50,000 km of motorways;
- about 28,000 km of inland navigation routes;
- 204 airports with more than 100,000 passengers/year, with 30 of them treating 75% of the total air traffic.

17.2.2 Characteristics

If we want to better understand the contents of the car fleet, we can consider the histogram of Fig. 17.13, showing the breakdown of cars registered from 1995 to 2004 according to different market segments and body types.

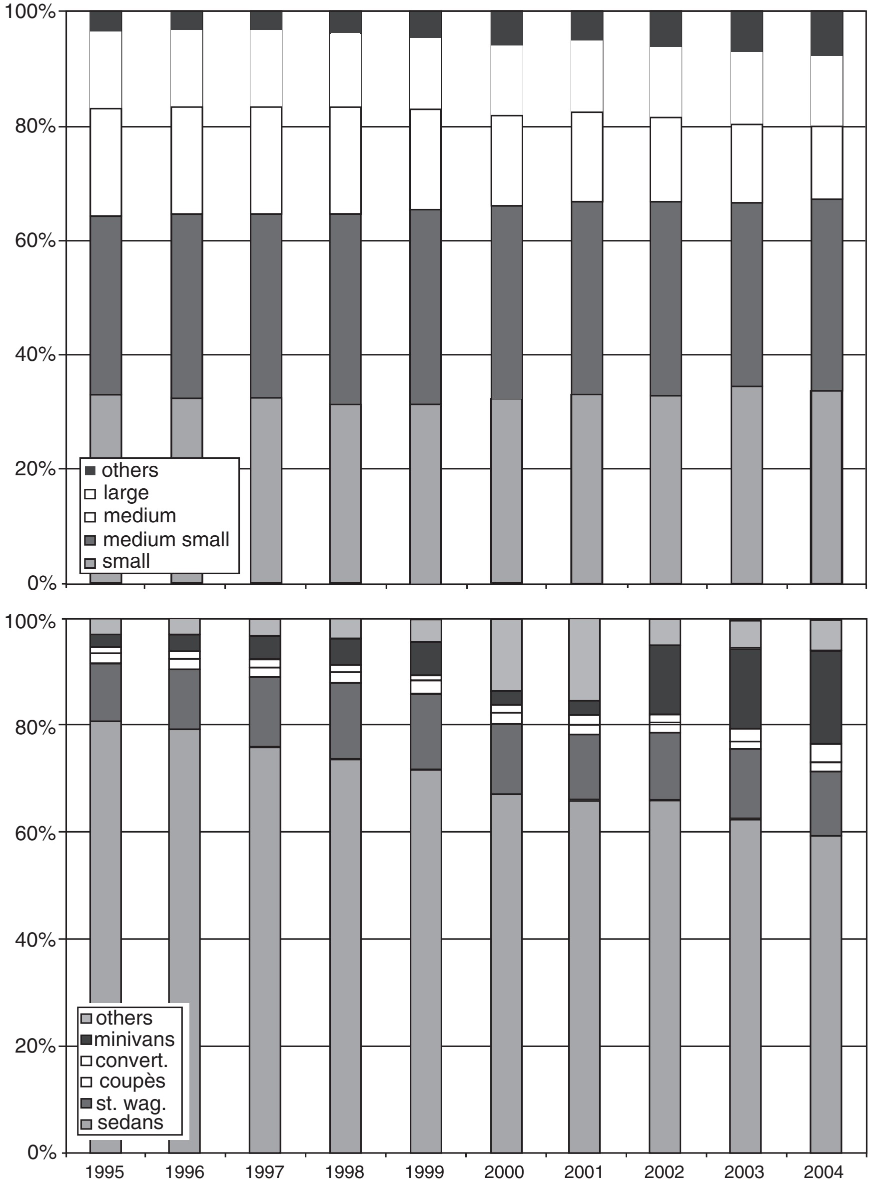


FIGURE 17.13. Car types registred in Europe from 1995 to 2004, classified according to market segments and body types; large, medium, medium small and small cars are defined, according to their length: larger than 4.5 m, 4 m, 3.5 m or equal to or smaller than 3.5 m (Source: ACEA).

TABLE 17.1. Road vehicles of the Italian operating fleet by age (Source: ISTAT).

Age	Cars	Busses	Trucks
0	2.033.296	3.819	222.443
1	2.541.933	6.056	260.116
2	2.518.499	5.381	243.297
3	2.391.709	5.485	197.700
4	2.399.014	4.569	173.021
5	2.381.400	3.936	136.940
6	1.667.344	3.409	142.841
7	1.619.341	2.610	136.149
8	1.533.972	1.898	108.402
9	1.497.088	1.866	102.005
10	1.993.566	2.852	134.100
>10	11.068.915	49.519	1.563.077
unknown	60.376	316	9.761
Total	33.706.153	91.716	3.429.852

Large, medium, medium small and small cars are considered, defined according to an overall length of more than 4.5 m, more than 4 m, more than 3.5 m and less than or equal to 3.5 m.

These segments show no substantial variation; in terms of type, a constant decline of sedans can be noticed, with a simultaneous growth of what were once considered niche segments, in particular minivans.

Diesel engines, introduced into mass production after the Second World War, have suffered from fiscal and regulatory intervention; at this time their fleet share is about 24%, while their market share is 44% (Source: ANFIA).

By analyzing and elaborating fleet characteristics, some information on expected life can be gathered; the task is particularly difficult because many data referring to the past are missing or are not comparable with present information.

As an example we can look at Table 17.1, where the Italian fleet is classified according to vehicle categories and their registration age.

In Italy, the average age of the running fleet is rather high: 32.8% of cars were more than 10 years old in 2002. The percentage for trucks reaches 46.1%.

We observe also that the weight of cars and trucks more than 10 years old has increased as compared with previous years, because they have benefitted from incentives favoring newer, less polluting vehicles.

Newer cars (less than one year of age) have moved from 7.2% in the year 2000 to 6.0% in 2002. A different trend appears in trucks, where newer vehicles went from 5.1% in 2000 to 6.5% in 2002.

ANFIA data, which reports on more age classes, estimate an average age of 8.85 years for cars in the year 2002. Analyzing these data, cars with gasoline engines appear to be the older category (9.35 years), but this must be weighed against the relatively recent success of diesel engines.

In the European Union the average age for cars is about 8 years; 70% of the fleet is younger than 10 years (source ACEA).

For industrial vehicles in Italy, the average age is about 10.5 years.

The estimate of vehicle expected life is hard to predict; but barring major changes, an expected life of 15 years for cars and 20 years for industrial vehicles would be a reasonable forecast.

The expected evolution of emission and passive safety regulations could promote a shorter life, increasing fleet obsolescence. Macroeconomics should not be forgotten.

The yearly distance covered by a vehicle can be estimated by dividing traffic volume by the number of operating vehicles and available places; in reality, not many vehicles operate at maximum capacity.

For example, in the European Union, cars deliver a traffic volume of 3.779 Gpass×km (see Fig. 17.1) with a working fleet of 187,400,000 units (see Fig. 17.10); by crediting each car with five places, we would obtain about 4,000 km/year.

The so-called *occupation factor* should be taken into account; it is defined as the ratio between occupied and available places; statistical surveys measured a mere 26.5% for this value, reducing total occupation to only 1.33 passengers per car.

The average yearly distance covered is therefore about 15,000 km/year (source ACEA).

A reasonable estimate for a car's life expectancy, therefore, should be close to 200,000 km.

Following the same process for other vehicle categories, we obtain:

- more than 400,000 km for busses;
- more than 800,000 km for long haul trucks.

17.3 SOCIAL IMPACT

As we have seen, transportation has a strong bearing on daily life. Every morning European Union services have to move more than 150 millions people to their working places and to return them to their homes in the evening, as well as serving longer routes; in addition, about 50,000,000 tons of freight are transported every day.

Considering passenger traffic only, each citizen travels approximately 12,700 km per year, using all available means of transportation; as a consequence, transportation is highly relevant to how people live.

We will consider in the following sections:

- accidents attributable to the use of transportation means;
- emissions of primary pollutant products;

- jobs offered by this economic sector;
- tax revenue generated by the transportation system.

As far as energy consumption is concerned, we refer to the previous section on this topic.

We will take into account mainly motor vehicles, our main field of interest, reporting also some reference data for other means of transportation.

17.3.1 Accidents

Like all human activities, road transportation involves risks and the number of accidents caused by the use of motor vehicles is remarkable in all countries of the world.

Their economic and human cost is high enough that the objective of increasing vehicle safety is generally considered a social and technical priority.

To evaluate the extent of these damages it may be useful to report a statistic on causes of death in the United States; these data could be similar to those in any other developed country.

These figures for 2002 are shown on Table 17.2. The number of fatalities connected to road transportation is higher than those caused by all remaining means of transportation and represents 44% of all fatalities from accidental causes[6].

In the European Union, transportation accidents caused 41,500 fatalities in the year 2000; 98% of these were due to road accidents. For people younger than 45, road accidents are the leading cause of death.

Figure 17.14 shows a summary of this worrying situation.

Total fatalities are decreasing, notwithstanding the traffic volume increase; this result is attributable to better driving education, infrastructure improvement and vehicle passive safety owing to the increasing severity of regulations.

TABLE 17.2. Death risk for different causes, referring to the USA population in 2002.

Cause	Total number of fatalities	Percentage
All causes	2.403.351	100
Heart troubles	936.923	39,0
Cancer	553.091	23,0
Total accidents	97.900	4,1
Motor vehicles	43.354	1,8
Generic accidents	17.437	0,73
Falls	13.322	0,55
Poisoning	12.757	0,53
Drowning	3.842	0,16
Burns	3.377	0,14

[6] Source: http:\\www.the-eggman.com/writings/death_stats.html.

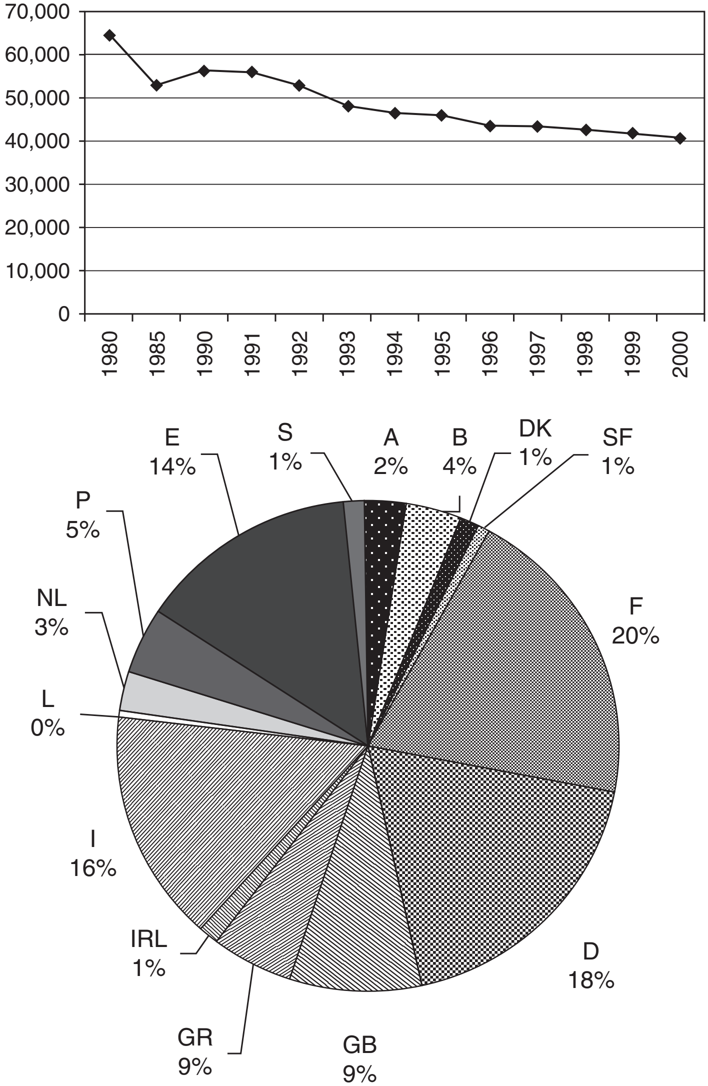


FIGURE 17.14. Time series of fatalities caused by road accidents in the European Union; the pie chart shows the contributions of the different States (Source: Eurostat).

The average mortality rate is about 109 deaths for each million residents ($1{,}09{\cdot}10^{-4}$); Italy and Ireland are close to the average; the lowest value is found in the United Kingdom ($0{,}60{\cdot}10^{-4}$), while the highest is in Greece ($1{,}98{\cdot}10^{-4}$).

55% of accident fatalities are represented by car occupants, 23% by bicycle occupants, 6% by bus occupants and the remainder by pedestrians.

Referring fatalities to different passenger traffic volumes, we obtain the following mortality rates:

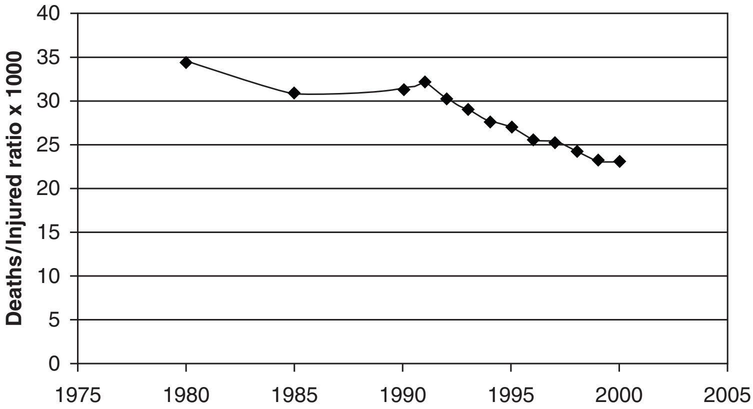


FIGURE 17.15. Time series of the ratio between deaths and non-fatal injuries due to road accidents in the European Union (Source: Eurostat).

- $10{\cdot}10^{-9}$ deaths/pass×km, for road transportation;
- $3{\cdot}10^{-9}$ deaths/pass×km, for railway transportation;
- $0.27{\cdot}10^{-9}$ deaths/pass×km, for air transportation.

Air transportation poses a challenge; one might consider accidents occurring inside the borders of the European Union, or accidents occurring to European airlines, whether inside the Union or abroad. Only European citizens might be considered or any person involved.

If we consider that most accidents occur near airports, the different counting policies give different conclusions. Moreover, these accidents, fortunately few, fluctuate over time and are difficult to average meaningfully.

The reported figure refers to all accidents occurring in 1999 within the borders of the European Union.

Returning to road transportation, accident severity has also decreased, as we can conclude by examining Fig. 17.15 showing the time series of the ratios between deaths and non-fatal injuries.

17.3.2 Emissions

The main pollutants emitted by the combustion of oil refinery products, in general, and by road traffic, in particular — all demonstrated to be harmful for public health — are the following:

- carbon monoxide (CO);
- nitrogen oxides (NO_x);

- non-methane organic compounds (NMOC);
- particulate matter (PM).

In recent times other gases have been added to the list; these are not directly harmful, but contribute to creating the so-called greenhouse effect. They are known, therefore, as greenhouse gases (GHG).

Carbon monoxide is a flavorless, colorless and poisonous gas; if exchanged with blood hemoglobin, in the lungs, it impairs the quantity of oxygen delivered to body organs and tissues.

A significant quantity of CO emission is produced by gasoline engine combustion and, therefore, by cars; all combustion processes of organic fuels that are incomplete for lack of oxygen contribute to the production of CO. Such contributions are many, including other gasoline engines (motorcycles, etc.), diesel engines, incinerators and homes.

Figure 17.16 shows a CO breakdown by source as estimated for the European Union in the year 2000.

These values are constantly decreasing because of the conversion to natural gas of many wood-burning furnaces, and because of the regulation on vehicle emissions that reduced the allowed limits, for example, for gasoline engine cars from 4.05 g/km, in 1992, to 1 g/km in 2005; the introduction of catalysts in 1992 had already reduced CO emission by ten times.

Nitrogen oxides (NO_x) are made by mixing NO and NO_2 and are the result of the combination of atmospheric nitrogen and oxygen due to combustion processes at high temperature and pressure; we can, therefore, say that the more efficient the combustion process, the higher the rate of nitrogen oxide formation.

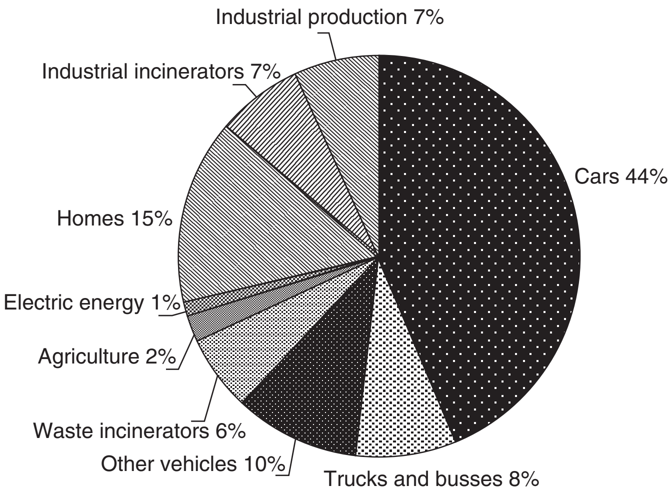


FIGURE 17.16. CO breakdown by source for the European Union for the year 2000 (source ACEA).

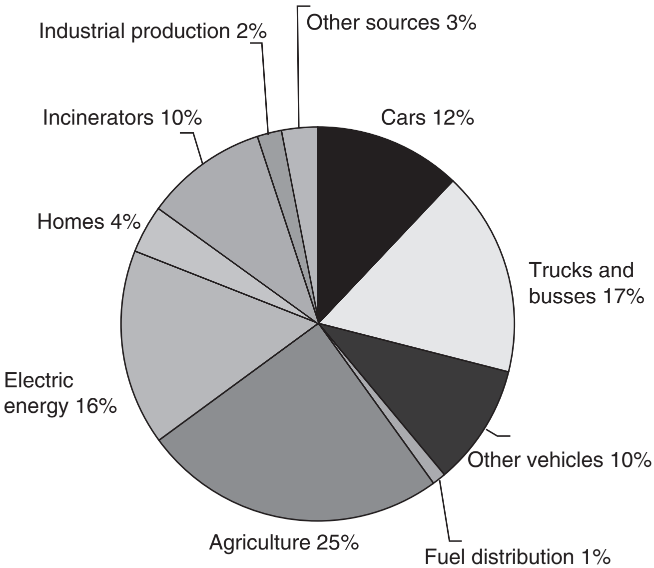


FIGURE 17.17. NO_x breakdown by source for the European Union in the year 2000 (Source: ACEA).

For this reason fuel consumption and CO_2 emission reductions conflict with reduced emissions of NO_x.

A second major source of NO_x is nitrate salts used in agriculture, which produce acids emitting nitrogen in the presence of water.

Nitrogen dioxide (NO_2) irritates the lungs and can reduce their resistance to infection, with increased risk for bronchitis and pneumonia.

Contributions to this pollutant are many, as shown in Fig. 17.17, again based on the year 2000.

We should remark that NO_x, together with NMOC are also precursors of complex chemical reaction leading to the formation of ozone (O_3) into the low altitude atmosphere, proven to be noxious to human health.

Anthropogenic sources of this pollutant are many; also in this case there is a clear trend to decrease. The evolution of vehicle regulation has reduced NO_x limits from 0.78 g/km in 1992, to 0.25 g/km in 2005.

Fig. 17.18 shows a similar diagram for NMOC; the evaporation of fuels and solvents is a major contributor.

NMOC also follows a decreasing trend; vehicle regulations have reduced levels from 0.66 g/km to 0.10 g/km for gasoline engines, and from 0.2 g/km to 0.05 g/km for diesel engines in the period 1992 to 2005.

Particulate matter is a mix of particles of different size that is harmful to health; it is also damaging to exposed materials and can reduce visibility. It is usually classified according to the average diameter of particles involved; these

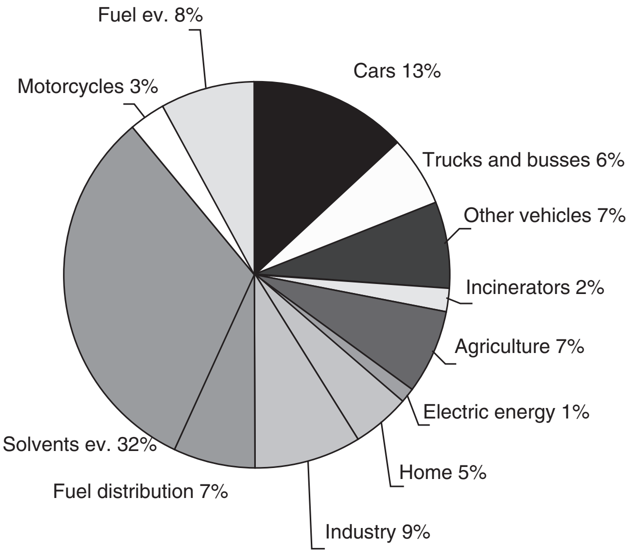


FIGURE 17.18. NMHC breakdown by source, in the European Union in the year 2000 (Source: ACEA).

are suspended in the atmosphere and precipitate very slowly. The most noxious particulates are those suspended in the atmosphere.

PM-10 indicates particles smaller than 10 μm, while PM-2,5 refers to sizes smaller than 2,5 μm.

The smaller the particle the greater the risk for human health. Extended exposure to these particles affects breathing, can worsen existing pulmonary diseases and increases cancer risk.

Beyond combustion products, particles also contain dust, ash, smoke and airborne droplets. If not washed away by rain or artificial means, powders on the ground can again become airborne due to natural wind or passing vehicles.

Fig. 17.19 shows a breakdown of the main sources of PM-10.

Gasses contributing to the greenhouse effect (GHG) include a basket of six chemical compounds that were identified in the final document of the Kyoto protocol; these are: carbon dioxide (CO_2), methane (CH_4), nitrogen dioxide (NO_2), chlorofluorocarbons (HFC), perfluorocarbons (PFC) and SF_6.

All these gasses, if diffused into the atmosphere, limit infrared radiation, contributing to an increase in the atmosphere's average temperature.

They are measured according to their heating potential, which is reported as CO_2 equivalent; their quantity is multiplied by weights p_i, which express the *carbon dioxide equivalent.*

The weights are the following: $p_{CO_2} = 1$, $p_{CH_4} = 21$, $p_{NO_2} = 310$, $p_{SF_6} = 23,900$. HFC and PFC include two large families of different gasses, each with its own weight.

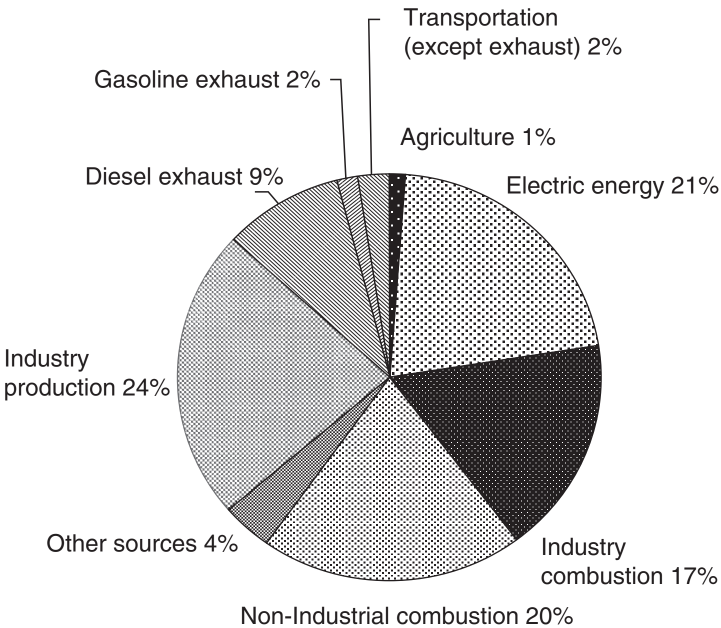


FIGURE 17.19. PM-10 particulate breakdown by source in the European Union in the year 2000 (Source: Auto-Oil II).

The pie chart showing the GHG breakdown by source is shown in Fig. 17.20.[7]

GHG emissions are strongly correlated to the population: France, Germany, Italy and the United Kingdom account for more than 50% of the total for Europe.

These emissions can be reduced only by reducing the burning of fossil fuels.

Air pollution is a phenomenon preceding development of the automobile, especially in urban environments and it has been declining for many years.

If public perception has increased, this is due more to the evolution of laws, than the problem per se.

Figure 17.21 shows an interesting diagram reporting SO_2 and smoke evolution recorded in London during the last four centuries; the period up to 1920 is an estimate based on coal consumption, while figures after that date are certain.

Urban pollution decreased considerably in the second half of the past century and is now lower than at any time in the last 400 years.

Similar diagrams are available for all major towns; on the other hand, towns of recent development show curves that are still increasing.

[7]These data are unfortunately not consistent with the others, because they refer to the European Union as extended to 25 countries.

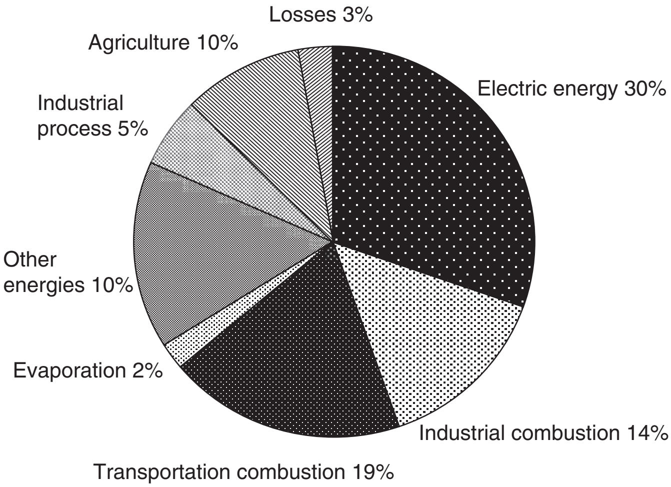


FIGURE 17.20. Greenhouse gasses broken down by source, measured as CO_2 equivalents (Source: Eurostat).

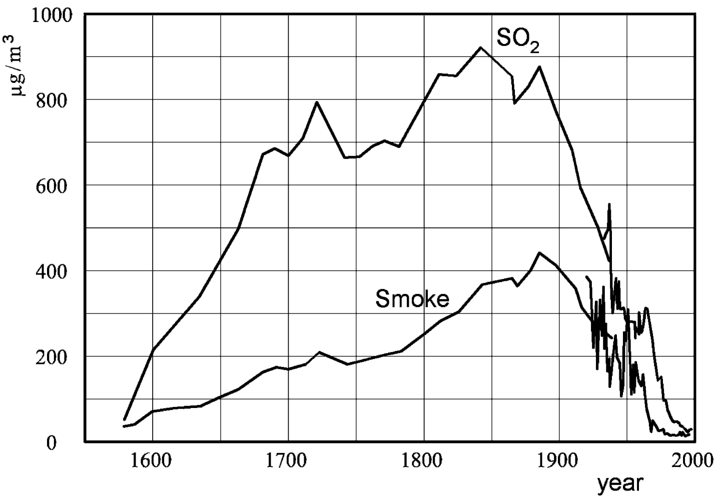


FIGURE 17.21. Diagram of SO_2 concentration and smoke, as functions of time, in London.

17.3.3 Economic figures

Limiting the figures to road transportation only, ACEA manufacturers produced in 2004 about 16,900,000 vehicles, 16,400,000 of them registered in the European Union with the remainder exported.

This production activity accounts for 1,200,000 jobs at vehicle manufacturers and 800,000 jobs at parts manufacturers; related activity, including distribution, service, parts and fuels distribution, car rentals, insurance, waste disposal, driving schools, dedicated press and infrastructure management, creates jobs for 12 millions people.

The yearly sales of vehicles alone have reached 452 billion euro in 2001; investments were about 8% of sales and research and development expenditures about 5%. The positive contribution to the trade balance was 33.4 billion euro.

Taxation on sales and property transfers, on vehicle ownership, on tolls and petroleum products was 346 billion euro in 2003, about 3.8% of the European Union GNP.