ASSESSING THE HEALTH IMPACT AND SOCIAL COSTS OF MOPEDS: FEASIBILITY STUDY IN ROME

By

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ABSTRACT

This report, a case study based in Rome, assesses the health impact of the use of mopeds. This study was carried out to present a method for measuring the negative effects on the general population caused by using mopeds as a means of transport. It provides data on the use of mopeds, emissions and accidents and provides a preliminary evaluation of the burden of disease brought on by their use. The economic burden and scientific uncertainty are also discussed. The report provides recommendations and outlines specific needs for further research. Since the report contains a methodological discussion and has practical application in quantifying exposure to moped use, it is also recommended as a handbook for local health and administrative officers. Attempts to estimate the proportion of air pollution attributable to mopeds are subject to amendment and review.

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CONTENTS

ANNEXES

TABLES

FIGURES

FOREWORD

Throughout southern Europe and particularly in Italy, mopeds (two-wheeled vehicles equipped with a less than 50 cc two-stroke engine) are widely used. They represent important means of transport, especially in the large cities, helping to meet daily urban transport needs. In these countries, the use of mopeds is facilitated by the mild climate and it is linked to several factors including ease in parking, agility in traffic jams, inexpensive maintenance and in some countries the absence of any taxation on the sale or purchase of second-hand mopeds.

Over the years concerns have been expressed on the contribution of mopeds to urban air pollution through their two-stroke engines as well as to injuries, deaths and disabilities due to the high accident rates involving in most cases young people. In Italy, in the last years, several measures have been taken to address these concerns such as the mandatory use of helmets for riders of any age as well as measures to promote the purchase of four-stroke motorcycles, more expensive but with more powerful and less polluting engines. The latter measure has been driven by the European Union directives on emissions from motor vehicles aiming to facilitate the removal of the most polluting vehicles from circulation. It is possible that the recent decrease in the sales of mopeds observed in Italy can be attributed to these measures although the use of mopeds is still very common. As of today, out of the 9.5 million Italians currently using any form of two-wheeled motor vehicle, about two thirds use a moped.

The study carried out by the WHO European Centre for Environment and Health, Rome Office, has been commissioned by the Ministry of Environment of Italy to allow for the initial assessment of the specific contribution of mopeds to the health effects associated to transport. It touches not only the contribution to air pollution, but also the accidents and the other social costs associated in the community to the extensive use of this type of vehicles. The study represents an initial attempt to investigate the burden of disease associated to mopeds use and can be considered as a pilot example of how complex scientific methodologies can contribute to the understanding of the environmental causes of health effects thus contributing to the identification of feasible and effective solutions.

We are confident that studies aiming to develop specific health impact assessments such as this one, will be more and more used in the future to guide policy development and the assessment of the effectiveness of policy responses. As a public health organization we will continue working with scientific institutions and national and local governments to improve and simplify methodologies and facilitate a more objective and sound response to environmental health concerns.

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EXECUTIVE SUMMARY

This feasibility study on the health impact and social costs of mopeds in urban settings investigated five distinct areas:

– the contribution by mopeds to air pollution in the city of Rome;
– accidents involving mopeds;
– health effects on the population of Rome attributable to the air pollution generated by mopeds;
– the social costs of accidents; and
– noise exposure.

One of the study's most important conclusions is that mopeds play a considerable role in producing Rome's urban pollution. Each of the city's estimated 443 000 mopeds covers an average of about 6 000 km annually for a total of 2.58 billion km. These 443 000 mopeds are responsible for 20% of the carbon monoxide and 21% of the PM10 concentrations measured by monitoring stations and represent 17% of the total circulating vehicles in Rome (about 2 600 000).

PM emissions from mopeds are responsible for about 350 premature deaths annually, which comprise 1.4% of deaths of people aged 30 years or older in the City of Rome; about 450 people are admitted to hospital for respiratory illnesses (2.2% of total admissions) and 660 for cardiovascular problems (1.0% of total admissions), in addition to other minor health problems.

For accidents, two large cities, Rome and Milan, were used for comparison and to ensure a reliable data set. Rome has more than 4 000 accidents involving mopeds annually, resulting in more than 6 000 injured people, and Milan had similar figures. Seventeen percent of the accidents caused by mopeds in urban areas are severe and involve hospitalization; 83% are minor and do not require hospitalization. Fatal urban accidents involving motorcycles and powerful scooters (engine displacement exceeding 50 cc) number about four times those involving mopeds. In 2000, insurance companies spent an average of €2 100 per claim for mopeds, 64% related to personal injury. The cost in health care expenses and lost work time owing to urban accidents was estimated to be €36 million in Rome for 2000.

In the compilation of this report, more than 25 public and private institutions, universities and research centres were contacted in various cities. Sixteen external private research institutes also provided input, for a total of about 32 collaborators who, for various purposes, elaborated data, performed surveys and designed interpretative models. Finally, another 20 researchers and public officials kindly made many direct studies and specific databases available, for a total of over 50 people contacted.

Research on noise exposure has not supplied quantitative data for Rome.

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1. INTRODUCTION

This assessment of the impact of mopeds on health and social costs in Italy is a national case study carried out within the transport, environment and health programme of the WHO Regional Office for Europe. The programme was proposed by WHO and endorsed by the European ministers responsible for environment and health at the WHO Third Ministerial Conference on Environment and Health in London in June 1999.

Italy's Ministry of the Environment took responsibility for an in-depth assessment study on the impact of mopeds and asked the WHO European Centre for Environment and Health, Rome Office to prepare a case study on a national scale. Nevertheless, given the uncertainty regarding the real availability of data and the objective methodological difficulties inherent in assessing the impact of an individual vehicle that represents only part of the overall traffic flow, the WHO European Centre for Environment and Health decided to conduct a feasibility study before attempting to assess the overall impact.

The feasibility study presented in this report examines the availability of data and the possibility of estimating the impact of mopeds by carrying out real tests in the circumscribed urban setting constituted by the City of Rome. Feasibility is deduced from the quantitative research carried out in Rome, but many of the data and studies consulted refer to other cities as well or are valid at the national level.

The report has five sections, each with its own results, which should supply an overall picture of the population's exposure to mopeds. The five sections focus on

– quantifying the phenomenon – total stock of motor vehicles, kilometres covered, number of trips and vehicle users;
– exhaust emissions and studying the proportion of urban air pollution attributable to mopeds;
– the overall picture of accidents in which mopeds are involved and assessing their health impact;
– assessing the health impact attributable to the air pollution generated by mopeds; and
– assessing the social and health costs related to accidents.

A sixth section on noise exposure would be useful, but since the scarcity of data and studies proved to be an impediment, noise exposure studies are only briefly mentioned.

This feasibility study does not evaluate the costs and benefits deriving from the use of mopeds and has thus not investigated the motives underlying their use nor the advantages this vehicle could have in transport planning.

2. QUANTITATIVE DATA ON MOPEDS IN ROME

This chapter describes the content and results of the feasibility study on the use of mopeds in Rome. A moped is defined as a two-wheeled motor vehicle[1] with less than 50 cc of engine displacement and a two-stroke engine able to reach a maximum speed of 45 km/h on a flat road.[2] The data on the total number of vehicles and average distance covered refer to the City of Rome. The pilot study made use of external consultants as well as other original contributions collected or retrieved by WHO staff. The work phases were as follows:

- estimate of the total number of vehicles in Rome and of vehicle ages;
- estimate of the number of riders and kilometres travelled per moped;
- emissions calculation; and
- how mopeds are used.

The study showed the following results.

About 443 000 mopeds are circulating in Rome.
The average age of a moped in Rome is 7 years.
The average annual distance covered is about 6 000 km.
About 40% of moped users are older than 35 years.
The most frequent purpose for using a moped is for commuting.

2.1. Estimate of total circulating mopeds

According to the National Association of Cycles and Motorcycles, the total number of mopeds in Italy is the highest in Europe: more than 6 million in 1998. A precise estimate of the total in each city is complicated by the fact that mopeds are considered unregistered property (like bicycles); thus there is no single, official figure on the existing and circulating total in each geographical unit. Assessment is based on indirect information.

The only existing official data on a national scale are:

- the number of payments made for moped registration;
- the number of insurance policies;
- the total number of licence plates requested; and
- ad hoc sample studies.

[1] Excluded are three-wheeled vehicles and "mini-cars" or non-licensed atypical vehicles.

[2] The speed limitations established are only theoretical, as the mopeds in circulation can easily be modified to boost performance. This is a typical characteristic of two-stroke engines.

The data from these sources vary considerably. The year referred to by the assessments is equally variable, as it depends on when the study was done. Finally, assessment methods vary as well. The assumption of the validation criteria in the selection of a study and acceptance of its estimate over others is quite complex, if not arbitrary. Considering that a) the objective of this chapter is to estimate the average total number of mopeds in the City of Rome in a single year (the year 2000 was taken as the baseline for subsequent chapters), b) the objective of this feasibility study is to indicate how to carry out an impact assessment on a national level and c) the study conducted here rules out the existence of a single sound and unequivocal assessment method, taking an average of the figures supplied by the studies seems more reliable than depending on a single figure furnished by an individual study. For the purposes of this assessment, the choice of averaging the estimates, although feasible since it supplies a reference proxy, unfortunately ensures considerable weakness in the capacity to estimate the total kilometres covered by mopeds annually. Until 1999, the trend in the sale of mopeds was generally increasing. In 2000, sales were halved, probably because the obligatory helmet law that entered into force applied to riders older than 18 years as well for minors, who had already been required to wear them since 1985 (National Association of Cycles and Motorcycles, unpublished data, 2002). This event most likely shifted sales in favour of larger-engine-capacity motorcycles (see also the DOXA survey described in section 2.3) for which helmets were already compulsory. Given the average moped age of 7 years, reduced sales have not immediately affected the total number of mopeds. The Rome Mobility Agency (2002), in its report to the City of Rome in which it indicates and updates the number of circulating vehicles, demonstrates substantial constancy in the number of mopeds in 1998, 1999 and 2000, with fluctuations of about 0.4%. This fact allows for fewer uncertainties regarding the possibility for projecting estimates of the total number of mopeds based on a given year – 2000 – and of averaging it with others.

For the purposes of completing the information, Table 1 shows the data supplied by the National Association of Insurance Companies on moped insurance policies in 1998, 1999 and 2000 (Annex 8). Extending the table to obtain information on the total number of mopeds is difficult since the data shown refer to a sample of auto insurance companies, and the numbers that do and do not insure mopeds are unknown. Further, the number of companies that insure mopeds has diminished over time. The percentages indicated in the columns refer to the market share covered by the companies in the sector and not to the number of individual operators who participated in the study. Finally, the National Association of Insurance Companies does not include all the insurance companies operating in Italy.

TABLE 1. INSURANCE POLICIES STIPULATED FOR MOPEDS OVER A THREE-YEAR PERIOD

	1998	1999	2000
Market share of the companies participating in the study (all auto insurance companies)	50%	65%	77%
Average number of insured mopeds in each of the 103 provinces	22 266	25 717	27 179
Standardized average assuming that the year 2000 = 100	30 073	29 725	27 179
Total number of insured mopeds in 103 provinces	2 293 373	2 648 870	2 799 430

Source: National Association of Insurance Companies database, 1997.

Seven studies, analysed to estimate the total number of mopeds circulating, are illustrated below. Annex 1 shows the list of sources and contacts used in this estimate.

2.1.1. Critical examination of the official sources

Ministry of Transport

The Ministry of Transport (2001) publishes the number of mopeds (subject to paying vehicle registration tax) circulating nationally, even though the number is believed to be underestimated: in fact, mopeds are not necessarily registered at the Public Vehicle Registry.

The Department of Motor Vehicles office of the Province of Rome (which includes the City of Rome) supplied the number of moped licence plates issued to residents of the Province. There is no correspondence between the actual number of circulating mopeds and the number of licence plates since these are assigned to individual people and do not correspond to the circulating moped itself.

Automobile Club of Italy

The Automobile Club of Italy (ACI) publishes the total number of vehicles in Italy calculated based on ownership, supplied by the Public Vehicle Registry; these data also show that there could be some relationship between the number of vehicles registered with the Public Vehicle Registry and the actual number circulating on the roads.

The estimates underestimate the stock: the percentage of the taxes paid is equal to 57% of the licence plates issued by the Department of Motor Vehicles. The maximum level of territorial detail is the provinces and considers the category of motorcycles.

National Association of Insurance Companies

The Public Vehicle Registry supplies the number of insured mopeds according to the province of residence of the insured party and other technical insurance-related features. The data are drawn from a sample study conducted in 1997 and do not refer to the total number of mopeds circulating.

The insurance firms that collaborated extensively with the study, and whose data proved sufficiently reliable, control about 43% of the market.

The data supplied by the insurance firms can be biased by differences among provinces in insurance rates. Some mopeds may be insured in a province other than the one in which the moped is used to save money. Grouping the data according to administrative levels below the regional level could make the estimates less reliable.

The project staff conducted an ad hoc study of moped insurance firms in Rome, requesting information on the number of mopeds insured between 1998 and 2001 whose owners resided in Rome.

Only one third of the insurance firms contacted responded. Nevertheless, many firms do not insure mopeds. Although they were explicitly requested to indicate that they do not provide this insurance product, some may not have responded for this reason. Good data reliability would have been obtained from the study with a response rate of 80–90%. The firms' databases record the number of moped–years[3] insured.

City of Rome

The City of Rome has promoted studies through the Rome Mobility Agency that are useful in calculating the total number of mopeds. Its report on air quality in the City of Rome in 2000 estimates the total number of mopeds in 1999.

National Association of Cycles and Motorcycles

The web site of the National Association of Cycles and Motorcycles offers a broad series of historical data (from the early 1950s to the present) on the production, sales and registration of motorcycles, motor scooters and mopeds by province.

2.1.2. Collected studies and estimates of the total number of mopeds

It is not believed suitable to subdivide the estimated total mopeds into conventional and EURO 1[4] moped classifications, since the European Union

[3] This figure is useful in standardizing the number of insured vehicles and in accounting for seasonal effects. The calculation divides the total days of insurance coverage supplied in the year by 365.

[4] This classification pertains to the maximum pollution emitted by the moped to allow it to be sold.

directive issued in 1997 went into force in 1999. Thus, the EURO 1 mopeds circulating are negligible in the years considered (Italian Agency for the Protection of the Environment and for Technical Services, 2000a).

Rome Mobility Agency

In 2000, the Rome Mobility Agency estimated the total number of mopeds based on the number of licence plates issued by the Province of Rome through 1999; we adjusted this figure, assuming that 70% of the mopeds are circulating, to arrive at the actual number in circulation. We applied a further reduction coefficient of 0.96 to the result to take into account mopeds circulating outside of the City of Rome.

The City of Rome has an estimated 336 507 mopeds.

The Rome Mobility Agency further subdivides the total vehicles into conventional mopeds (registered before 17 June 1999) and EURO 1 mopeds (registered after 17 June 1999). EURO 1 mopeds represent 3% of the total mopeds circulating in the City of Rome.

University of Rome La Sapienza and the Province of Rome

The University of Rome La Sapienza and the Province of Rome, in the context of a conference on the creation of dedicated public transport lanes in the metropolitan area of Rome, estimated the total number of mopeds to be 576 000 in 1999.

City of Rome

The General Urban Traffic Plan of Rome of 28 June 1999 states that “the total mopeds circulating in the Province of Rome amount to 700 000, and their average use on working days and in the absence of rain is very nearly 400 000 per day in the overall Rome metropolitan area”.

Francesco Monni

In a report given at a seminar on mopeds: damages and remedies on 10 June 1999, Francesco Monni (1999a) estimated the total mopeds present in the Rome metropolitan area to be 488 706, based on the number of licence plates issued in Rome between 1993 and 1998 according to the Centro Elaborazione Dati Motorizzazione Civile e Trasporti in Concessione.

ISIS hypothesis 1 based on ACI data

The ISIS (Institute of Studies for the Integration of Systems) uses the same criterion used by the study of Francesco Monni based on the number of licence plates issued in the entire Lazio Region but refines it by eliminating mopeds registered and retired in the same year (according to ACI statistics on vehicles no longer circulating) and in previous years. A provincial coefficient of 0.96 is applied to the total thus obtained that takes into account the mopeds circulating in the entire province. The results are shown in Table 2.

TABLE 2. MOPED LICENCE PLATES BY YEAR AND ESTIMATED TOTAL CIRCULATING IN ROME

Year	Moped licence plates	Mopeds in use	Provincial coefficient
1993	37 026	36 952	0.96
1994	260 217	259 489	
1995	79 715	79 556	
1996	58 851	58 733	
1997	60 550	60 408	
1998	48 638	48 559	
1999	30 399	30 244	
Total	575 396	573 941	550 983

Source: Institute of Studies for the Integration of Systems, unpublished report.

ISIS hypothesis 2 based on data from the National Association of Insurance Companies

The ISIS used data furnished by the National Association of Insurance Companies on the number of insured mopeds according to the owner's residence and the knowledge that this sample represents 43% of the total market of this transport segment and estimates 301 000 total mopeds circulating in the Province of Rome. Applying the provincial coefficient to this result produces a total of 290 000 mopeds in the City of Rome. For the reasons already stated, this underestimates the figure.

Il Messaggero *daily newspaper*

Newspaper articles and some interviews with urban police officers estimate that the total number of mopeds circulating in urban Rome in 1999 could be considered about 460 000 based not on official data and/or models but on unpublished original studies.

2.1.3. Consideration of estimates

Table 3 summarizes the seven estimates of the total number of mopeds circulating in 1998–1999.

TABLE 3. ESTIMATES OF THE TOTAL MOPEDS CIRCULATING IN THE CITY OF ROME (1998–1999)

Study	Estimated number of mopeds
Rome Mobility Agency	336 507
University of Rome La Sapienza and Lazio Region	576 000
City of Rome	400 000
Francesco Monni (1999b)	488 706
ISIS hypothesis on ACI data	550 983
ISIS hypothesis on National Association of Insurance Companies data	290 000
Il Messaggero daily newspaper	460 000

The data in Table 3 are assumed to be a series of approximate measures of the same phenomenon. The distribution is centered around 440 000, and the probable value is located in the range of 300 000–500 000.

Further, given that the arithmetical average of 443 171 is similar to the median of 460 000, the arithmetical average rounded off to the nearest thousand indicates the total circulating mopeds in Rome: 443 000.

Value assumed for the present study: 443 000

The seven studies did not provide confidence intervals for their estimates.

2.2. Average age of the mopeds circulating

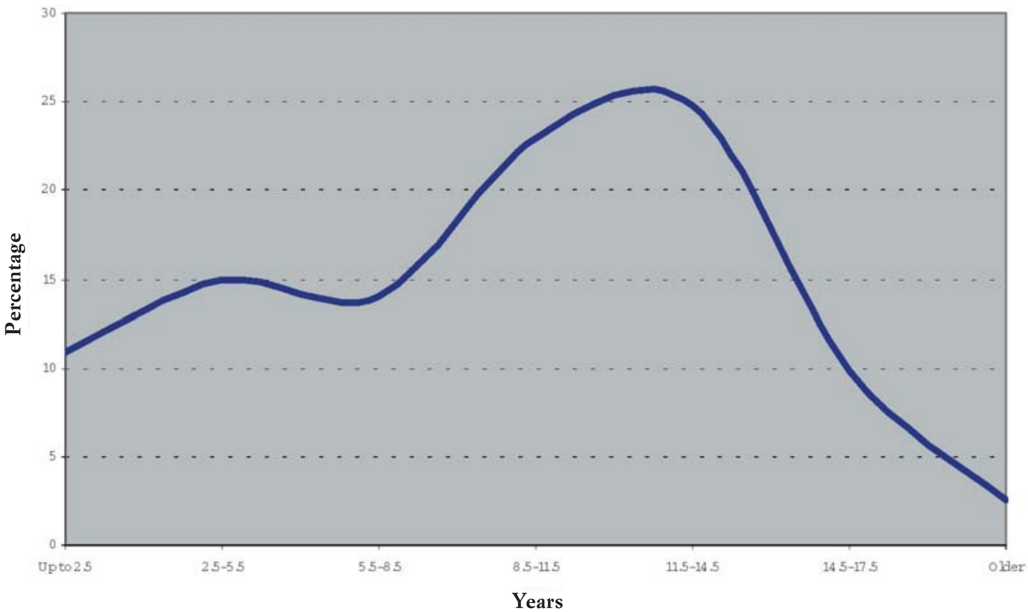
Few studies were found on the average age of the total mopeds circulating. In its 2001 report on the environment, Italy's Ministry of the Environment stressed the need to address the problem of determining the average age of the total mopeds circulating. Table 4 shows an extract of Rustia's (1996) study on the age of mopeds. The study is old, but its data might vary little if transformed into current values. In fact, the DOXA telephone survey of 16 000 respondents (personal communication, National Association of Cycles and Motorcycles, 2001) on the use of mopeds in Italy showed that more than 80% of the mopeds in 2000 were already present in the homes of interviewees in 1995; 52% of the total number were already owned at some point between 1990 and 1997. Rustia's (1996) study indicates that 62% of the total were between 5.5 and 14.5 years old, and these data concur with the 2001 DOXA survey.

TABLE 4. AGE OF THE MOPEDS IN THE CITY OF ROME

	Age of mopeds (years)						
	Up to 2.5	**2.5–5.5**	**5.5–8.5**	**8.5–11.5**	**11.5–14.5**	**14.5–17.5**	**Older**
% of mopeds	10.9	14.9	14.0	22.9	24.8	9.8	2.5

Source: Rustia (1996).

FIG. 1. DISTRIBUTION OF MOPED AGE GROUPS



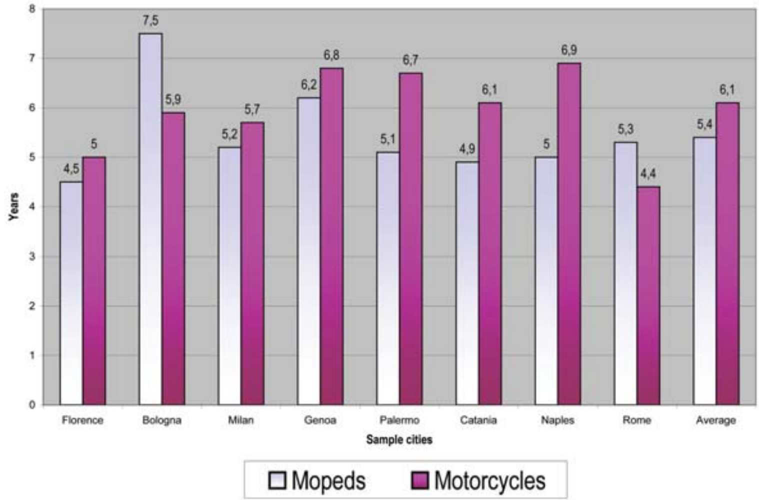
Source: based on data from Rustia (1996).

Fig. 1 shows that 11–14 years is the most numerous group. If we give the central value of the age groups their respective weights and calculate the arithmetical average, we obtain:

O#CL_i 1 P_i0]#n_i = 9.27 years

The Vado Pulito (running clean) study (ARPAT & ACI Toscana Service, 2001) established the average age of 2 860 mopeds and motorcycles checked in the sample of eight cities. The results are shown in Fig. 2. The average age was 5.4 years.

FIG. 2. AVERAGE AGE (IN YEARS) OF MOPEDS AND MOTORCYCLES IN EIGHT CITIES IN ITALY IN 2001



Source: ARPAT & ACI Toscana Service (2001).

We assume that the average age of the mopeds is equal to the arithmetical average of the two studies rounded to the nearest year: 7 years. This figure is confirmed by a 1999 study (ACI, Censis Servizi Spa & Piaggio, 2000) in which 11 000 people were interviewed on their use of two-wheeled vehicles; 76% had owned one for more than 5 years. The DOXA study also indirectly confirms the data presented. Nevertheless, a study by Friends of the Earth (2000) estimates the average moped lifespan to be 14 years.

2.3. Use of mopeds

There are very few studies on how mopeds are used, either in general or in the urban setting, and their results are based on sample surveys.

A report on two-wheeled motor vehicles in 1999 (ACI, Censis Servizi Spa & Piaggio, 2000) based its findings on a sample of readers of the magazine *l'Automobile*, with whom 11 000 interviews were conducted. The sample is therefore biased in favour of people with a special interest in vehicles and driving.

Nevertheless, this report provides interesting indications of a typical moped user.

- Of the total interviewees, 56% were medium- or medium- to high-level professionals: managers, officials, self-employed professionals, business executives, office workers or teachers.
- Of the interviewees, 51% were over 40 years of age.
- Of the interviewees, 34% travelled about 5 000 km annually.
- Mopeds are mainly used for commuting, especially in metropolitan areas (40%).

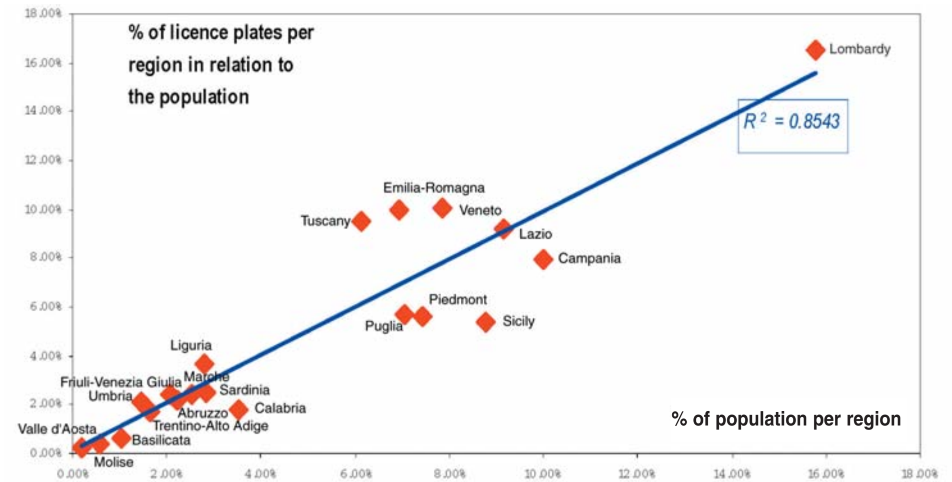
- Of the interviewees, 57% owned a two-wheeled motor vehicle; of these, 77% were its exclusive owner, and the remaining 23% shared its use and ownership with other family members.
- More men than women had exclusive use of the moped, to a greater extent among young people up to the age of 24 years, which dropped off with increased age to reach its lowest value between 30 and 39 years, rose again in the subsequent age group and levelled off at about 20%.
- The City of Rome stood out in terms of traffic violations: in particular, parking on pavements (74% of a sample of all moped riders in Rome versus 48% among a sample of riders in other cities) and driving down a one-way street in the opposite direction (36% of a sample of all moped riders in Rome) are typical driving infractions.
- The average percentage of traffic violations committed in metropolitan areas was calculated to rank the "cities with the most violations": Rome was first.

The DOXA study tends to confirm the results of the ACI, Censis Servizi Spa & Piaggio (2000) study:

- 9.5 million residents of Italy use a two-wheeled motor vehicle (of any sort);
- 75% are men;
- 40% are older than 35 years;
- 13% are younger than 18 years;
- 80% bought the vehicle new (> 50 cc scooters and mopeds);
- 66% of the total motorized two-wheelers bought new in 1999 were mopeds (displacement < 50 cc), and this declined to 38% in 2001;
- 20% of two-wheeled motor vehicles were used by people younger than 18 years (average 1999–2001);
- 60% use the moped (> 50 cc scooters and mopeds) year-round instead of seasonally;
- 64% use the moped for everyday purposes (> 50 cc scooters and mopeds); and
- 26% use the moped at least two or three times per week (> 50 cc scooters and mopeds).

Finally, as regards important geographical distribution data, the DOXA study demonstrates that the population in each region is directly proportional to the number of mopeds. The data supply the expected evidence of the rise in the number of mopeds with the number of inhabitants but indicates that the latitude of the regions does not seem to represent a variable (Annex 2). This would lead to the assumption that climatic conditions do not influence the ownership of mopeds in Italy. Fig. 3 shows the correlation between the proportion of the total population in a region and the percentage of the population having licence plates. The southern regions appear below the regression line (fewer mopeds per person), whereas the central and northern regions are above the line. Fig. 4 also explores the hypothesis that climatic conditions do not seem to influence moped ownership: moped distribution according to the number of licence plates per 100 inhabitants according province and to region. In this case, although the indicator considered is not precise (licence plates as an indicator of vehicle use), the concentration of mopeds is greater in northern Italy. The number of licence plates may be underestimated in the south, but the north and centre are either at or above the national average of 14.11 mopeds per 100 inhabitants. The Province of Rome coincides with the national average, whereas that of Valle d'Aosta, for example, is above it.

FIG. 3. PERCENTAGE OF THE POPULATION WITH LICENCE PLATES IN A REGION VERSUS THE PERCENTAGE OF THE TOTAL POPULATION IN THAT REGION



Source: ARPAT & ACI Toscana Service (2001).

To complete this rapid glance at the characteristics of the phenomenon of moped use, Annex 13 uses two maps of Italy to show the distribution of the licence plates versus the disposable income of families according to province. The number of licence plates increases somewhat from south to north, which follows, although less obviously, the previously mentioned positive gradient from south to north in disposable income (personal communication, Istituto Guglielmo Tagliacarne, 2002).

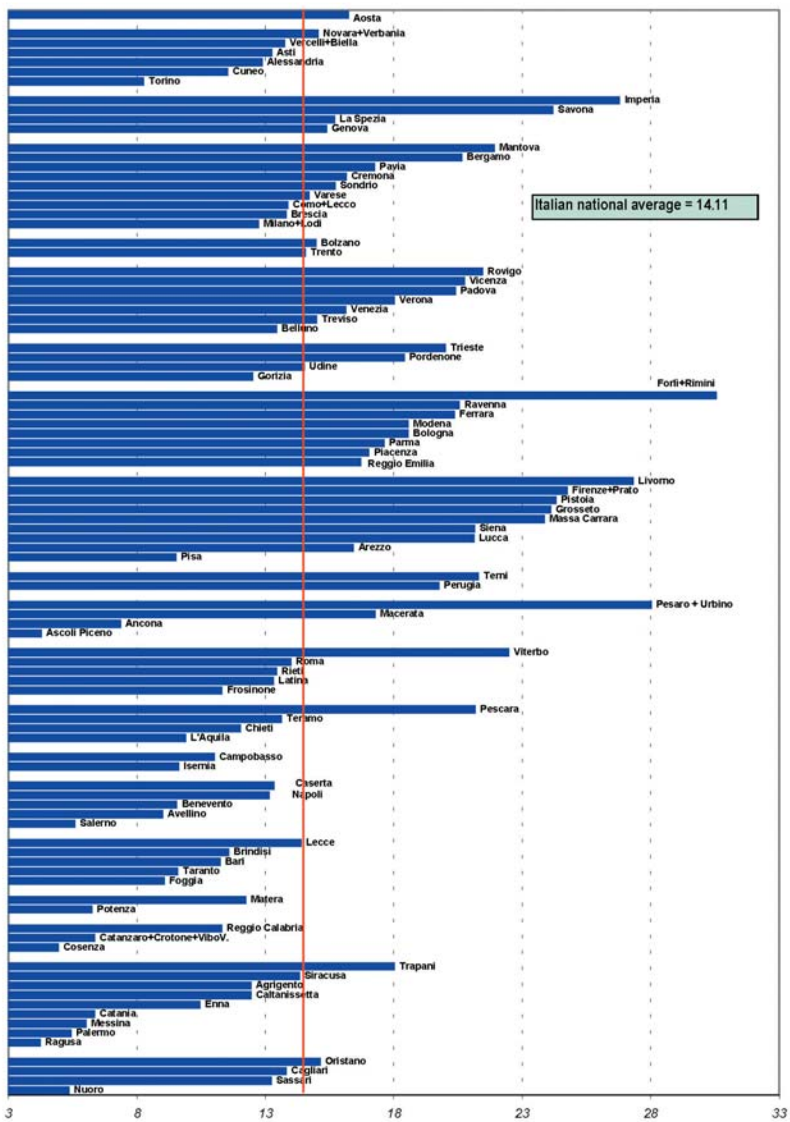
Based on the data listed in section 2.3 and the figure in Annex 13, several results that may not be very well known can be summarized.

- Motorized two-wheelers are mostly used by people who already have jobs.
- As 14- to 18-year-olds represent 5.1% of the population (ISTAT, personal communication) and use 13% of the total mopeds, mopeds are very common among minors.
- Motorized two-wheelers are bought to be used daily or almost daily.

– In 2001 the tendency to buy larger scooters (> 50 cc) doubled (new mopeds as a percentage of all motorized two-wheelers bought declined from 66% in 1999 to 38% in 2001).

– Disposable income is a more important factor in moped use than geographical location. Italy's northern regions have a higher per capita income than do southern regions (Annex 13).

FIG. 4. DISTRIBUTION OF MOPEDS IN ITALY ACCORDING TO PROVINCE – LICENCE PLATES PER 100 INHABITANTS



2.4. Estimate of the number of kilometres travelled per moped

The number of kilometres travelled per moped was estimated based on data retrieval and analysis of available studies.

Friends of the Earth Italy

On behalf of the ACI, Friends of the Earth Italy (2000) estimated the average annual distance covered by mopeds nationally for the years 1991 to 1996. The average supplied is 6 154 km per year.

The distances are calculated at a national level and therefore tend to be underestimated for the City of Rome because of the size of the municipal territory.

ACI

The ACI (1997) found an annual average distance of 5 000 km for the last year available.

Ventura & Grechi

Ventura & Grechi (1999) report the average distance travelled by mopeds in the City of Florence and others similar to it to be 3 100 km per year. Other studies described below show a 1:2 relationship between the kilometres travelled in Florence versus those in Rome, producing an average distance of 6 200 km per year travelled in Rome.

Francesco Monni

Monni (1999b) reported an average distance covered for Rome of 10 000 to 12 000 km per year (twice that of Florence). Monni's study was based on data collected from moped dealers.

Italian Agency for the Protection of the Environment and for Technical Services

The Italian Agency for the Protection of the Environment and for Technical Services (2000b) calculated an average annual distance covered of 5 000 km per year.

ARPAT & ACI Toscana Service

ARPAT & ACI Toscana Service (2001) used the voluntary monitoring of air pollution emissions of motorized two-wheelers in eight cities, including Rome, to obtain distances by relating the reading of the kilometre counter to the year the vehicle went on the road. The sample of 227 mopeds (just for the City of Florence) had travelled an average distance of 5 652 km per year.

ACI based on ARPAT & ACI Toscana Service

ACI elaborated the data obtained in the Vado Pulito study (ARPAT & ACI Toscana Service, 2001) in the remaining seven cities, including Rome, and obtained an average distance covered of between 6 000 and 15 000 km per year with the following distribution:

Classes of annual average distances (km)	1 000	2 000	3 000	4 000	5 000	6 000	7 000	8 000	9 000	10 000	> 10 000
%	9.5	15.6	20.8	17.7	11.3	8.8	6.0	3.3	1.3	1.1	4.8

Calculating the weighted average of this distribution yields an average annual distance covered of about 4 500 km/year.

TABLE. 5. ESTIMATE OF THE AVERAGE ANNUAL DISTANCE COVERED BY MOPEDS IN ROME

Study	Average distance covered per moped (km per year)
Friends of the Earth Italy (2000)	6 154
ACI (1997)	5 000
Ventura & Grechi (1999)	6 200
Monni (1999b)	10 000 to 12 000
Italian Agency for the Protection of the Environment and for Technical Services (2000b)	5 000
ARPAT & ACI Toscana Service (2001), Florence	5 652
ACI based on ARPAT & ACI Toscana Service (2001)	4 500

The distribution is regular, and the average is 6 072 km per year.

An occupant coefficient of 1.1[5] yields 6 679 rider–km per year, which leads to the assumption than each moped travels 6 000 km per year and each moped generates 6 680 rider–km per year.

6 000 km mopeds/year

6 680 riders km/year

[5] Although the law mandates a maximum of one rider per moped, it is believed (default estimate) that at least 10% of mopeds carry a second person.

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3. MOPED EXHAUST EMISSIONS AND THE PROPORTION OF TOTAL POLLUTION ATTRIBUTABLE TO THEM

This chapter summarizes the main studies, conducted mostly in Italy, evaluating the exhaust emissions of mopeds and two-stroke engine motorcycles. This type of engine emits various pollutants in quantities that vary according to the power (horsepower), age and condition of the engine and the vehicle's state of repair, use and modifications made to its various components after purchase (see Annex 3 and related bibliography). This variability can be seen in the weight differences among the quantities of various pollutants recorded by the numerous technical tests cited in the studies of various institutions. Other differences between the studies examined concern the type of pollutant emitted. For example, the Vado Pulito study (ARPAT & ACI Toscana Service, 2001) does not measure PM but supplies more information on hydrocarbons than the more recent studies conducted by Labeco Italia Srl (personal communication, 2002) for the Regions of Emilia-Romagna, Piedmont and Liguria. Vehicles with catalytic converters, that is, manufactured under EURO 1/EURO 2 standard emissions specifications, and ones without catalytic converters differ greatly in emissions of PM and other pollutants. European Union Directive 97/24/EC came into force on 17 June 1999; mopeds manufactured earlier than that date are referred to as conventional. Section 3.1 briefly describes and lists the emissions studies examined arranged by pollutant. Section 3.2 cites studies commissioned specifically by the WHO European Centre for Environment and Health to estimate the proportion of pollution attributable to mopeds.

3.1. Emissions assessment of mopeds with two-stroke engines

Given the varying results of the various studies as well as the specificity of the matter, this paragraph summarizes the conclusions of emissions tests conducted. See Annex 3 and other references cited for more detail. The main pollutants present in the exhaust of two-stroke mopeds are:

- carbon monoxide (CO);
- volatile organic compounds (VOC);
- nitrogen oxides (NOx); and
- particulate matter (PM).

European Union Directive 97/24/EC regulates emissions of the first three compounds. Table 6 shows the emissions limits for EURO 1 (1999) and EURO 2 (2002) mopeds according to the ECE 47 drive cycle.

TABLE 6. EUROPEAN UNION EMISSION LIMITS ON MOPEDS SOLD AFTER 17 JUNE 1999

	CO (g/km travelled)	Hydrocarbons + NOx (g/km travelled)
EURO 1 (1999)	6	3
EURO 2 (2002)	1	1.2

3.1.1. The main pollutants and studies examined

CO

The formation of CO is linked with the combustion that takes place in the cylinder of the two-stroke motor: as the air–gasoline mixture is poor in oxygen, all the carbon present in the fuel cannot be transformed into carbon dioxide. Given the rich gasoline content in the air–fuel mixture, the two-stroke engine emits high CO concentrations in its exhaust. The studies examined (Prati et al., 1999; Rijkeboer, 1999) show the emissions of various mopeds following all the specifications of the ECE 47 drive cycle except for the maximum speed limitation, to account for any modifications made after purchase. The emissions factors were then compared with the COPERT indications (COPERT is a computer program to calculate emissions from road transport in a standard procedure established by the European Environment Agency). Palke & Tyo (1999) measure the emission factors according to the ECE 40 drive cycle, which does not account for the actual number of revolutions per minute reached by two-stroke engines with simple modifications and supplies lower emissions values.

NOx

NOx represents the sum of nitrogen monoxide (NO) and nitrogen dioxide (NO_2).

NOx emissions in internal combustion engines mainly comprise NO; this compound is formed by combining oxygen and nitrogen (naturally present in the air) in high-temperature processes. The higher the temperature of the combustion process, the greater the NO emissions.

Since the temperature of the exhaust is lower, the NOx emissions of two-stroke engines are much lower than those of four-stroke engines. In the two-stroke engine both the gasoline and the unburned engine oil cool the exhaust emissions considerably. The studies examined are the same ones designed for the CO measured by the EMEP/CORINAIR emissions inventory (European Environment Agency, 2002) and Keller & De Haan (2000).

VOC

The principle mechanism in the formation of the VOC present in the emissions of two-stroke engines is the incomplete combustion of the VOC present in the gasoline itself. For this reason, the amount and type of compounds emitted not only depend on the technology of the engine but also on the chemical composition of the gasoline and oil lubricant mixture. VOC are essentially composed of aromatic hydrocarbons, aldehydes, ketones, alkanes, cycloalkanes, alkynes and polycyclic aromatic hydrocarbons.

The studies examined are the same as those for CO verified by the Italian Agency for the Protection of the Environment and for Technical Services evaporation level estimate (Saija et al., 2000) and using the COPERT method (Saija et al., 2000). With regard to benzene, the study by Fuselli (1999) was examined, which reviews the emissions factors for vehicles with catalytic converters as well (Nuti & Cundari, 1993).

For formaldehyde, acetaldehyde and benzo[*a*]pyrene emissions, we used the study by Laimboch (1991).

PM

Mopeds emit particles because of the presence of unburned engine oil in their exhaust (Palke & Tyo, 1999; Santino & Picini, 2001).

The PM (defined as the portions of exhaust gases trapped in a filter in the form of both aerosols and solid particles) in exhaust emissions comprises more than 95% unburned or slightly oxidized (non-solid) engine oil, and the remaining 5% comprises solid carbonaceous and inorganic PM (Palke & Tyo, 1999). A study by the Japan Automobile Research Institute on the composition of the PM emitted by two-stroke engines (Takayuki et al., 1999) confirms Palke & Tyo's 95%, specifying that these are soluble organic particles, differentiating them from those emitted by diesel engines, also in terms of their higher carcinogenic characteristics.

Very few studies have dealt with the measurement of this pollutant. Those available were done by the Italian National Agency for New Technologies, Energy and the Environment (Santino & Picini, 2001), Society of Automotive Engineers (Laimboch, 1991; Palke & Tyo, 1999) and Labeco Italia Srl (personal communication, 2002). The last study, in addition to being the most recent, considered more mopeds than that of the Italian National Agency for New Technologies, Energy and the Environment. The vehicles studied were both catalytic as well as conventional, two- and four-stroke and larger and smaller than 50 cc. What makes this study so interesting is the type of the test carried out, consisting of repeated trips along two typical tracts of urban roadway in Bologna, each requiring about 40 minutes of travel time.

Although none of the studies examined indicates the size of the PM emitted by the two-stroke engine, the technicians who designed the tests indicate that all particles emitted were either PM10 or smaller. The bench-check technicians all agreed in this assumption, as a result of both the nature and size of the test filters and the nature of this unidentifiable PM as a fine hydrocarbon aerosol (interviews with the Italian National Agency for New Technologies, Energy and the Environment, National Research Council Istituto Motori CNR and Labeco Italia Srl).

A very close relationship between oil consumption and the PM emissions of non-catalytic mopeds (Fig. 5) supports the hypothesis of the fine aerosol. It is not known how the particles are transformed in the atmosphere or their role in the formation of the PM10 concentrations measured in the city.

3.1.2. Emissions summary table

Table 7 shows the emission factors taken from various studies quoted in Annex 3.

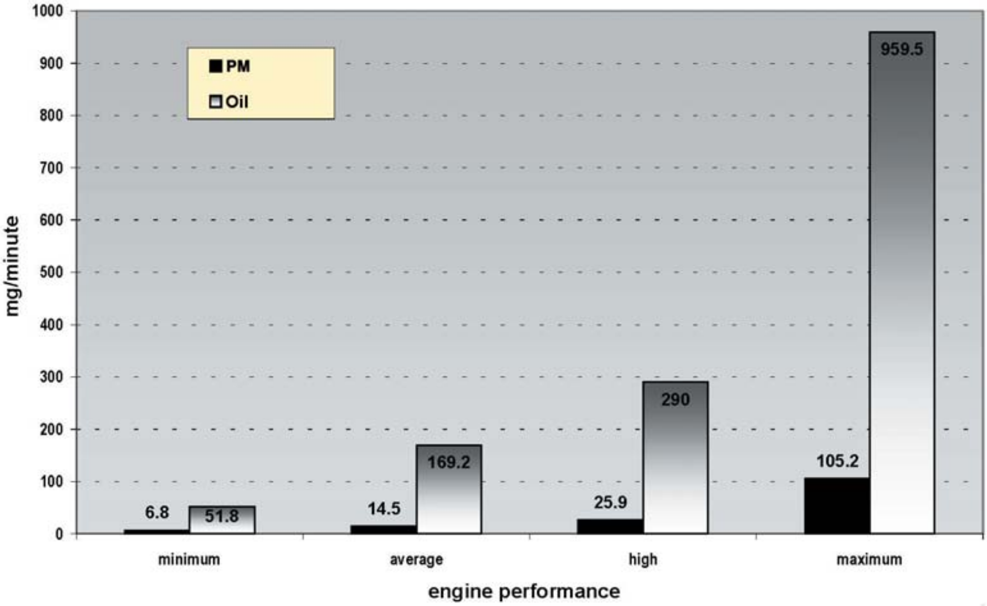
TABLE 7. EMISSION FACTORS OF TWO-STROKE ENGINE MOPEDS

		Conventional	EURO 1 (catalytic converter)
CO	g/km	15.00	7.50
Non-methane VOC	g/km	9.30	4.20
NO_x	g/km	0.03	0.03
Benzene	mg/km	156.70	16.40
PM	mg/km	91.40	33.90
1,3-Butadiene	mg/km	48.00	0
Benzo[*a*]pyrene	µg/km	2.15	0.40
Formaldehyde	mg/km	15.00	0.50
Acetaldehyde	mg/km	5.50	0.30

Source: Institute of Studies for the Integration of Systems (Annex 3).

The value of 91.4 mg/km proposed for PM is the average of three studies: the Italian National Agency for New Technologies, Energy and the Environment (Santino & Picini, 2001), Laimboch (1991) and Palke & Tyo (1999). In our opinion, the latter two should be excluded. Laimboch's study is from 10 years ago and used measurement instruments that could reasonably be considered too different from those in use today. That of Palke & Tyo was performed with the ECE 40 drive cycle (maximum speed of 45 km/h) on engines at top speed, without calculating the transition up to top speed after a cold start.

FIG. 5. PM EMISSIONS AND OIL CONSUMPTION



Source: Santino & Picini (2001).

Finally, we would add the Labeco Italia Srl study (personal communication, 2002), which was only recently made available after the conclusion of the ISIS study (Annex 3).

The Labeco study performed three bench-checks on four mopeds (two conventional, one catalytic and one with a four-stroke engine) that reproduced two urban street driving sequences of 40 and 50 minutes of travel time each. The values of the PM measured by the Labeco tests are much higher than those of the Italian National Agency for New Technologies, Energy and the Environment study (Santino & Picini, 2001), probably as a result of the urban driving sequence simulation that required many trips: that is, many departures and varying speed. The emissions of a two-stroke motor vary considerably during the transition time to reach optimal speed and revolutions per minute. For example, the Palke & Tyo (1999) test, performed at a constant speed with a warmed-up engine and maximum manufacturer's speed of 45 km/h, finds 35.2 mg of PM per km travelled. This figure concurs with the study of Santino & Picini (2001) at similar speeds but is more than quadrupled in the simulation of road-run speed and at higher speeds – with engines that have been transformed from the factory original that can reach higher speed. Within the described limitations, and inserting the required time to reach maximum speed from a cold start, Laimboch (1991) had already supplied emissions of 90 mg of PM per km travelled.

For a final PM estimate, the emissions of the three conventional and two catalytic mopeds measured in the Italian National Agency for New Technologies, Energy and the Environment (Santino & Picini, 2001) and Labeco Italia Srl (personal communication, 2002) studies were averaged (Table 8).

TABLE 8. PM EMISSIONS OF TWO-STROKE ENGINES

Study		Conventional	Catalytic
Italian National Agency for New Technologies, Energy and the Environment (Santino & Picini, 2001)	mg/km	172.0	42.7
Labeco Italia Srl (personal communication, 2002) moped 1	mg/km	234.9	Not applicable
Labeco Italia Srl (personal communication, 2002) moped 2	mg/km	323.4	Not applicable
Labeco Italia Srl (personal communication, 2002) catalytic	mg/km	Not applicable	15.3

This study therefore assumes the following values as PM emissions factors: 243.4 mg of PM per km travelled for conventional mopeds and 29.0 mg of PM per km travelled for mopeds with catalytic converters.

3.1.3. Total emissions and consumption calculated for Rome

Given the previously determined average of 443 000 mopeds circulating in Rome and that each covers 6 000 km per year, the total distance covered annually is therefore 2 658 million km per year.

For the purpose of calculating emissions, the marketing of EURO 1 mopeds began in June 1999. Their number has no influence on the total. Thus, the total circulating number is exclusively conventional mopeds. The Italian National Agency for New Technologies, Energy and the Environment (Santino & Picini, 2001), Prati et al. (1999) and the COPERT III model studied gasoline consumption, and all supplied values of about 25 g/km.

Table 9 shows the total pollutant emissions generated by moped exhaust in the City of Rome in 2000.

TABLE 9. ESTIMATED EMISSIONS AND TOTAL CONSUMPTION OF GASOLINE BY MOPEDS IN ROME, 2000

Pollutant	Specific emissions		Emissions per year	
CO	g/km	15.00	tonnes	39 870
Non-methane VOC	g/km	9.30	tonnes	24 719
NOx	g/km	0.03	tonnes	80
Benzene	mg/km	156.70	tonnes	417
PM	mg/km	243.40	tonnes	647
1,3-Butadiene	mg/km	48.00	tonnes	128
Benzo[*a*]pyrene	µg/km	2.20	kg	6
Formaldehyde	mg/km	15.00	tonnes	40
Acetaldehyde	mg/km	5.50	tonnes	15
Gasoline consumption	g/km	25.00	tonnes	66 450

3.2. Estimate of the proportion of pollution attributable to mopeds

In considering the feasibility of assessing the health impact and social costs of mopeds, this section describes three possibilities for estimating the proportion of urban pollution attributable to mopeds. This proportion is then used in Chapter 5 to evaluate the health risks attributable to mopeds. Given that the estimate concerns, in any case, the total urban air pollution, the values of pollutant concentrations are examined to deduce an exposure factor for the population. Nevertheless, since this assessment focuses on only one type of vehicle polluting the urban air, the proportion of pollution for which mopeds are responsible should be estimated. This requires referring to the calculation of pollutant emissions of the various types of motor vehicles circulating in the city and deriving the relative impact on the measurement of the concentrations supplied by the monitoring stations. This estimate presents many uncertainties, and the numbers it yields require further study.

There are at least three operative difficulties in assessing the amount of pollution that can be attributed to mopeds.

The first difficulty is a general one and lies in the complex relationships linking the PM emitted by the various classes of vehicles to the pollutant concentrations recorded by the monitors. How much of the PM10 concentrations are produced by motor vehicles? Thus, the amount of natural or industrial fine dust not attributable to vehicles needs to be determined. Some pollutants measured such as CO and NO are very sensitive to the proximity of the emission source; others, such as PM and ozone, are not. Given that CO is a primary pollutant correlated with vehicular traffic flow, its concentrations are proportional to traffic emissions. The relationship between CO and dust could, therefore, be indicative in the assessment proposed here.

A study (Zauili Sajani et al., 2002) conducted by the environmental epidemiology division of the Regional Environmental Protection Agency of Emilia-Romagna dealt with the correlation between pollutant concentrations in 42 monitoring stations in 10 regional cities. The study recorded great variation in the measurements of pollutants such as CO because of the geographical distance between the stations, confirming the high local concentrations of this pollutant. It also registered a close correlation between CO and NO (both are pollutants related to road traffic), a stable correlation between total PM and PM10 concentration (r = 0.75) and an interesting correlation of about 0.6 between PM10 and CO concentrations (Zauili Sajani et al., 2002). To complete the picture, Table 10 shows some of these daily concentration correlation values taken from the Zauili Sajani et al. study that tend to be confirmed by the comparisons with monthly data over the period of one year.

TABLE 10. CORRELATION COEFFICIENTS (R) AMONG DAILY CONCENTRATIONS OF POLLUTANTS AT MONITORING STATIONS IN EMILIA-ROMAGNA

	CO and NO	CO and total suspended particulate	CO and PM10	CO and benzene	PM10 and total suspended particulate	PM10 and benzene	PM10 and NO
Median	0.86	0.59	0.63	0.70	0.75	0.59	0.51
Average	0.84	0.54	0.60	0.67	0.69	0.59	0.50
Maximum	0.93	0.66	0.74	0.84	0.86	0.62	0.62
Minimum	0.61	0.30	0.36	0.43	0.43	0.54	0.30
Number of considered stations	42	17	10	6	7	4	10

Source: Zauili Sajani et al. (2002).

The Italian Agency for the Protection of the Environment and for Technical Services (Cirillo, 2002), in the context of setting up an emissions inventory, indicated that 60% of the fraction of the PM10 concentration measured by the urban monitoring station networks was attributable to vehicular traffic in Italian cities.

Fillinger et al. (1999) estimate that the proportion of PM10 related to vehicular traffic increases with the increase in the concentrations found. For concentrations greater than 40 μg/m3, the amount related to traffic is estimated to be 58%.

In addition, data in Table 10 support the correlation between road traffic and the PM10 concentration in urban air. CO is emitted from the combustion of endothermic engines only and is therefore a proxy indicator of the volume of the road traffic. The proportion of the urban PM10 concentration, measured by monitoring stations attributable to motor vehicles, is taken from the Italian Agency for the Protection of the Environment and for Technical Services studies.

This feasibility study assumes that the fraction of urban PM10 measures by monitoring station attributable to vehicle emissions as estimated in the ANPA studies.

The percentage of PM10 concentrations related to vehicular traffic is 60%

The second difficulty lies in the calculation of the specific pollutant emissions for a given configuration of the total vehicles circulating in a city. Thus, the more calibrated the model for calculating vehicles and emissions, the greater the vagueness of the individual variables required by the model. Emissions assessment models require input data such as the average distance covered and average speeds for each category of circulating vehicle, and for each year of production, in the city under examination. Annex 7 reports the composition of the total circulating vehicles in Rome and their relative particulate emissions, as adopted by this study.

The third difficulty concerns the main pollutant considered by the health impact assessment: PM10. The PM measured in vehicular emissions is composed of aerosols, which partly combine with the atmosphere and differ from what is collected and measured by the monitors. Moreover, the particles are carried even at a great distance, which makes establishing a direct relationship between emissions and concentrations measured in proximity to a tract of roadway difficult. Specific site studies do not offer much information in this sense, but it can be supposed that the monitors also measure particles produced far from the roadway site where they are located. To this end, De Munari (2002) compared the PM10 concentrations measured by all the monitoring stations of Emilia-Romagna in November–December 2001 and January 2002, revealing substantially equal concentrations per city for the stations located in background, residential and heavy traffic sites. The study concludes by maintaining that PM measurements represent an overall picture of the city and not of a specific area (De Munari, 2002). Further, the correlations between PM and other pollutant concentrations measured by the same station are the object of heated debate. A solid correlation with CO is difficult to find. CO under certain weather conditions can be directly proportional to the volume of vehicular traffic. This uncertainty, in turn, makes it difficult to establish relations between road traffic flow and PM10 concentrations.

Nevertheless, Avino P., Brocco D., Lepore L. (2001) and Avino P., Brocco D., Cecinato A., (2001) analysed the composition of the PM10 at the two Rome stations – Villa Ada park (background) and Fermi (heavy traffic) – and discovered a substantial equivalence for PM10 composed of 30–40% carbonaceous matter of organic origin (hydrocarbons, other oxygenated compounds, alkanes, isopropanol alkenes and isopropanol nitrites) and graphite. This is strongly related to vehicular traffic. Annex 5 reports the chemical analysis of the PM samples of the two stations.

Essentially, this feasibility study considers the PM emitted by mopeds as comparable to PM10, as has already been postulated by the bench-check technicians (section 3.2.1).

The feasibility study proposes two different methods for assessing the proportion of pollution attributable to mopeds and uses the average of two coefficients as a parameter to estimate population exposure.

At the conclusion of this section, the feasibility study recommends that sound research programmes on the composition of particles and their relation to traffic volume be launched to further refine the assessments offered here.

3.2.1. The method of the Rome Mobility Agency and WHO

The WHO project staff commissioned the Rome Mobility Agency to study the flow of mopeds near the air quality monitoring stations. Annex 4 reproduces the entire study.

To form a hypothesis on the contribution by mopeds to urban air pollution, the Rome Mobility Agency took only CO emissions into consideration and estimated traffic flow and emissions, supplying then the percentage of CO concentrations measured at the station relative to mopeds. The Rome Mobility Agency pursued two methods: direct calculation and traffic flow according to the origin destination table.

Direct calculation

Traffic flow was measured from 26 November 2001 to 7 December 2001 directly along the main axis of Via Magna Grecia, where a monitoring station was set up (excluding 30 November and 1 December, days on which traffic data were not reliable). The hourly traffic flows obtained provided the basis for calculating emissions using the TEE (Traffic Emission and Energy) model and of concentrations obtained from the ADMS-Urban model (a development of the Atmospheric Dispersion Modelling System) (see Annex 4 for references).

The concentrations were then compared and substantiated against those measured by the local monitoring station.

For further confirmation, the flow of cars and two-wheeled vehicles (mopeds and motorcycles) was calculated for the five daily peak hours 7:45–8:45, 9:45–10:45, 14:30–15:30, 17:00–18:00 and 20:00–21:00) of the work and school days of 6 and 7 March 2002 by means of video observation. Given the difficulty of distinguishing mopeds from motorcycles, the proportions were assumed to be two thirds 50 cc mopeds and one third motorcycles. The calculation of the unmonitored hours was completed using the City of Rome origin–destination table. The data show that the average daily flow of mopeds is 12% of total motor vehicle flow and the average CO concentration attributable to them is 21% (Annex 4).

Traffic flow according to the origin–destination table

The Rome Mobility Agency chose three tracts of roadway in the City of Rome located in correspondence with the Magna Grecia, Fermi and Marconi measurement stations. Using the TEE model, flows were calculated in terms of cars per day and two-wheeled vehicles per day and their related emissions.

This second approach was based on the use of the City of Rome origin–destination table and on applying planning models that allow a traffic flow to be assigned to every roadway in the City's primary network. These flows represent the average traffic on a non-rainy school and work day, calibrated by the monitoring station. This approach allows for evaluation on a broader spatial scale, considering several stretches of roadway corresponding to the three stations, as well as the flow of traffic corresponding not to a specific time span but to an average traffic flow.

The results show that mopeds represent 13–16% of total motor vehicles and cause 16–29% of overall CO pollution (Annex 4). The variability depends on the three stretches of road considered, which differ in flow and the average speed indicated by the origin–destination table. The TEE model is sensitive to speed and tends to reduce the CO emissions for thoroughfares that flow more rapidly.

In any case, this second model-based method provides values similar to those of the direct calculation method. It would be legitimate then to assume, based on the Rome Mobility Agency study, that mopeds emit 20% of the CO measured in Rome. The question remains what proportion of the PM10 concentrations measured by the stations is attributable to mopeds.

Attribution of PM based on Rome Mobility Agency data

Assuming that CO is the main indicator of vehicular traffic, it could be asserted that the CO level would be zero if there were no vehicles. Each component of the total circulating vehicles therefore contributes some amount of CO. Thus, a ratio is established between PM emissions and CO emissions for each category of vehicle. A weighted average was taken of the ratios between PM and CO to establish how many grams of PM are emitted by all motor vehicles in Rome except for mopeds. Annex 6 presents these data. An identical relationship was found between moped emission factors (Table 9), which establishes that mopeds emit 29 mg of PM for every gram of CO, and the total fleet of vehicles in Rome (weighted average) emit 15 mg of PM for each gram of CO.

Relating these two coefficients means that mopeds can be assumed to emit 1.9 times as much PM per gram of CO emitted as the average emissions of the total fleet of vehicles.

Arbitrarily assuming that the PM emitted by mopeds has a diameter of 10 μm, and having established that 20% of CO is attributable to mopeds, they would then be responsible for 38% of the PM10 concentrations measured at the monitoring stations and attributable to vehicular traffic.

Summarizing the final assumption of the method we can list:

CO concentration attributed to mopeds	20%
PM/CO ratio for mopeds out of the total rolling stock	1.9%
PM10 of vehicular origin attributable to mopeds	**38%**

3.2.2. Estimation using Italian Agency for the Protection of the Environment and for Technical Services methods

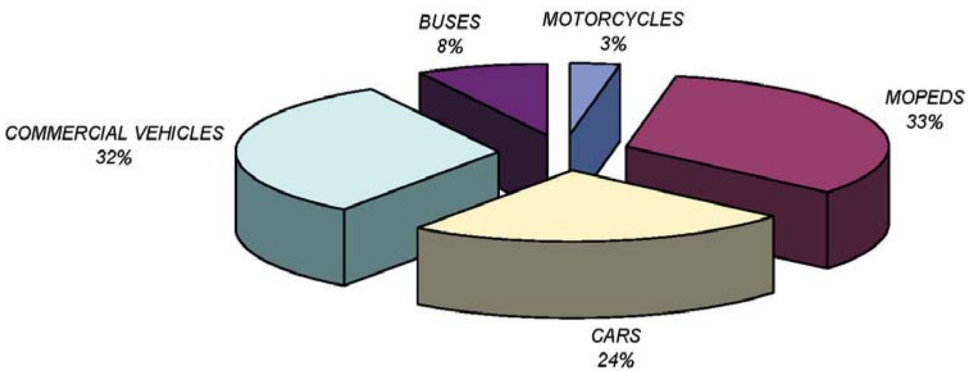
This estimate is based on the calculation of the PM emitted by mopeds as compared with that emitted by all motor vehicles in the City of Rome. Data on the composition of the total number of motor vehicles and on average annual distances travelled were supplied by ATAC SpA (the city bus company), Romatour (tourist bus company), Associazione Nazionale Autotrasporto Viaggiatori (regional bus company with departure terminals located in the City) and FITA-CNA (National Association of Small and Medium-sized Freight Transport Companies). The Rome Mobility Agency provided the remaining categories. COTRAL (responsible for public transport in the Rome region) and AMA SpA (Rome's public environmental services company) were unable to supply data on total vehicles or distances in the city. The data on mopeds are those discussed in this report. The PM coefficients in grams per km travelled for other vehicles are taken from COPERT III and from TNO – Netherlands Organisation for Applied Scientific Research (personal communication, 2003). As regards the COPERT factors, the baseline speed assumed for all vehicles is that indicated by the Rome Mobility Agency for cars and two-wheeled motor vehicles: 18.2 km/h. Annex 7 shows the complete table with data, specific emissions by vehicle category and explanatory notes. The total circulating vehicles emit 1939 tonnes of PM per year. Mopeds account for 33% of this: 647 tonnes per year.

Summarizing the final assumption of the method we can list:

PM emitted by the total circulating vehicles, tonnes/year	1 939
PM emitted by mopeds only, tonnes/year	647
PM of vehicular origin attributable to mopeds	**33%**

In this case, pollution emissions are reported as TSP (total suspended particulates) and not as PM10. In reality, the TNO (personal communication, 2003) factors for TSP and PM10 correspond and, as stated in section 3.1.1, the research institutes that perform motor tests agree that, for two-wheeled motor vehicles, the PM emitted is comparable to the PM10 emitted. Fig. 6 illustrates the proportion of PM emissions in Rome according to the type of motor vehicle (please refer to Annex 7).

FIG. 6. TOTAL PM EMISSIONS IN ROME IN 2000 ACCORDING TO TYPE OF VEHICLE



3.2.3. Estimate of the proportion of PM attributable to mopeds

The first study is valid since it is based on real traffic flows, but it refers to three narrow sections of the metropolitan area. In contrast, the second study quantifies the PM emissions for the entire urban area, but figures are derived based on distance and speed estimates that make it more uncertain.

Since the values do not differ much, it was believed appropriate to consider an intermediate value of 35% for PM of vehicular origin attributable to mopeds. Given that the PM10 concentration caused by urban vehicular emissions has been established at 60%, the contribution to PM10 pollution generated by mopeds is 35% times 60% = 21%.

Amount of urban PM10 concentrations attributable to mopeds = ………21%

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4. ROAD ACCIDENTS

The feasibility study investigated the availability of data on accidents involving mopeds, using Rome and Milan as sample cities. Three main types of data were available: accident statistics, specific studies on health impact and compensation paid by insurance companies. The fourth theoretically useful set of data consisted of the statistics on visits to emergency facilities and hospital admissions. These data, however, do not give information on the health impact of road accidents in general because of the difficulty in building a record linkage system between treatment facility admissions and the events that generate the need for hospital care. In other words, as maintained by Franco Taggi (personal communication) of the National Institute of Health, author of the Casco 2000 study, the hospital may record how many head injuries it treats but does not identify the cause of the trauma.

The feasibility study cites substantial difficulties in estimating the health effects of accidents and identifies this as an area requiring much more study, with another aim of finding feasible administrative provisions that might allow road accidents recorded by the police to be tracked inside treatment facilities.

4.1. Material and methods

The feasibility study drew on data on accidents "involving mopeds" that took place from 1995 to 2000 in the two sample cities of Rome and Milan.

The data were drawn from ISTAT (National Institute of Statistics) files in collaboration with the research department of the ACI Road Accidents Observatory. They extracted specific data for the two cities since ISTAT publications do not subdivide specific information on mopeds by city.

In addition to the data produced by ISTAT, data on the number of accidents from 1995 to 2000 "involving mopeds" were requested from the city police headquarters of Rome and Milan. The city police kindly supported the study by providing data and assistance.

Regarding the effects of accidents, the ISTAT (ISTAT & ACI, 2001) statistics offer only the total number of deaths and injuries and no indication for injuries about severity, type or any other element of prognosis. Health effects were estimated based on the sample studies of specific projects conducted on very small populations. The data from these studies were projected onto the data set of accidents in Milan and Rome, assuming that the same types of injuries can be detected for accidents involving mopeds.

The studies available and used include:

– National Association of Insurance Companies (personal communication) studies on a sample of 4 603 accidents involving mopeds between 1999 and 2000;

- MAIDS (Motorcycle Accidents In-depth Study) project studies[6] (Marinoni et al., 2000) on a sample of 128 mopeds involved in urban accidents between July 1999 and July 2000 in which 85% of the riders were wearing helmets; and
- studies on 659 emergency room visits following moped accidents in various Italian cities supplied by the Epidemiology and Biostatistics Laboratory of the National Institute of Health, which gathered data between April and June 2000 for a study on the effects of the new obligatory helmet law (personal communication, Franco Taggi and Marco Giustini, National Institute of Health, 2000; Giustini et al., 2000).

Evaluated, but not considered in the estimate, as they date back several years, were the SISI study (Taggi, 1993) and a study in Barcelona (Cirera et al., 2001).

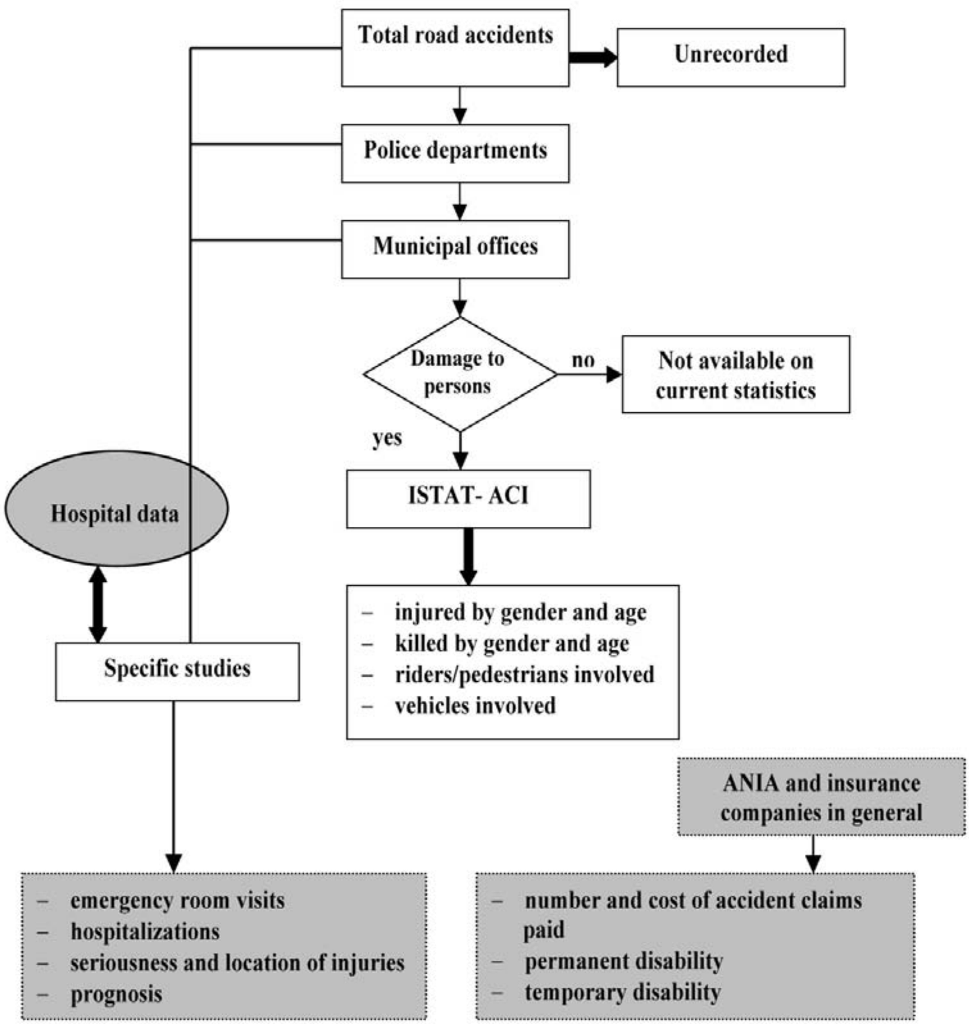
Further information came from data processed compiled by the Regional Public Health Agency of Lazio and based on emergency room visits in the City of Rome. Fig. 7 shows the flow and availability of the data supplied by the sources. For the purposes of the feasibility of a nationwide study, the following are important.

- ISTAT records only accidents that affect people; for municipalities with more than 25 000 inhabitants, it receives data from the city statistics offices that, in turn, collect the ISTAT forms filled by the police departments dealing with the accident.
- Of the total accidents, the current statistics do not take into account those in which the police did not intervene or those involving only property damage.
- The data on the health effects of accidents are not specific to the population examined but are drawn from studies conducted to this end on accident samples.
- The data owned by insurance companies constitute a separate archival source.

For estimating the health effects (the numbers of deaths and injuries) of moped accidents, we decided to study only 2000. Indeed, the data for 2001 were not yet available at that time, and prior to 2000 the obligatory helmet law was not yet in force for all riders. The feasibility study examined how the population of Italy is exposed to the use of the moped, which must be studied in terms of the laws in force. The distribution of the types of injuries reported and, in general, the severity of the effects of the accidents, vary after the entry into force of Law No. 472/99, which requires helmets to be worn by moped drivers of all ages, in contrast to the previous law limited to people younger than 18 years (Giustini et al., 2000).

[6] Data were still being analysed while this study was carried out.

FIG. 7. FLOW CHART FOR DATA RELATED TO ROAD ACCIDENTS IN ITALY



4.1.1. Reliability of data

As mentioned above, this feasibility study takes the year 2000 as its baseline. ISTAT & ACI (2001) cite a remarkably underestimated number of accidents as having taken place in the City of Rome in that year. Table 11 compares the data from the files of the two police headquarters of Rome and Milan with those of the ISTAT. For Milan, there is a slight deviation in the number of deaths and injuries for accidents in general. The number of mopeds is more uncertain. The 7% difference in this group could be considered as constituting the proportion of accidents that did not cause personal injury, which thus renders reliable the ISTAT figures on the numbers of people injured and killed. In contrast, Rome had a large deviation that, moreover, increased in 2000 compared with 1999 and was greater for those injured on mopeds. Thus, the ISTAT data do not constitute the total road accidents that took place in the city and cannot be used as absolute values but only as percentages relative to the other series of data being examined.

Table 11. Comparision of city police and ISTAT statistics

	City police	ISTAT	ISTAT compared with police	City police	ISTAT	ISTAT compared with police
Rome		**2000**			**1999**	
Number of accidents in which people were injured	19 767	9 070	–54.1%		13 435	
Number of people injured in road accidents	23 014	11 497	–50.0%	22 871	17 455	–23.7%
Number of people injured while riding mopeds	6 691	2 060	–69.2%	7 641	4 490	–41.2%
Number of people killed in road accidents	176	99	–43.7%	128	123	–3.9%
Number of people killed while riding mopeds	21	8	–61.9%	25	15	–40.0%
Milan						
Number of mopeds involved in accidents	4 561	4 236	–7.1%	4 833	4 436	–8.2%
Number of people injured in road accidents	22 273	22 996	+3.1%	22 850	23 678	+3.5%
Number of people killed in road accidents	112	114	+1.7%	77	80	+3.7%

Source: city police headquarters and ISTAT & ACI (2001).

The historical data for Rome show that, until 1998, the number of road accidents reported increased every year. They began to decrease in 1999 (13 435 versus 18 177 in 1998) and again in 2000 (9 070). According to the ACI, the partial nature of the data on Rome could result from the fact that the central municipality was responsible for transmitting information until 1998, but since 1999 it has been delegated to the 20 administrative districts in Rome, which perhaps had not yet set up the procedure in all its various aspects. Moreover, an automatic procedure had not yet been adopted for recording accidents such as the one used, although not to its full potential, in Milan.

As represented in Fig. 7, the data transmitted to the ISTAT do not represent all events, since police intervention is not requested in all accidents, especially those with minor consequences.

Further, the number of deaths from the statistics on road accidents is about 30–35% lower than that from health statistics (ISTAT & ACI, 2001; Taggi, 2001). This results in part from the difference in information sources and from the fact that, until 1998 only the deaths occurring within 7 days of the accident were recorded; this was later extended to 30 days in keeping with European Union regulations.

Finally, the numbers of people killed and injured from the summary tables for each accident at times do not correspond with the totals obtained from the detailed tables. Box 1 shows the data made available by the ISTAT that briefly illustrate the two groups of summary and detailed data, explains the reason for possible differences between the totals of the two series and estimates the underestimation of the total annual number of accidents in Italy.

ISTAT records on road accidents

The ISTAT files contain data on road accidents involving injury to people arranged as follows:

1. date, location, nature, circumstances of the accident and reference to the authority that recorded it;
2. summary information on the total number of people killed or injured in the accident;
3. detailed information on the type of vehicles; date of registration and total number of kilometres travelled by the vehicles; gender, age and health outcome (dead or injured) for each individual occupant (these detailed data have the limitation of being present solely for a maximum of three vehicles involved and, for each of these, only for the driver and four passengers); and
4. detailed information on the gender and age of up to four pedestrians involved.

In this chapter, the total number of people killed or injured was obtained by adding up the summary data in point 2, and the number of people killed or

their relative distribution by age group are drawn from detailed data in points 3 and 4.
In its publication on road accident statistics in 2000 (ISTAT & ACI, 2000), ISTAT notes evidence of significant underestimation indicated by the correlation between the number of accidents and the resident population of r = 0.938 and accidents and total vehicles of r = 0.946, whereas these variables are correlated at r = 0.997. In particular, ISTAT notes a decrease in the number of accidents between 1999 and 2000 presumably not corresponding to a real reduction in the phenomenon. The greatest decreases were observed in the regions of Molise (39%), Basilicata (31%), Puglia (26%) and Lazio (20%) in addition to the decrease in registered accidents in Rome in 1999. Considering the various organs reporting, a general decrease of about 13% was attributable to highway police and to a decrease in the data communicated by the city police of Lazio, Basilicata, Sardinia and Friuli-Venezia Giulia.

4.1.2. Other data sources potentially useful in studying road accidents

The ISTAT statistics on rates of death by cause were not used since, in addition to not distinguishing between the various types of two-wheeled vehicles, they were not available until too long after the event had occurred. Mortality data by cause at the municipal level are not available by means of current statistics but must be the object of agreements – at times even burdensome ones – to be made on a case-by-case basis with ISTAT.

Greater care is recommended in filling out forms for statistics and/or the obligatory use of standard systems of automatically recording accidents directly on the street. Another way would be regulation allowing accident databases to be linked with those of emergency rooms using a code, such as the patient's tax identification number.

Another important source of data is statistics on emergency room visits. As previously noted, the Regional Public Health Agency of Lazio is working on updating survey procedures that record data on the cause of the injury, allowing for a more reliable picture of road accidents with details on the types of vehicle and greater information on the health effects. For the purposes of geographical comparison of data on accidents and costs (see section 4.2.10), a system capable of recording injuries based on where they occur, in addition to where the injured party resides, would be desirable.

4.1.3. Indicators used to describe the results of accidents

The feasibility study considered the standard indicators used by ISTAT and ACI; it elaborated outcome rates for distances travelled and vehicles and adopted the Abbreviated Injury Scale and Injury Severity Score to measure the severity of accidents involving at least one moped in Milan and Rome.

The standard indicators used by ISTAT and ACI are:

- mortality = people killed per 1 000 accidents;
- injury rate = people injured per 1 000 accidents; and
- severity = people killed per 1 000 accidents (those involving either death or injury).

The rates calculated for the City of Rome for mopeds, motorcycles and automobiles are:
- number of people injured per million circulating vehicles;
- number of people injured per billion km travelled;
- number of people killed per million circulating vehicles; and
- number of people killed per billion km travelled.

Table 12 illustrates the Abbreviated Injury Scale, which is applied to each individual injury. In studies evaluating the effects of an accident, health care personnel code the injury by assigning an Abbreviated Injury Scale score to each injury, referring to the area of the body involved.

TABLE 12. ABBREVIATED INJURY SCALE CODE

Severity of injury	Description
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Fatal

The Injury Severity Score, in contrast, refers to the patient, and can be defined as follows: (1) the highest Abbreviated Injury Scale code is taken for each injured part of the body; (2) of the total Abbreviated Injury Scale codes obtained, the squares of the three highest values are summed. Thus, the Injury Severity Score can range from 0 to 75, which is the highest value (3 times $5^2 = 75$). If the Abbreviated Injury Scale code is 6 (fatal injury) the Injury Severity Score assigned is automatically 75. The Injury Severity Score also indicates mortality, morbidity and hospitalization rates but, as it is calculated by means of the square of the code for each injury, it can amplify eventual errors in the Abbreviated Injury Scale score assigned (Baker et al., 1974).

4.2. Results

4.2.1. Overall picture of accidents in Rome and Milan: ISTAT data

The ISTAT has data on the number of accidents, deaths and injuries in Rome and Milan according to age group for 1995–2000. As described in section 4.1.1 and illustrated in Table 11, the ISTAT data on Rome are not accurate, as they are underestimated by at least 50%.

Table 13 shows the number of moped injuries and of accidents in general in Rome and Milan.

"Involving mopeds" means accidents with at least one moped involved, regardless of the number of other vehicles involved, occupants, responsibility, the presence of pedestrians, etc. Finally, the term "occupants" means drivers plus passengers.

TABLE 13. DISTRIBUTION OF PEOPLE INJURED WHILE RIDING MOPEDS, 2000

	Total vehicles		Involving mopeds		Of which only while riding mopeds	
	Rome	Milan	Rome	Milan	Rome	Milan
Number of accidents	9 070	16 378	2 091	4 155		
Total injured people	11 497	22 996	2 392[a]	4 814[a]		
Occupants injured	10 634	21 020	2 244[a]	4 576[a]	2 060	4 323
Number of which were passengers					124	7
Pedestrians injured	863	1976	147[a]	236[a]		
Total deaths	99	114	11	14		
Occupants killed	76	80	10	13	8	12
Pedestrians killed	23	34	1	1		

Source: city police headquarters and ISTAT & ACI (2001).

[a] *The summary and detailed data differ (see Box 1).*

4.2.2. Deaths and injuries by age group

The age groups in the following table and charts are not homogeneous. This is because it was preferable to differentiate the various types of moped user. In particular, the third and fourth age groups combined are the same size as the subsequent groups.

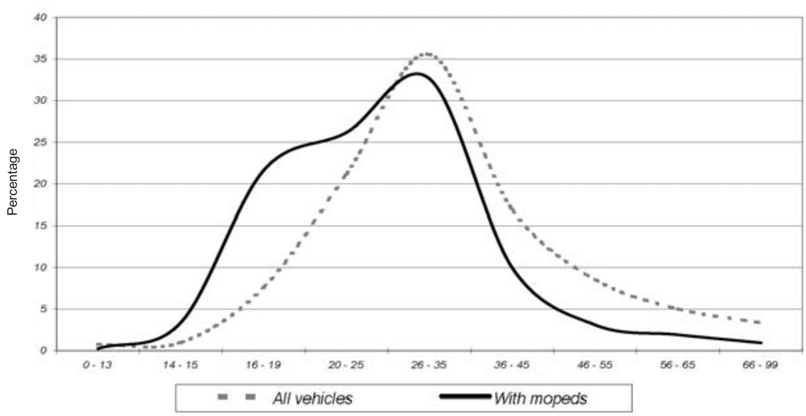
Table 14 and Fig. 8 illustrate the distribution by age group of injuries for all accidents and for those while riding mopeds. The distribution confirms the lower age of injuries for the moped group, but the group aged 26–35 years contains about one third of the injuries in both groups of vehicles, and about 80% of those injured on mopeds are between 16 and 35 years of age. The result, as is known through the public health system, is a matter of concern for the entire society.

TABLE 14. DISTRIBUTION OF INJURY PERCENTAGES IN ITALY ACCORDING TO AGE GROUP, 2000

Entire population[a]		People injured in accidents in general				People injured while riding mopeds			
Age (years)	%	Rome[b]		Milan		Rome[b]		Milan	
		n	%	*n*	%	*n*	%	*n*	%
0–13	13	107	1.5	156	0.8	8	0.5	6	0.1
14–15	2	90	1.3	203	1.0	74	4.2	123	2.9
16–19	4	601	8.6	1 526	7.4	406	23.3	911	21.2
20–25	8	1 461	20.8	4 623	22.5	432	24.8	1 193	27.7
26–35	16	2 345	33.4	7 484	36.4	544	31.2	1 429	33.2
36–45	15	1 214	17.3	3 184	15.5	180	10.3	392	9.1
46–55	13	608	8.7	1 641	8.0	58	3.3	120	2.8
56–65	12	334	4.8	1 044	5.1	24	1.4	97	2.2
66–99	17	254	3.6	689	3.3	18	1.0	34	0.8
		7 014[c]		20 550[c]		1 744[c]		4 305[c]	

Source: ISTAT.
[a] *Until 1 January 2001.*
[b] *Rome values underestimated by about 50%: see section 4.1.1.*
[c] *Differences between summary and detailed data (see Box 1).*

FIG. 8. AGE GROUPS OF PEOPLE INJURED IN ROAD ACCIDENTS IN ROME AND MILAN, 2000



Source: ISTAT.

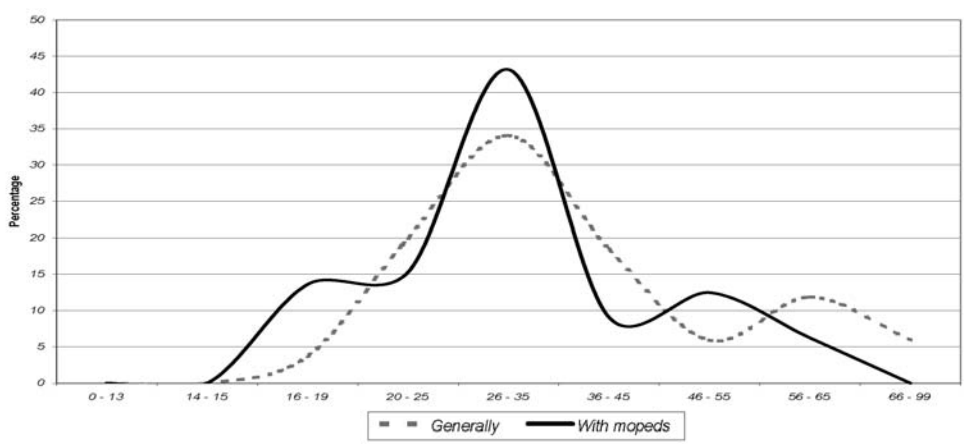
Similarly, Table 15 and Fig. 9 list the age group percentages for deaths in road accidents in Rome and Milan. The trend highlighted is similar to that for injuries, which peaks in the age group 26–35 years. Nevertheless, Fig. 9 shows that fatalities in the age group 26–35 years are more frequent with mopeds than with other vehicles. Any general conclusions must be drawn cautiously from Table 15 since the absolute number of deaths while riding mopeds is low.

TABLE 15. DISTRIBUTION OF PEOPLE KILLED IN ROAD ACCIDENTS AND WHILE RIDING MOPEDS IN ITALY ACCORDING TO AGE GROUP, 2000

General population[a]		Total road accident deaths				Deaths while riding mopeds			
Age (years)	%	Rome[b]		Milan		Rome[b]		Milan	
		n	%	*n*	%	*n*	%	*n*	%
0–13	13	0	0.0	0	0.0	0	0.0	0	0.0
14–15	2	0	0.0	0	0.0	0	0.0	0	0.0
16–19	4	1	1.5	6	7.7	0	0.0	4	33.3
20–25	8	14	20.6	17	21.8	1	12.5	2	16.7
26–35	16	24	35.3	26	33.3	4	50.0	4	33.3
36–45	15	15	22.1	11	14.1	0	0.0	2	16.7
46–55	13	5	7.3	3	3.8	2	25.0	0	0.0
56–65	12	6	8.8	10	12.8	1	12.5	0	0.0
66–99	17	3	4.4	5	6.4	0	0.0	0	0.0
		68[c]		78[c]		8		12	

Source: ISTAT.
[a] *Until 1 January 2001.*
[b] *Rome values underestimated by about 50%: see section 4.1.1.*
[c] *Differences between summary and detailed data (see Box 1).*

FIG. 9. AGE GROUPS OF PEOPLE KILLED IN ROAD ACCIDENTS IN ROME AND MILAN, 2000

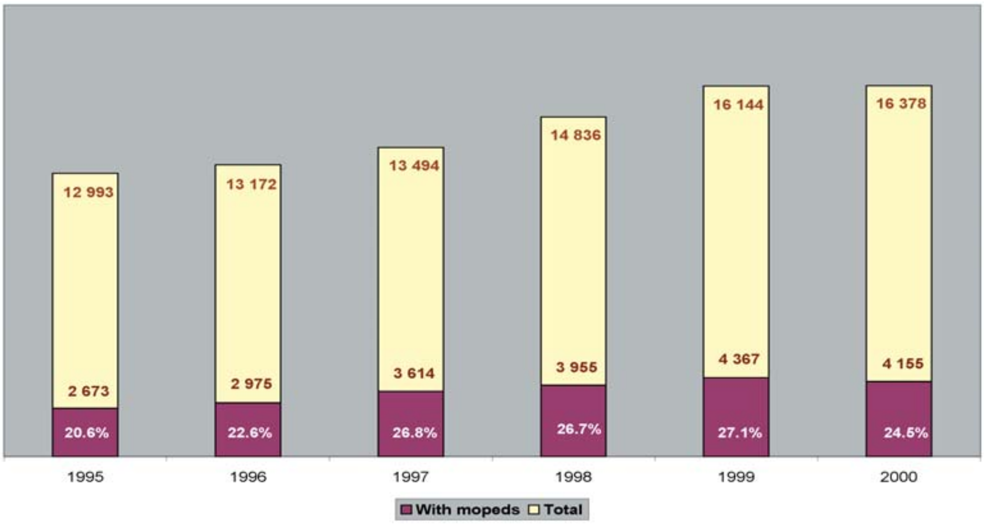


Source: ISTAT.

4.2.3. Time trend

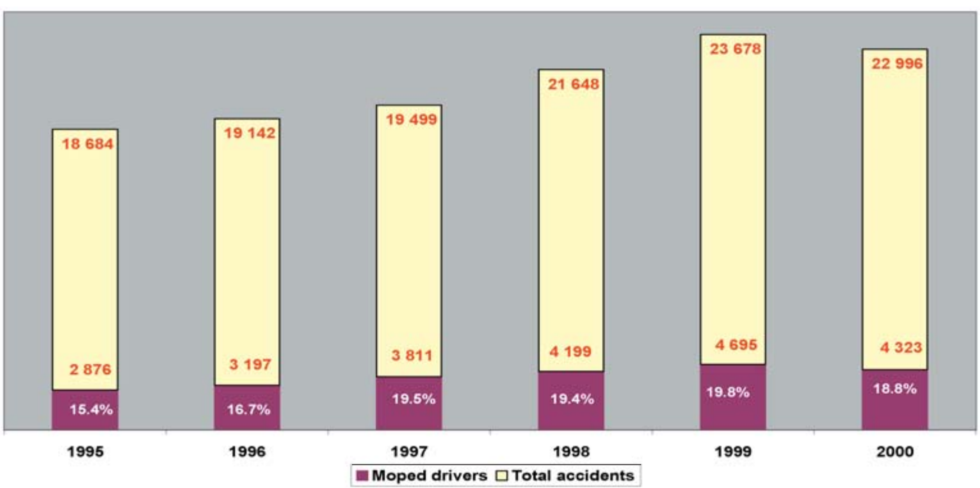
Fig. 10 and 11 compare the data from 1995 to 2000 for the city of Milan.

FIG. 10. NUMBER OF TOTAL ROAD ACCIDENTS AND ONES INVOLVING MOPEDS IN MILAN, 1995–2000



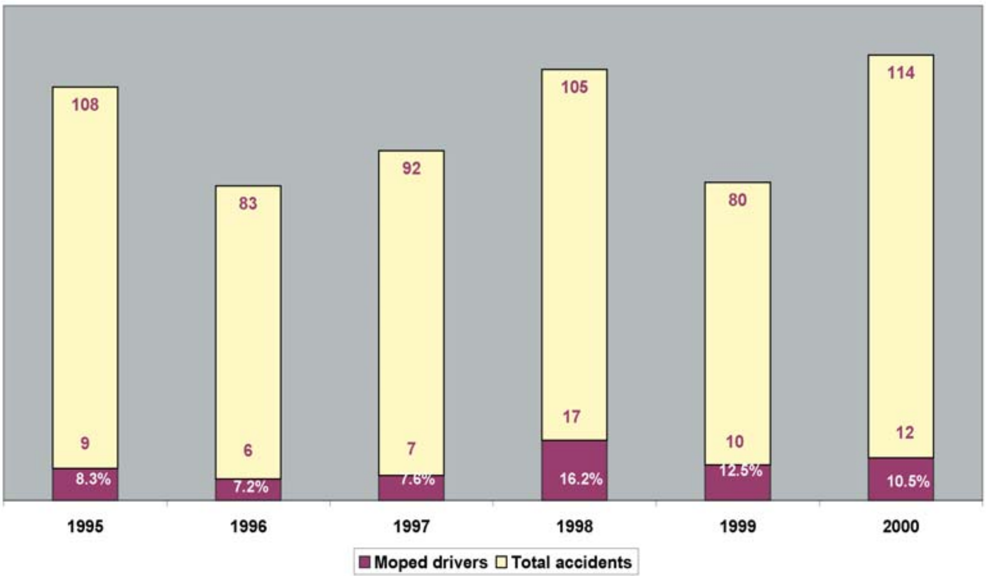
Source: ISTAT.

FIG. 11. NUMBER OF TOTAL ROAD ACCIDENTS INJURIES AND ONES INVOLVING MOPEDS IN MILAN, 1995–2000



Source: ISTAT.

FIG. 12. NUMBER OF TOTAL ROAD ACCIDENTS DEATHS AND ONES INVOLVING MOPEDS IN MILAN, 1995–2000[a]



Source: ISTAT.
[a] The system of death registration changed in 1999, as records began to be kept of deaths up to 30 days after the accident.

All the variables show the same trend over time: rising until 1999 and levelling off, or slightly declining, in 2000. The trend for the number of people killed is more irregular. The system of death registration changed in 1999 to include deaths up to day 30 after the accident. Previously death was attributable to the accident when it occurred within seven days of the accident. The data shown are those of Milan, given that the ISTAT data on Rome include a varying underestimate over time. Nevertheless, the percentage of road accidents, injuries and deaths in Rome involving mopeds can be compared over time (Table 16). These are 36–37% from 1995 to 1998, 33% in 1999 and 23% in 2000. In Milan the comparable figures are on the same order of magnitude but smaller: 25% in 2000, 27% from 1997 to 1999 and about 22% between 1995 and 1996. Comparison of the two cities could tend to indicate that moped use in Milan is increasing. Rome's 23% in 2000, although a percentage value, could be distorted by the ISTAT underestimates illustrated in section 4.1.1. For this reason the column regarding the year 2000 should not be used in comparing over time.

TABLE 16. ACCIDENTS, INJURIES AND DEATHS INVOLVING MOPEDS AS PERCENTAGES OF TOTAL ROAD ACCIDENTS IN ROME

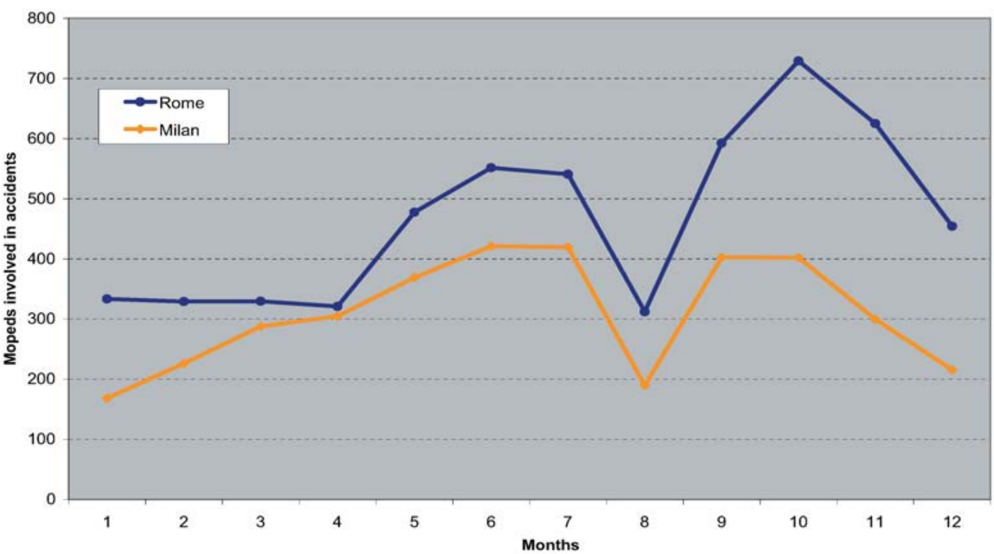
Years	Rome					
	1995	1996	1997	1998	1999	2000[a]
Accidents involving mopeds (%)	35.6	37.5	37.6	37.6	32.8	23.1
Mopeds out of total vehicles in accidents (%)	21.1	20.7	21.9	21.3	19.2	13.8
People injured in moped accidents out of total road injuries (%)	32.4	32.0	34.2	33.5	29.6	20.8
People killed in moped accidents out of total road deaths (%)	11.6	20.5	11.5	14.0	14.6	11.1

Source: ISTAT.
[a] *The percentage decrease shown for 2000 could be an effect of the underestimate mentioned in section 4.1.1.*

4.2.4. Frequency of injuries during the year

Fig. 13 shows the frequency of accidents involving at least one moped.

FIG. 13. MONTHLY PATTERN OF ACCIDENTS INVOLVING MOPEDS IN ROME AND MILAN, 1995–2000



Source: ISTAT.

The trend in the number of accidents per month is remarkably similar between Rome and Milan. The largest numbers of accidents occur in the months immediately before and after August. If the frequency of accidents is assumed to indicate vehicle use, in both cities use declines during August and also during winter, more markedly in Milan than in Rome. The peak of 700 accidents with injuries recorded in the City of Rome from September to November could be explained by the reopening of schools along with the climate's characteristic mildness.

4.2.5. Nature of injuries

Table 17 shows the circumstances that provoke injuries. Sixty per cent of the accidents involve the side of the vehicle. From the viewpoint of road safety, this would reinforce the conclusions of the MAIDS project studies (Marinoni et al., 2000), already postulated by motorcycle manufacturers, that the invisibility of two-wheeled motor vehicles to drivers of other vehicles is an important cause of accidents.

Indeed, the moped user's manual recommends wise choices such as using bright clothing and headlights even in daytime. In any case, the percentage of accidents caused by loss of control is high (11–16%). In reality, Taggi (1993) estimates that about 85% of accidents with injuries are caused by loss of control. Taggi studied this phenomenon by means of interviews with emergency treatment facilities. The police do not record many minor injuries, especially when they do not involve other vehicles, even when the injured person uses emergency medical services. The difference between the statistics drawn from the forms filled out by the police and Taggi's study (as Taggi notes) results from the large number of these minor accidents.

TABLE 17. MOPED ACCIDENTS WITH INJURIES IN ROME AND MILAN ACCORDING TO THE TYPE OF ACCIDENT

Type of accident	Rome (%)	Milan (%)
Head-on collision	4.78	2.84
Frontal-lateral collision	37.73	39.81
Lateral collision	25.49	15.84
Rear-end collision	10.09	6.57
Pedestrian struck	6.41	5.05
Collision with stopped vehicle	2.97	8.23
Collision with standing vehicle	0.67	1.88
Collision with obstacle	0.96	3.27
Swerving	9.90	10.54
Sudden braking	0.67	0.89
Fall from vehicle	0.33	5.08

Source: ISTAT.

4.2.6. *Severity of accidents*

Table 18 displays data on injury, death and the danger potential of road accidents in Rome and Milan involving all vehicles as well as at least one moped.

TABLE 18. INJURY, DEATH AND DANGER POTENTIAL OF ROAD ACCIDENTS IN ROME AND MILAN, 2000

INDICATORS	All vehicles		Mopeds	
	Milan	Rome	Milan	Rome
A. Injuries per 1000 accidents	1 404	1 268	1 159	1 144
B. Occupants injured per 1000 vehicles involved	571	670	1 021	949
C. Deaths per 1000 accidents	7	11	3	5
D. Deaths per 1000 people involved in accidents	5	9	3	5
E. Pedestrians injured per 1000 accidents	121	95	57	70
F. Pedestrians killed per 1000 accidents	2	3	0.2	0.5

Source: ISTAT.

The injury rate is calculated as the ratio between the number of injured people and the number of accidents related to the vehicle in question. Mortality is the ratio between the number of people killed and the number of injuries. The severity is the ratio between the number of deaths and the number of people involved in accidents involving death or injury (ISTAT & ACI, 2001). The rate of occupants injured per 1 000 vehicles involved in accidents is also calculated.

The injury rate (A) suggested by ISTAT cannot be used in evaluating the differences between different vehicles (such as four-wheeled versus two-wheeled). As mentioned in section 4.1, ISTAT records only accidents in which there is “injury to people” and not all accidents. For example, the simple city-street accident between two cars resulting in no injury is not included in the statistics, leaving the injury rate in accidents involving cars apparently equal to that of mopeds. On the other hand, the number of occupants injured per 1 000 vehicles involved (B) can be used to point out the greater likelihood for injuries in accidents with mopeds (an average of 94% of all cases) as compared with vehicles in general (an average 62%).

The death (C) and severity (D) rates lead to the consideration that when an urban accident injures people, the average consequences of those involving mopeds are less lethal than others despite the higher probability of injuries, even severe ones. Table 19 shows the greater probability of exposure to bodily injury when riding a moped but the limited risk of death. In accidents involving mopeds and with personal injury, 93.3% record injuries, whereas the mortality rate remains low at 0.3% of accidents.

TABLE 19. RESULTS OF ACCIDENTS AMONG MOPED RIDERS IN MILAN, 1998–2000

RESULT	%
Uninjured	6.4%
Injured	93.3%
Killed	0.3%

Source: ISTAT.

The WHO project staff analysed various data from the viewpoint of public health, with the aim of establishing a more reliable injury potential parameter than the one that can be drawn from current ISTAT statistics. Table 20 describes four indicators: the number of people injured and killed per number of vehicles circulating and per number of kilometres travelled. No data were available on the total number of vehicles and distances travelled for Milan.

Table 20 highlights the severe impact of urban road traffic on pedestrians. From the viewpoint of road safety and public health, municipalities should seriously consider adopting policies to safeguard these users of city roads. WHO recommends daily physical activity on foot and by bicycle, but public policy must allow this recommendation to be carried out in a practical and safe manner.

The results show, both in terms of the number of vehicles as well as kilometres travelled, that travelling by two-wheeled motor vehicle is riskier than travelling by car, and that, among two-wheeled motor vehicles, those with larger engines are more dangerous. In particular, the rate ratio (Table 21) indicates that the risk of being injured on a motorcycle in Italy is 4.46 times greater than in a four-wheeled vehicle, for each circulating vehicle versus 3.18 times for mopeds. The risk associated with two-wheeled motor vehicles as a group is 3.54 times greater than that associated with four-wheeled vehicles.

Table 20. Accidents in relation to total circulating vehicles and distances travelled in Rome, 2000

	Private and commercial automobiles	Motorcycles	Mopeds	Cyclists	Pedestrians
Vehicles circulating	1 972 000	177 000	443 000		
Total distance driven annually (km)[a]	9.052 billion	1.062 billion	2.658 billion		
People injured[b]	9 377	3 752	6 691	181	3 013
People killed[b]	39	35	21	5	76
People injured per 10^6 vehicles circulating	4 755	21 198	15 104		
People killed per 10^6 vehicles circulating	20	198	47		
People injured per 10^9 km travelled	1 036	3 533	2 517		
People killed per 10^9 km travelled	4	33	8		

Source: WHO elaboration of data from (a) Rome Mobility Agency and (b) Rome City Police.

The number of people killed and injured refers to the accidents registered by the Rome City Police throughout the Rome metropolitan area, which includes large thoroughfares such as the Grande Raccordo Anulare (the city ring road). Nevertheless, based on the ISTAT data on Rome, the Rome City Police records 74% of the accidents reported to ISTAT (26% are recorded by other police authorities), and at least 72% of these take place along city streets. The table therefore represents well the relative risk of vehicles in the urban context.

TABLE 21. COMPARISON OF INJURY AND DEATH POTENTIAL RATIOS FOR TWO-WHEELED VERSUS FOUR-WHEELED MOTOR VEHICLES IN ROME, 2000

INDICATORS	Motorcycles versus total four-wheeled vehicles	Mopeds versus total four-wheeled vehicles	Total two-wheeled versus total four-wheeled vehicles
People injured per 10^6 vehicles circulating per year	4.46	3.18	3.54
People killed per 10^6 vehicles circulating per year	9.90	2.35	4.52
People injured per 10^9 km per year	3.41	2.43	2.71
People killed per 10^9 km per year	8.25	2.00	3.76

Source: Rome Mobility Agency and Rome City Police.

4.2.7. *Accident frequency and effects: National Association of Insurance Companies data*

The National Association of Insurance Companies, which encompasses 98% of all insurance companies in Italy, performs annual analysis to determine the number, frequency and average cost of accidents for which compensation is paid according to the policy-holder's province of residence. Annex 8 lists provincial data from 1998 to 2000, arranged according to the accident frequency calculated in 2000.

Table 22. Frequency and average costs of accidents for which mopeds are partially or totally responsible in the Provinces of Milan and Rome and in Italy as a whole, 1998–2000

	Insured motor vehicles	Number of accidents	Frequency of accidents (% of insured motor vehicles)	Average cost (euros)	Of the average cost, amount for personal compensation (euros)
1998					
Province of Milan	121 551	6 589	5.42	1 600	880
Province of Rome	112 281	11 278	10.04	1 625	893
National totals and averages	2 306 985	133 570	5.79	1 435	789
1999					
Province of Milan	140 154	7 824	5.58	1 723	1 034
Province of Rome	129 233	12 285	9.51	1 881	1 129
National totals and averages	2 680 271	148 514	5.54	1 629	461
2000					
Province of Milan	144 031	7 759	5.39	1 796	1 149
Province of Rome	151 032	10 868	7.20	2 148	1 375
National totals and averages	2 800 324	129 490	4.62	1 907	1 221

Source: data from the National Association of Insurance Companies.

The information on the frequency of accidents (Table 22) could indicate vehicle use or density but is affected by variables barely under statistical control, such as driving style, fraudulent insurance claims and policies often taken out in provinces other than the one in which the operator actually uses the vehicle.

For comparison with the rest of the total circulating vehicles, the National Association of Insurance Companies kindly furnished the 2000 data for cars alone. These show a frequency of accidents (as a percentage of total motor vehicles) of 12.2% in Milan and of 13.6% in Rome. The average costs of a car accident were €2 670 in Milan and €2 363 in Rome, and 55% of this (based on the national average) was compensation for injury to people (€1 468 in Milan and €1 300 in Rome).

These data supplement those already supplied and do not allow for comparison, since they refer to entire provinces and not to the Cities of Milan and Rome alone. The average cost and, even more so, frequency of accidents is higher in Rome than in Milan, and both cities exceed the national average for this parameter. The amount of compensation for personal injury is about €1 250 per accident. Nevertheless, these data do not include accidents caused by loss of control or for which another vehicle is entirely at fault and therefore represent only some of the accidents involving mopeds.

Permanent and temporary disability

Table 23 quantifies in percentages the physical and social effects caused by moped accidents. The data derive from a sample study carried out by the National Association of Insurance Companies on 40 000 accidents with injury to people from 1998 to 2000. Of these, 4 603 (about 11%) involved mopeds. The National Association of Insurance Companies statistics on temporary and permanent disability were used in estimating the social costs.

TABLE 23. EFFECTS OF ACCIDENTS INVOLVING MOPEDS IN ITALY, 1998–2000

	Number of cases	Minimum	Maximum	Median	Average	Standard deviation	Average per accident for all vehicles
Percentage of permanent disability	3 017	1%	89%	3	3.8	4.06	3.05 (40 000 cases)
Days of temporary disability	4 603	1	712	64	49	33	53 (40 000 cases)

Source: data from the National Association of Insurance Companies.

The average duration of temporary disability in accidents is slightly shorter for injuries suffered on mopeds, whereas permanent disability is more severe, although only slightly. Permanent disability was acknowledged in 65% of cases with personal injury, even though the percentage of disability in most cases is very low.

4.2.8. Severity and health effects of accidents: sample studies

As mentioned previously, the effects of accidents could be evaluated in terms of injuries and treatment by means of ad hoc studies performed on accident samples.

MAIDS study

The data presented here were taken from the MAIDS study, a direct and detailed examination of motorcycle and moped accidents in five European countries. The study, which also collects data on how accidents happen, is still underway (year 2002). The Department of Applied Health Sciences of the University of Pavia, which coordinates the data collected in Italy and manages the databank, kindly allowed the WHO European Centre for Environment and Health access to the data for Italy and some early attempts to describe health effects.

The sample consists of 128 urban accidents involving at least one moped: 35 of these took place before the obligatory helmet law for riders of all ages entered into force in 2000 and 93 afterwards.

Table 24 lists 260 injuries suffered by 134 emergency room patients, according to the Abbreviated Injury Scale by anatomical area. The Abbreviated Injury Scale code indicates the severity of individual injuries, focusing not on severity in and of itself but on threat to survival. The code was introduced in 1969 and since then has been continually revised and monitored by the Association for the Advancement of Automotive Medicine (Copes et al., 1989).

Table 24. Injury percentage by anatomical area and Abbreviated Injury Scale code for a sample of 128 moped accidents

	Abbreviated Injury Scale code					
Anatomical area	**AIS 1**	**AIS 2**	**AIS 3**	**AIS 4**	**AIS 5**	**Total**
Head	9.62%	3.46%	1.54%	1.15%	1.92%	17.69%
Neck	10.77%					10.79%
Chest	1.15%		0.77%		0.38%	2.31%
Upper limbs	12.31%	4.62%				16.92%
Abdomen	2.31%					2.31%
Pelvis	0.77%	1.54%				2.31%
Spinal column	0.38%					0.38%
Lower limbs	25.77%	8.08%	2.69%			36.54%
Entire body	10.77%					10.77%
Totals	73.85%	17.69%	5.00%	1.15%	2.31%	100.00%

Source: personal communication, Alessandra Marinoni and Mario Comelli, Department of Applied Health Sciences, University of Parma.

Head injuries comprise 18% of all injuries, and limb injuries are the most numerous. In addition, 23 injuries (17%) were treated in hospital, and the average duration of hospital stay was 14 days (range 2–59 days).

Casco 2000 study

The Epidemiology and Biostatistics Laboratory of the National Institute of Health provided the data illustrated below from the database of the Casco 2000 study (personal communication, Franco Taggi and Marco Giustini, National Institute of Health, 2000; Giustini et al., 2000). This study, whose final results are in the process of being published, deals with emergency room access in many cities in Italy. The present feasibility study selected eight cities with a significant number of moped accidents. The sample comprised 1 548 cases, 659 of them after the mandatory helmet law for riders of all ages entered into force. The differences in the two columns of Table 25 are interesting. The most frequent type of injury is to the limbs, the incidence of head injury diminished notably after the helmet law entered into force and about one fourth of those injured suffer multiple injuries. Helmet use tends to increase the incidence of whiplash.

In addition, after the helmet law entered into force, head injuries occurred in 17% of cases versus 37% before.

TABLE 25. INJURIES IN MOPED ACCIDENTS IN EIGHT CITIES IN ITALY ACCORDING TO THE PART OF THE BODY INJURED AND ACCORDING TO WHETHER THEY OCCURRED BEFORE OR AFTER THE MANDATORY HELMET LAW FOR MOPED RIDERS OF ALL AGES ENTERED INTO FORCE

Part of the body injured	Before mandatory helmet law	After mandatory helmet law
Limbs	53.5%	72.0%
Limbs + neck (whiplash)	9.7%	11.5%
Head injury	5.0%	2.3%
Head injury + limb injury	22.3%	9.4%
Head injury + limb injury + neck injury	9.5%	4.9%

Source: National Institute of Health, Epidemiology and Biostatistics Laboratory, Department of Biostatistical Methods and Models, unpublished data.

Table 26 shows the recovery prognosis in terms of the number of days assigned to emergency room patients. The entry into force of the helmet law produced no significant differences, except for reductions in the longest prognoses, indirectly confirming the importance of this law. Indeed, the excess injuries described in Table 25, mainly head injuries, can probably be attributed to fatalities that do not appear in the table of those hospitalized. Once the risk of death is reduced by wearing a helmet, the average injuries reported in accidents are practically all of the same type and severity.

TABLE 26. RECOVERY PROGNOSIS IN MOPED ACCIDENTS IN EIGHT CITIES IN ITALY IN DAYS ACCORDING TO WHETHER THEY OCCURRED BEFORE OR AFTER THE MANDATORY HELMET LAW FOR MOPED RIDERS OF ALL AGES ENTERED INTO FORCE

Days	Before mandatory helmet law	After mandatory helmet law
0	9.7%	9.3%
1–4	11.2%	10.2%
5–9	40.3%	39.5%
10–14	16.2%	22.1%
> 15	22.7%	18.8%

Source: National Institute of Health, Epidemiology and Biostatistics Laboratory, Department of Biostatistical Methods and Models, unpublished data.

As an index of injury severity in these types of accidents, 18.8% have a prognosis of 15 days or more. Table 27 lists the health care outcome, surveyed after the injured party's arrival in the emergency room. In this case, following the entry into force of the obligatory helmet law in 2000, the number hospitalized declined to 17% of those injured in accidents.

TABLE 27. HEALTH CARE OUTCOME AFTER ENTERING THE EMERGENCY ROOM IN MOPED ACCIDENTS IN EIGHT CITIES IN ITALY BEFORE AND AFTER THE MANDATORY HELMET LAW FOR MOPED RIDERS OF ALL AGES ENTERED INTO FORCE

Destination	Before mandatory helmet law	After mandatory helmet law
Not hospitalized	**78.6%**	**83.0%**
Sent home	70.8%	76.3%
Hospitalization refused	7.8%	6.7%
Hospitalized	**21.4%**	**17.0%**
Casualty ward	6.1%	3.8%
Specialized ward	14.3%	12.6%
Transfer to another hospital	1.0%	0.7%

Source: National Institute of Health, Epidemiology and Biostatistics Laboratory, Department of Biostatistical Methods and Models, unpublished data.

This figure coincides with the MAIDS study findings that differentiate the percentage of severe injuries (17%) from minor injuries (83%). Economists then used this parameter to estimate the cost of accidents.

Table 28 shows the distribution of injuries based on the Injury Severity Score calculated by the National Institute of Health. The table confirms the radical reduction of severe cases after the new helmet law entered into force.

The Injury Severity Score is applied to people with multiple injuries and not to the individual injury, as in the Abbreviated Injury Scale. As described in section 4.1.3, the Injury Severity Score is calculated by taking the sum of the squares of the three highest values on the Abbreviated Injury Scale, taking one only for each injured part of the body. For example, if an accident involves abrasion and fracture of a limb, the Injury Severity Score considers the Abbreviated Injury Scale relative to the fracture. Injury Severity Score values range from 0 to 75; if an Abbreviated Injury Scale index of 6 is assigned (fatal injury) then the Injury Severity Score is automatically assigned 75. The Injury Severity Score simultaneously indicates mortality, morbidity and hospitalization.

TABLE 28. SEVERITY OF MOPED ACCIDENTS IN EIGHT CITIES IN ITALY ACCORDING TO THE INJURY SEVERITY SCORE BEFORE AND AFTER THE MANDATORY HELMET LAW FOR MOPED RIDERS OF ALL AGES ENTERED INTO FORCE

Injury Severity Score	Before mandatory helmet law	After mandatory helmet law
1	34.6%	40.4%
2	32.3%	30.9%
3	7.4%	6.8%
4	5.4%	7.8%
5	10.1%	8.1%
6	3.4%	1.4%
7–8	0.6%	0.6%
9	2.2%	2.2%
10	1.2%	1.4%
11–15	1.1%	0.4%
16–19	1.1%	0.0%
20–34	0.6%	0.0%

Source: Franco Taggi and Marco Giustini, National Institute of Health, 2000, unpublished.

4.2.9. Health effects: rehabilitation data

No data were available to quantify rehabilitation costs; the only information comes from the Italian Severe Brain Injury and Rehabilitation Study Group (GISCAR), which indicates that about 70% of the people treated were injured in road accidents (Zampolini, 2003).

4.2.10. Estimates based on emergency room access

The Regional Public Health Agency of Lazio estimated road accident injuries in the Rome area for 2000 based on the data of the emergency health information system and those in hospital discharges. Unfortunately, the data from these archives do not indicate with any certainty the cause of the road accident. The only information available is on the part of the body injured and the place where the accident occurred. The study therefore considered all injuries originating in the "street", and later a further selection was made to identify those that could be associated with road accidents. Annex 12 presents the methods used and the results of the study in their entirety. Nevertheless, given the large number of cases, this section includes some data to compare with those of the other studies.

The number of people injured in road accidents was estimated to be 73 946. This number is much higher than the number reported by the city police for the same year (Table 11). This could result from selection criteria that do not sufficiently filter road accidents. Nevertheless, this deviation could account for some cases not reported to the police. After all, the data must reflect the underestimation of the phenomenon obtained when the ISTAT data are considered alone, even when data are not recorded or transmitted, as happened in Rome for 2000 (Table 11). The Regional Public Health Agency of Lazio is working on modifying the procedures for surveying emergency room visits to obtain more complete statistics.

Similar to the sample studies examined, the data on the various types of injuries and on admissions to hospital facilities reveal that injuries to limbs are the most numerous, followed by those to the neck and head. Annex 12 shows a peak in injuries, especially those to the head and limbs, in the age group 15–24 years that could indicate a greater incidence in events related to moped use. With regard to outcome, 86% were sent home, 7.5% refused hospitalization and only 1% of the cases exceed 60 days of hospitalization. In some cases, the causes of later hospitalization were traced back to the same event.

Finally, information could be traced for a small number of cases (about 12 000) to calculate the cost of hospitalization based on diagnosis-related group[7] rates (standard fixed rates paid to hospitals by public health authorities in Italy according to the services provided). The average cost for hospitalization was €2 446 excluding emergency room costs.

These data cannot be used for this feasibility assessment, since the study led by the Regional Public Health Agency of Lazio cannot provide the number of moped accidents (or with two-wheeled vehicles in general) compared with the total. Nor is the number of deaths comparable with the data provided by ISTAT since only the deaths in hospital or on the way to hospital are included, whereas those occurring at the scene of the accident are not.

4.3. Use of helmets

Data on the usefulness of wearing a helmet in reducing the effects of accidents, especially severe ones, to riders of two-wheeled motor vehicles were supplied previously. Nevertheless, road accidents constitute the main cause of death in people under 40 years of age. Although the mortality rate per 100 000 population has declined over the last 30 years, it has not among those 15–29 years of age. Additional data on this subject would be helpful.

Taggi (2001) used a model (Taggi, 1984) to estimate that the transition from 20% of all moped riders using helmets before the law (1985) to 50% in 2000 was associated with a 17% decline in the number of deceased, disabled and accident victims in Italy. The transition from 20% to 90% of riders younger than 18 years led to a reduction of 40% in this group. In practice, every percentage point of increased helmet use has led to fewer people killed (2 per year projected), severely disabled (4 per year) and hospitalized for head injury (100 per year), with direct and indirect savings in social and health care costs of about €2.6 million per year.

The Casco 2000 study (Giustini et al., 2000) indicated that the extension of the obligatory helmet law to all riders of two-wheeled vehicles in 2000 increased use from a national average of 24% to 90%. The percentages of use by moped drivers after the law entered into force were 98% in the north, 96% in the centre and 61% in the south. The law also indirectly affected motorcycle riders (>50 cc), among which helmet use increased from 68% to 91%.

Taggi (1993) estimates that each road accident results in an average of 40 years of life lost, as compared with the 7–10 years resulting from cancer or heart disease, and this number increases when the evaluation is narrowed to accidents with mopeds only. Before the 2000 helmet law, 20% of emergency room arrivals following road accidents were moped riders; 43% of these were 15–19 years old. Head injuries caused 54% of deaths, and road accidents caused more than 50% of cases of traumatic paraplegia. Further, head injuries caused by moped accidents resulted in an estimated 378 deaths and 756 cases of severe disability (Taggi, 1993).

Based on the studies underway at the Epidemiology and Biostatistics Laboratory of the National Institute of Health within the DATIS project,[8] 93% of two-wheeled motor vehicle riders in both Rome and Milan wear a helmet. There is no great difference between moped and motorcycle riders. Unfortunately, not everyone wears the helmet properly, but no quantitative data are available.

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[7] Diagnosis-related group is a system to determine the reimbursement for hospital patients based on the diagnosis.

[8] The DATIS project (DATi Incidenti Stradali), supervised by Franco Taggi, was founded by the Inspectorate General for Traffic and Road Safety of the Ministry of Infrastructure and Transport and focuses on collecting data on the health care aspects of road accidents. The project includes a safety monitoring system known as ULISSE from which the data in this text were drawn.

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5. MORTALITY AND MORBIDITY ATTRIBUTABLE TO AIR POLLUTION PRODUCED BY MOPEDS

This chapter evaluates the possibility of estimating the potential health effects associated with moped exhaust emissions. As in the preceding chapters, feasibility is assessed using quantitative data on the City of Rome. The primary pollutant considered is PM10. This is a very important urban air pollutant, and it has been associated with adverse health outcomes ranging from relatively minor respiratory symptoms to premature death. The choice of this pollutant as the overall indicator of harmful pollution levels is supported by dozens of scientific studies published over the past decade that demonstrate a strong association between PM10 concentration and poor health. These studies have been undertaken in cities throughout the world at latitudes ranging from that of Los Angeles to that of Bangkok, including several cities in Europe, thus covering a wide variety of climatic conditions, lifestyles, baseline health levels and exposure conditions. Together these studies provide an important scientific basis for a causal association between PM and health levels and furnish a series of quantitative data useful for risk assessment. The *Air quality guidelines for Europe* (WHO Regional Office for Europe, 2000) provide an overview of the health effects associated with this pollutant.

The objective of this assessment was to generate quantitative estimates associated with the current pollution concentrations of PM10 produced by mopeds in Rome and to indicate the potential benefits associated with controlling this pollutant. However, there are clearly many uncertainties in assessing this impact: the quantification of concentration–response functions; the population's actual exposure level; and attributing to mopeds alone a proportion of the total pollution measured and produced by all circulating vehicles. In comparing the results, we attempted to address these points quantitatively, by applying confidence limits around the assessments, and qualitatively.

Several efforts have been made to assess the health benefits associated with reducing the population's exposure to PM10. Ostro (1996) provided a basic method for estimating health effects based on epidemiological evidence. Künzli et al. (2000) estimated the health effects attributed to PM generated by road traffic in Switzerland, Austria and France. Martuzzi et al. (2001) estimated the health effects of PM10 concentrations in eight major cities in Italy. Ostro & Chestnut (1998) calculated the health benefits associated with the standards for PM2.5 proposed by the United States Environmental Protection Agency. The Agency has embarked on many significant efforts to quantitatively evaluate the health risks associated with exposure to ambient PM10 and PM2.5, including a report to the United States Congress (United States Environmental Protection Agency, 1999). Martuzzi et al. (2001) extensively evaluated the methods for quantifying the health effects of air pollution.

5.1. Methods and data

Three components are necessary to quantify the health effects (and potential benefits resulting from reduced PM) associated with the PM10 emitted by mopeds. The first factor consists of the concentration–response functions obtained from epidemiological studies that indicate the variation of a given health effect per unit change of a pollutant (PM10 in this case). The second factor in the quantification process is the baseline incidence rate of specific adverse health outcomes in the population under observation. The third is the change in pollution concentrations and the consequent number of people exposed to this change. Each of these factors is briefly discussed below. Martuzzi et al. (2001) provide further details.

5.1.1. Concentration–response functions and incidence of illness

There is currently a great deal of epidemiological literature on the development of concentration–response functions related to both exposure peaks and long-term exposure. These studies relate changes in the health risk to PM10 concentrations in the free-living population and, in most cases, also control for other factors that influence health status such as smoking and other lifestyle habits.

These studies were conducted all over the world and observed populations consisting of various age groups, climatic exposure, behaviour and lifestyles, baseline health status and exposure conditions.

The increase in mortality can be attributed both to short-term effects (within a few days) and long-term effects (after several years). The data on premature death supplied by the studies varies: those that investigate short-term effects estimate the number of premature deaths per year but do not estimate the reduction in life expectancy. Those that study long-term exposure can supply not only information on the number of cases of premature mortality per year but produce results that, when applied to life tables, indicate reductions in life expectancy (the number of years of life lost for each case examined).

Morbidity is derived from epidemiological studies on short-term health effects such as the rate of hospital admissions for cardiovascular and respiratory disease, cases of acute bronchitis, exacerbation of asthma, restricted activity days and acute respiratory symptoms.

For many health end-points, the central estimate of the necessary relative risk (the risk above the baseline per unit change in PM10 concentration) and confidence intervals were derived using a weighted average of several existing studies. This approach incorporates information from all the pertinent studies by weighting each study's estimate by its associated uncertainty (standard error). When results from large studies conducted in Italy were available, risk estimates from these studies were used but support from studies conducted in other parts of the world was evaluated.

Martuzzi et al. (2001) review many of these studies and provides details on the development of concentration–response functions.

5.1.2. Baseline incidence rates

The baseline incidence rates for the City of Rome in 1997 were used for several of the health end-points estimated in this analysis – including premature mortality from all causes, cardiopulmonary disease and lung cancer and admission to hospital for both cardiovascular and respiratory disease. The rates for 2000 were generally similar to these baseline incidence rates.

5.1.3. Population exposure

The estimates of PM10 currently emitted by mopeds were obtained from various sources. The annual concentrations of PM10 were calculated based on surveys carried out by three monitoring stations (using beta ray absorption) set up in residential areas of the city: Via Arenula, Via Fermi and Via Magna Grecia. A fourth station in Villa Ada was not included since the location is a public park and largely buffered from PM10 exposure. The annual average PM10 concentrations for these three stations were 51.5 $\mu g/m^3$ in 1998, 50.8 $\mu g/m^3$ in 1999 and 52.1 $\mu g/m^3$ in 2000. Thus, an average PM10 concentration of 51.5 $\mu g/m^3$ was used.

Estimating the overall health effects resulting from PM10 emissions by mopeds requires a baseline value: the PM10 concentration that would be observed if the contribution of moped emissions were removed. Based on the data described in section 3.2.3, 35% of the PM10 emitted by vehicular traffic is attributable to moped emissions. Since all vehicular traffic emissions represent 60% of what the monitoring stations measure, the contribution by mopeds is estimated to be 10.8 $\mu g/m^3$, 21% of the concentrations measured (51.5 $\mu g/m^3$).

Applying this potential change in air quality associated with the hypothetical elimination of PM10 emissions by mopeds, it is assumed that other emission factors would remain unchanged.

The existing concentrations are well above any concentration at which there would be "no effects" (threshold effect). Most existing epidemiological studies supply evidence of linear and near-linear concentration-response functions that suggest a continuum of effects down to the background or near-background PM levels. For example, most studies report a linear association between the population's relative risk of mortality (percentage increase in mortality) and PM10 concentrations (Daniels et al., 2000; Samet et al., 2000; Schwartz & Zanobetti, 2000). These studies respectively examined 20, 88 and 10 cities together with no indication of a threshold concentration for cardiovascular-related mortality. In Europe, the most compelling evidence comes from the large multi-city APHEA (Air Pollution Health Effects – A European Approach) project (Katsouyanni et al., 2001), which evaluated the short-term effects of air pollution in 29 cities. Moreover, several mortality studies have been conducted at relatively low mean concentrations. Examples include: 26 $\mu g/m^3$ in Birmingham, United Kingdom (Wordley et al., 1997); 25 $\mu g/m^3$ for six United States cities (Schwartz et al., 1996) and 26 $\mu g/m^3$ for the eight largest cities in Canada (Burnett et al., 2000).

Likewise, in examining the largest study conducted on mortality and long-term exposure, Krewski et al. (2000) also failed to detect a threshold in the concentration–response relationship. Thus, based on existing evidence, it appears reasonable to expect increased health benefits in association with potential reductions in moped-generated PM10.

5.1.4. Quantification methods

The relative risk (RR) for each of the health end-points considered was determined by pooling the estimates of the various available studies. The risk is the increase in the probability of a given health end-point associated with a given increase in exposure level (in the epidemiological studies of PM10, this is generally 10 µg/m3). The proportion (A) of health effects attributable to air pollution for the entire population can be calculated as:

$$(1)\ A = (RR - 1)/RR$$

The following formula was used to calculate the cases attributable to PM10 emitted by mopeds (E):

$$(2)\ E = A * B * C * P$$

where
B = the population baseline for the given health effect;
C = the relative change in air pollution; and
P = the relevant exposed population for the health effect.

Following Künzli et al. (1999), the population baseline is the proportion of the exposed population that would suffer the health outcome assuming a baseline (or no effects) level of air pollution. This can be calculated as:

$$(3)\ B = BO / [1 + (RR - 1)(C/10)]$$

where
BO = the observed rate of the health effect under current exposure, as obtained from available health statistics.

The relative rate is divided by ten to obtain the risk factor per unit. This formula uses the relative risk to adjust the current prevalence or incidence level of the health effect to the level that would exist with a lower air pollution concentration.

5.1.5. Risk estimates used

The adverse health outcomes considered in this analysis include: cardiovascular mortality from long-term exposure, lung cancer from long-term exposure, all-cause mortality (excluding accidents and homicides) from short-term exposure and morbidity (hospital admissions, asthma attacks, restricted activity days for adults and respiratory symptoms) from short-term exposure. The alternatively derived mortality end-points should not be added but rather present two alternative, and somewhat overlapping, assessments (Martuzzi et al., 2001). Table 29 summarizes the health end-points and relative risks used in the estimation.

TABLE 29. SUMMARY OF RELATIVE RISKS FOR ESTIMATED HEALTH OUTCOMES FOR VARIOUS AGE GROUPS PER 10 $\mu G/M^3$ CHANGE IN PM10[a] CONCENTRATION BASED ON VARIOUS STUDIES

Cause (study used)	Relative risk		
	Central estimate	95% confidence interval	Age group
Cardiopulmonary mortality from long-term exposure (Pope et al., 2002)[a]	1.08	1.02 - 1.14	Adults over 30
Lung cancer mortality from long-term exposure (Pope et al., 2002)[a]	1.13	1.04 - 1.22	Adults over 30
All-cause mortality from short-term exposure (Biggeri et al., 2001)	1.011	1.008 - 1.41	All age groups
Hospital admissions for cardiovascular diseases (Biggeri et al., 2001)	1.010	1.006 - 1.017	All age groups
Hospital admissions for respiratory diseases (Biggeri et al., 2001)	1.021	1.017 - 1.024	All age groups
Acute bronchitis (Dockery et al., 1989, 1996; Braun-Fahrländer et al., 1997; cited in Martuzzi et al., 2001)	1.306	1.135 - 1.502	< 25 years
Asthma exacerbation (Martuzzi et al., 2001)	1.051	1.047 - 1.055	< 25 years
Asthma exacerbation (Martuzzi et al., 2001)	1.004	1.000 - 1.008	> 25 years
Restrictions in activity (Ostro, 1990; Ostro & Rothschild, 1989; cited in Martuzzi et al., 2001)	1.094	1.079 - 1.109	> 25 years
Occurrence of respiratory symptoms (Ostro et al., 1993; cited in Martuzzi et al., 2001)	1.07	1.02 - 1.11	All age groups

[a] The risk was calculated per 10 σg/m³ PM2.5, and the available PM10 data were adapted assuming that PM2.5 = 0.5 PM10.

5.2. Impact assessment

5.2.1 Mortality from long-term exposure

As observed by Martuzzi et al. (2001), long-term exposure (one or more years) to PM10 and PM2.5 is associated with mortality. Long-term exposure estimates are preferable since they embrace both long and short-term effects and clearly represent a significant reduction in life expectancy. For long-term exposure, this report used estimates drawn from Pope et al. (2002) of the American Cancer Society cohort data originally analysed by Pope et al. (1995) and reanalysed by Krewski et al. (2000). The Pope et al. study involved about 500 000 people followed over 16 years. These studies used individual-level data to properly account for such confounding personal factors as differences in body mass, exposure on the job, smoking (present and past), alcohol use, age and gender. The models examined whether long-term variation in PM concentrations is associated with differences in life expectancy controlling for individual risk factors. These studies demonstrate a very close and statistically significant relationship between exposure to PM (measured as PM10 or finer PM2.5 particles) and mortality and can be used to determine the number of premature deaths. Applying these results to life tables can predict the actual number of years of life lost annually associated with given levels of air pollution.

Estimates of the relative risk associated with PM2.5 are available for both cardiovascular mortality and lung cancer mortality (Table 29). Since the data used refer to the City of Rome in 1998–2000, the relative risk of Pope et al. was used based on exposure assessed from 1999 to 2000 rather than that based on the historical data from 1979 to 1983. The PM10 concentration estimated for the City of Rome was divided by 2 to approximate PM2.5 concentrations, since the relative risks in the original Pope et al. (2002) report are in terms of PM2.5. The baseline mortality estimates for Rome were 362 per 100 000 for cardiovascular mortality and 31 per 100 000 for lung cancer mortality.

5.2.2. Mortality from short-term exposure

As stated in the previous section, the long-term estimates include some of the effects of short-term exposure. The estimates based on short-term studies can be viewed as a minimum level of effect; they do not record, for example, cases of lung cancer or heart disease caused by exposure over a long period.

Short-term PM10 exposure estimates were drawn from a study by Biggeri et al. (2001) on mortality and morbidity in Rome, Milan, Turin, Bologna, Florence, Palermo, Verona and Ravenna. A similar model was used in each city to examine the association over time between daily counts of mortality and daily PM10 concentrations (the average of zero-day lag and one-day lag). The models' calculations took into account the presence of other factors that can influence daily mortality such as climate, season, influenza epidemics and time. The effects reported in this study originally suggested a change of about 1.1% in daily mortality for a PM10 variation of 10 $\mu g/m^3$. This effect is greater than those reported in multi-city analyses in the United States National Morbidity, Mortality and Air Pollution Study (Samet et al., 2000) and APHEA in Europe (Katsouyanni et al., 2001). Nevertheless, the southern European cities of this latter study were characterized by more pronounced effects owing, perhaps, to greater time spent outdoors. The greater effect of air pollution on daily mortality and morbidity in Italy compared with other countries in Europe and North America has been confirmed in a reanalysis of the available multi-city studies (Dominici et al., 2002). Such a re-evaluation was required because of problems with the statistical software previously used (Dominici et al., 2002). The final estimated increase in total deaths per 10 $\mu g/m^3$ PM10 was 0.6% (95% confidence interval = 0.4–0.8) in APHEA, 0.27% (95% confidence interval 0.17–0.37) in the United States National Morbidity, Mortality and Air Pollution Study (Health Effects Institute, 2003) and 0.98 (95% confidence interval 0.35–1.61) in the eight-city study in Italy (Biggeri et al., 2002).

Although using daily data and acute exposure has many statistical advantages (such as reducing confounding and error in measuring exposure), the quantitative implications may be uncertain. For example, there is uncertainty regarding the extent of the prematurity of mortality (reduction in life expectancy) as a result of acute exposure. Some deaths may merely be displaced by a few days or weeks. It seems, however, that for many deaths, especially those related to cardiovascular disease, prematurity is more on the order of several months or more (Schwartz, 2000; Zeger et al., 1999; Zanobetti et al., 2003), resulting in a significant impact on public health services.

5.2.3. Morbidity

The dose–response functions and associated relative risks were drawn from studies on various morbidity end-points conducted in the United States and Europe. Additional risks from PM for hospital admissions, emergency room visits, asthma exacerbation, acute bronchitis in children, restricted activity days and respiratory symptoms were calculated from studies on short-term exposure.

A meta-analytical approach similar to the one used for the mortality studies was used to combine the results of the various studies considered into a single assessment. In particular, the overall effect was evaluated by weighting each individual study by the inverse of the variance of the estimated effect. Studies conducted in Italy were used for the data on hospital admissions for cardiovascular and respiratory symptoms. For the remainder, studies conducted in Europe and North America with less severe end-points were pooled to obtain the final relative risk estimate. Martuzzi et al. (2001) and Künzli et al. (2000) provide more detail on the studies used.

5.2.4. Cardiovascular hospital admissions

Biggeri et al. (2001) analysed the association between daily counts of hospital admissions for cardiovascular diseases (ICD-9: 390–429) and PM10 concentrations in Rome, Milan, Turin, Bologna, Florence, Palermo, Verona and Ravenna. Like the mortality studies, a similar model was used for each city and the estimates were subsequently combined using a fixed effects procedure. Combining the data on the eight cities, a relative risk of 1.010 was obtained (95% confidence interval = 1.006–1.017) for a change in PM10 concentration of 10 mg/m^3. These estimates are similar to those obtained in studies previously conducted in Europe and North America.

5.2.5. Hospital admissions for respiratory causes

Extensive scientific evidence indicates that short-term changes in PM concentrations influence hospital admissions for respiratory disease (ICD-9: 460–519). Studies conducted both in Europe and in the United States report cases of numerous and multiple respiratory end-points, including all respiratory diseases. Biggeri et al. (2001) estimated the effect of PM10 on hospitalization for respiratory disease in eight cities in Italy. The pooled results yielded a relative risk of 1.021 (95% confidence interval = 1.017–1.024) for a change in PM10 concentration of 10 mg/m^3. This estimate is similar to that generated in a meta-analysis of previous studies (Martuzzi et al., 2001). The baseline rate of hospital admissions for respiratory disease based on Biggeri et al. (2001) is 769 per 100 000.

5.2.6. Other morbidity

Künzli et al. (1999, 2000) and Martuzzi et al. (2001) also provide concentration–response functions for other less severe morbidity outcomes. Specifically, estimates were generated for acute bronchitis in children, asthma exacerbation estimated separately for both children and adults, reduced activity (including missed work) for adults and minor respiratory symptoms.

5.2.7. Results

Table 30 illustrates the health effects attributable to the percentage of the PM10 concentration caused by moped emissions based on the 10.8 $\mu g/m^3$ derived in section 3.2. The two long-term causes considered (cardiovascular and lung cancer mortality) account for 350 deaths per year versus 170 from short-term effects. Respiratory and cardiovascular causes combined account for more than 1 000 hospital admissions. Other respiratory illnesses in children include about 7 000 cases of bronchitis and 5 600 cases of asthma attacks. For all these outcomes, the 95% confidence intervals are far from zero. The estimates for respiratory end-points for adults, by contrast, are more uncertain, with wider confidence intervals. Outcomes that address the economic costs of air pollution (days of restricted activity, generic respiratory symptoms) also indicate that moped PM10 emissions have a substantial impact.

Table 30. Estimated annual effects of exposure to moped pollution in Rome, 2000

Health end-point	Cases attributable	95% confidence interval
Long-term cardiopulmonary mortality	284	78–457
Long-term lung cancer mortality	59	21–88
Short-term all-cause mortality[a]	167	124–596
Hospital admissions, respiratory diseases (ICD-9 460–519), all age groups	437	357–496
Hospital admissions, cardiovascular diseases (ICD-9 390–459), all age groups	588	356–985
Incidence of chronic bronchitis, ≥ 25 years	119	14–196
Acute bronchitis, ≤ 14 years	6 931	4 082–8 537
Asthma exacerbation, ≤ 14 years	5 639	5 238–6 034
Asthma exacerbation, ≥ 15 years	2 071	0–4 109
Restricted activity days, ≥ 20 years	528 596	457 816–596 156
Respiratory symptoms	2 006 442	633 158–2 922 001

[a] *Most of the deaths estimated for short-term mortality are already included in long-term mortality.*

5.3. Observations on feasibility, uncertainty in estimates and necessary data

After analysing the municipal databases of Rome, the feasibility study concludes that exposure to the pollutants emitted by mopeds is likely to have significant health effects. In this section of the impact assessment, the feasibility study likewise indicates that the health impact of the emission of air pollutants can be assessed and that this impact in a city such as Rome is considerable. The estimates currently calculable are uncertain because the data used are limited. The shape of the concentration–response functions can also be uncertain, although the studies currently available support a reasonable assumption of linearity. Many recent epidemiological studies show associations between PM concentrations and health end-points over ranges of concentration typical of the current conditions in Rome. In addition, several studies conducted in Rome (Michelozzi et al., 1998; Biggeri et al., 2001; Fusco et al., 2001) show that air pollution affects both mortality and morbidity. Thus, significant health effects can very probably be associated with the mixture of particles found in Rome, comparable with the results of other studies.

The mortality and morbidity estimated here are accompanied by statistical uncertainty associated with the variation in the regression model and the data used. However, there may be other sources of uncertainty. For example, the studies could have omitted confounding variables (other risk factors) that could raise or lower the estimated pollution effect. Most more recent studies have been quite rigorous in controlling confounding factors, even though the importance of these variables remains uncertain, especially in large-scale studies.

Another significant source of uncertainty is the error in the estimated population exposure. In most epidemiological studies on air pollution, exposure is deduced from the concentrations measured by fixed-site monitoring stations. Any error in measuring the pollution concentrations to which individuals are actually exposed may introduce additional error into the analysis. In any case, specific examination of measurements mostly suggests that this error most probably underestimates the effects of pollution (Thomas, 1994; Zeger et al., 1999). There is also clinical uncertainty. Some outcomes, such as changes in lung functioning, are not assessed. This leads to an overall underestimation of the respiratory effects. Similarly, other factors that are difficult to quantify such as physician visits and/or averting or mitigating behaviour to reduce the effect of air pollution – such as staying indoors, not exercising or taking extra medication – would be underestimated. These are all social costs related to air pollution that would not be reflected in the present estimates.

Another limitation is using PM10 as a marker for all pollution from mopeds. Using PM10 may account for the impact of correlated pollutants, which varied with PM10 in the original epidemiological study. However, the particle constituents may be more or less toxic than general PM10. Moreover, as discussed in section 3.2, the particles emitted from mopeds tend to be quite small (less than 2.5 μm) and therefore are likely to be at least as toxic, if not more so, than general PM10. The impact assessment therefore assumes that the particles emitted in exhaust are as toxic as those of the generic PM10 formed in the urban atmosphere. This assumption, along with the scarce understanding of the eventual combined effects of PM in association with other pollutants emitted by two-stroke engines, produces another important type of uncertainty in the estimates. The feasibility study concludes, in particular, that this combination of aspects should be studied in greater depth, especially with regard to the differences in the nature of the PM emitted by mopeds as compared with what the monitoring stations measure.

5.3.1. Necessary data

The findings of this feasibility study, aimed at making the estimates more reliable and thus at leading to general application of the results to other cities, show that the following topics should be pursued in greater depth:

- input data in the various models used, such as the quantification of the total number of vehicles, distances travelled and emissions coefficients for a better estimate of the proportion of pollution attributable to mopeds;
- data on the formation and diffusion models of the PM measured by the monitors, starting with vehicle emissions;
- data on the toxicity of the PM measured by the monitors and on the probable biological mechanisms induced in the human body according to exposure levels (refining the risk curves); and
- epidemiological data on exposure to the pollution mixture emitted by two-stroke engines.

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6. THE HEALTH AND SOCIAL COSTS OF ROAD ACCIDENTS

This chapter examines the possibility of estimating the costs generated by road accidents. The many existing studies on the subject provide widely varying parameters and estimates. Many European research projects have already supplied models and coefficients for outlining the externalities of road transport and go on to evaluate events such as the loss of human life, loss of ability to work, disability, disease and others. Applying "general" parameters to the quantities illustrated in the preceding chapters would have allowed an approximate economic estimate. Nevertheless, in keeping with the study's objective of examining the feasibility of a monetary estimate of the effects of exposure to mopeds in Italy, an attempt has been made to assign monetary values to the quantitative data in Chapter 4 on the health effects of accidents. The effects associated with the loss of human life and work time as a result of pollution could be deduced from these, but too many assumptions need to be made, and the resulting values would therefore have been of little use. In its estimates, WHO staff used three separate consultants to examine the same data set and to evaluate the same queries from different perspectives. This chapter, therefore, summarizes the evaluations supplied by:

– the ACI working group engaged in estimating accident costs (Pennisi et al., personal communication);
– a working group of the Department of Economics of the University of Turin that conducted a research project on health costs for the Piedmont Region (Annex 10); and
– Paolo Liberatore of the CLES (Centre for Research into and Study of Labour, Economy and Development Problems), who specifically evaluated fatal events in the context of the health problems of workers at the Porto Marghera petrochemical plant (Annex 11).

All three evaluations estimated the social costs of accidents, but only the first two examined direct health costs (those supported by Italy's National Health Service). For the sake of clarity, we have separated the two cost categories into two distinct paragraphs.

6.1. Estimate of direct health costs

This section reports on the evaluation of hospitalization and treatment costs by the ACI and by the Department of Economics of the University of Turin.

6.1.1. ACI Road Accidents Observatory

The ACI study (Annex 9) considers the diagnosis-related group rates related to road accident injuries (Table 31). It selects the rates for the hypothesized injuries from the data set for mopeds in the City of Rome and works out an average rate to determine a corresponding cost of health care for every injured part of the body. The average of the rates is adjusted based on the frequency of the injuries found by the MAIDS study (Table 24) ranked according to the Abbreviated Injury Scale, both for inpatient and outpatient treatment. Taggi (2001) and the data set supplied by WHO (Table 27) enables the proportion of severe injuries hospitalized for at least one day to be estimated at 17% and those not requiring hospitalization at 83%. Zanola & Moreschi (2002) found the same distribution among minor and severe injuries (see section 4.2.8) using the Abbreviated Injury Scale for injury distribution, combining category 1 plus 50% of category 2 for minor injuries and the remaining categories for severe ones. However, as subsequently illustrated, if the Abbreviated Injury Scale is used, the number of injuries is based on the number of people injured, excluding de facto multiple injuries from the economic computation.

For people severely injured, the ACI study added ambulance and emergency room costs to those of the hospital stay; for those with minor injuries it applied a cost equal to the average emergency room and outpatient treatment cost.

The data set did not give information on hospital stays in the fatal cases examined by ACI. Events of this type are not included in the direct health cost estimates of the other study, except in terms of ambulance and emergency room costs.

6.1.2. Department of Economics, University of Turin – diagnosis-related groups (study 1)

Zanola & Moreschi (Annex 10) examined accidents in Rome and Milan (Table 32). Indeed, WHO includes the two series, since ISTAT admittedly underestimated

TABLE 31. ESTIMATE OF EMERGENCY ROOM AND HOSPITAL TREATMENT COSTS (IN EUROS) FOR INJURIES RESULTING FROM ACCIDENTS INVOLVING MOPEDS IN ROME

People injured in moped accidents in Rome[a]	Minor injuries[b]		Average cost per minor injury	Severe injuries[b]		Average cost per severe injury	Ambulance and emergency room costs	Total cost
	%	n		%	n			
2 392	83	1 985	€745	17	407	€4 385	€262	€3 370 154
Average health care cost per injured person								€1 408

Source: WHO elaboration of ACI and National Institute of Health data.

[a] The ISTAT figure on the number of injuries in Rome is underestimated by at least 50% (section 4.1.1).
[b] Taken from the Casco 2000 study (personal communicatin, Franco Taggi and Marco Giustini, National Institute of Health, 2000).

the data on Rome by at least 50%, whereas those on Milan were complete (Table 11). This underestimate is reflected in the computation of costs by the studies treated here, which have much lower figures for Rome than for Milan.

Unfortunately, the real distribution of injuries per accident in the two cities according to the Abbreviated Injury Scale index was not available. Zanola & Moreschi, like ACI, considered the MAIDS study by the University of Pavia (personal communication, Alessandra Marinoni and Mario Comelli, Department of

Table 32. Assumed distribution of injuries caused by moped accidents in Milan and Rome for calculating health and social costs

Milan						
	Severity of injuries according to the Abbreviated Injury Scale					
Area of the body	1	2	3	4	5	Total
Head	462	166	74	56	93	851
Neck	518					518
Chest	56		37		19	112
Upper limbs	592	222				814
Abdomen	111					111
Pelvis	37	74				111
Spinal column	19					19
Lower limbs	1 241	389	130			1 760
Entire body	518					518
Total	3 554	851	241	56	112	4 814[a]
Rome						
	Severity of injuries					
Area of the body	1	2	3	4	5	Total
Head	230	83	37	28	46	423
Neck	258					258
Chest	28		18		9	55
Upper limbs	294	110				405
Abdomen	55					55
Pelvis	18	37				55
Spinal column	9					9
Lower limbs	617	193	64			874
Entire body	258					258
Total	1 766	423	120	28	55	2 392[a]

Source: Zanola & Moreschi (Annex 10) using original MAIDS data.

[a] *The number of Abbreviated Injury Scale injuries per city is equal to the total number of injured people because of the model in which the number of injuries is made to coincide with the number of injured people. As partial confirmation of this choice, see the Casco 2000 study (personal communication, Franco Taggi and Marco Giustini, National Institute of Health, 2000) that shows the Injury Severity Score distribution relative to the analytic sample, demonstrating a limited presence of serious cases of multiple injuries.*

Applied Health Sciences, University of Pavia) (Table 24) and applied the resulting injury percentages to the two data sets for Milan and Rome, assuming that the number of injuries coincides with the number of injured people (Table 33). The Abbreviated Injury Scale notes the severity of the injuries and enumerates only these. This assumption, although somewhat drastic for tracing a health profile since it does not consider multiple injuries, is acceptable in any case for carrying out cost estimates. In contrast to the ACI study, that of the University of Turin calculated a cost for each individual injury. Table 32 shows the injury table for Rome and Milan.

The study attributed an average diagnosis-related group rate per area of the body injured. To determine the number of hospital admissions from these numbers, injuries with an Abbreviated Injury Scale score of 3, 4 or 5 were grouped along with 50% of those rated as 2. Seventeen percent of those injured were hospitalized. This parameter is the same one used by the ACI study and estimated by the WHO staff based on the data supplied by the National Institute of Health (personal communication, Franco Taggi and Marco Giustini, National Institute of Health, 2000) described in section 4.2.8.

For hospital admissions, the study considers the Lazio Regional Council rates, excluding those related to especially complex injuries that, if considered, would have heavily influenced the final estimate[9].

The costs for injured people not hospitalized (injuries scoring 1 on the Abbreviated Injury Scale) were computed based on the compensation guaranteed

Table 33. Estimated total emergency room and hospital treatment costs (in euros) of moped accident injuries in Milan and Rome in 2000 based on diagnosis-related group rates

Injury	Milan			Rome		
	Emergency room	Hospital treatment	Total	Emergency room	Hospital treatment	Total[a]
Head	32 070	1 109 000	1 141 000	15 960	552 000	568 000
Neck	21 380	0	21 000	10 640	0	11 000
Chest	2 320	113 000	115 000	1 140	55 000	56 000
Abdomen and pelvis	11 880	138 000	150 000	5 890	69 000	75 000
Spinal column	770	177 000	178 000	360	88 000	88 000
Upper limbs	41 680	864 000	906 000	20 660	427 000	447 000
Lower limbs	81 390	0	81 000	40 440	0	40 000
Entire body	21 380	0	21 000	10 640	0	11 000
Total	212 780	2 400 000	2 613	105 770	1 190 000	1 296 000
Total injured people			4 814			2 392
Health care cost per injured person			543			542

Source: data from Zanola & Moreschi (Annex 10).
[a] The totals for Rome are underestimated by at least 50% (section 4.1.1)

[9] As partial confirmation of this choice, see the Casco 2000 study (personal communication, Franco Taggi and Marco Giustini, National Institute of Health, 2000) that shows the Injury Severity Score distribution relative to the analytical sample, demonstrating few serious cases of multiple injuries.

according to the Triage code[10] of the Lazio Regional Council. Table 33 shows the results of this estimate. This table cannot be compared with Table 35, which considers the social costs associated with the injury suffered.

The average cost per accident is about half that estimated by ACI for two reasons. Although the number of people with minor and severe injuries coincides and the tariffs of the individual Abbreviated Injury Scale codes are equal, ACI probably overestimated since it calculated an average value between the two sets of minor and severe traumas and then multiplied it by the number of people presumed to have minor and severe injuries. This makes the number of head injuries, which is very high, a bit more predominant in the tariff averages. Secondly, ACI decided to hypothesize a high average cost per severely injured person of €4 385, which should take into account rehabilitation and subsequent costs calculated as a second hospitalization. The University of Turin study (Annex 10), in contrast, may have underestimated since it treats each injury individually according to its seriousness and matches the number of injuries with people injured. Thus, very costly treatment of multiple injuries cannot emerge. Nevertheless, the average of the two studies leads to an average health care cost per moped accident victim of €975.

6.1.3. Department of Economics, University of Turin – international scale for calculating both health and social costs (study 2)

The University of Turin study examined other cost evaluation scales as well. Again based on the data set shown in Table 23, the specific cost for each Abbreviated Injury Scale category was calculated by means of two different scales taken from the United States Federal Highway Administration (1994) and Fildes & Cameron (1998). The United States Federal Highway Administration scale considers health costs as well as those deriving from the loss of labour and domestic productivity and other intangible costs, such as suffering and legal and administrative expenses, for each degree of injury defined according to the Abbreviated Injury Scale. The Fildes & Cameron scale came later and evaluates the health care costs associated with nine areas of the human body but also considers temporary loss of work time, follow-up therapy, medicine and other substantial costs (Annex 10). Table 34 shows the social costs per injury calculated using the two scales, and Table 35 shows the calculations deriving from them for Rome and Milan.

Another important consideration for the feasibility study was to show the two scales and the respective values applied to the presumed injury seriousness chart for accidents in Rome and Milan. The cost differences between these figures and the

[10] Triage code: selection of patients based on the severity of the injury. Each patient is given a code going from “white” to “red”, with white being minor and red being imminent danger of death.

Table 34. Social costs per moped accident injury rated using the Abbreviated Injury Scale (millions of lire 1997)

Injury severity (Abbreviated Injury Scale)	Description	United States Federal Highway Administration (1994)	Fildes & Cameron (1998)
AIS 1	Minor	6.1	2.5
AIS 2	Moderate	49.1	15.3
AIS 3	Serious	184.2	47.3
AIS 4	Severe	602	89.8
AIS 5	Critical	2 433.70	290
AIS 6	Fatal	3 194.50	460.3

Sources: Copes et al. (1989) and Zanola & Moreschi (Annex 10).

€975 calculated by means of health system tariffs indicate two things. First, important external costs associated with the use of mopeds should be calculated. Second, the disparity in the calculations and cost parameters is too great, even within the same international injury evaluation scale, and this should be studied more extensively.

Table 35. Total social costs of moped accident injuries in Rome and Milan rated using the Abbreviated Injury Scale and valued according to two methods (millions of lire 1997)

Severity (Abbreviated Injury Scale)	Rome[a]			Milan		
	Number of cases[b]	United States Federal Highway Administration (1994)	Fildes & Cameron (1998)	Number of cases[b]	United States Federal Highway Administration (1994)	Fildes & Cameron (1998)
AIS 1	1 766	10 774	4 415	3 554	21 686	8 910
AIS 2	423	20 769	6 472	852	41 833	13 020
AIS 3	120	22 104	5 676	241	44 392	11 410
AIS 4	28	16 856	2 514	56	33 712	5 030
AIS 5	55	133 854	15 950	111	270 141	32 190
Total	2 392	204 356	35 027	4 814	411 764	70 560

Source: Zanola & Moreschi (Annex 10) based on MAIDS data (personal communication, Alessandra Marinoni and Mario Comelli, Department of Applied Health Sciences, University of Pavia).

[a] *The totals for Rome are underestimated by about 50%.*

[b] *The total number of Abbreviated Injury Scale injuries per city is equal to the total number of injured people according to the model in which the number of injuries coincides with the number of injured people. As partial confirmation of this choice, see the Casco 2000 study (personal communication, Franco Taggi and Marco Giustini, National Institute of Health, 2000) that shows the Injury Severity Score distribution relative to the analytic sample, demonstrating a limited presence of serious cases of multiple injuries.*

Based on Table 35, taking into account corrections based on the ISTAT actuarial index and converting the currency into euros, the average social costs of a moped accident injury in Rome and Milan were €48 454 according to the United States Federal Highway Administration method and €8 304 according to the Fildes & Cameron method.

6.2. Estimate of the social costs produced by accidents

This section summarizes the three separate contributions, illustrating the parameters adopted in attributing a value to the loss of life and missed activity. The viewpoint assumed is that of the social costs. The attempt, therefore, is to avoid including everything pertaining to personal values, affective and familial costs and other "intangible" costs. Table 36, prepared by the Department of Economics of the University of Turin, shows a distribution into three overall groups: direct health costs, loss of production costs and human costs, with the associated percentages. The last group includes the "intangible" costs for which the feasibility study does not furnish values except for overall parameters (aggregated and not analytical), such as those in Table 35 for the United States Federal Highway Administration scale.

The human costs are more significant in percentage (60% on the average). European Union Action COST 313 (Socio-economic Cost of Road Accidents) determined that the average health care costs for a "minor" injury – as are most of those that occur with mopeds – is €320, which is less, although not by much, than the amount indicated in the previous section.

Table 36. Average costs and distribution according to type for people injured in all road accidents (millions of lire 1997)

	Production loss	%	Health costs	%	Human costs	%	Total	%
Minor	1.57	26.8%	0.62	10.6%	3.66	62.6%	5.85	100%
Severe	27.10	29.0%	8.30	8.9%	58.20	62.2%	93.59	100%
Death	570.60	42.0%	2.14	0.9%	786.59	57.9%	1 359.41	100%

Source: Zanola & Moreschi (Annex 10) based on COST 313 data (European Commission, 1994).

Given that 83% of injuries in moped accidents are minor and 17% severe, established by the Casco 2000 study (personal communication, Franco Taggi and Marco Giustini, National Institute of Health, 2000), the average cost of the injury, according to COST 313, was €995 (83% of €320 + 17% of €4 290), which is close to the amount proposed by this feasibility study.

6.2.1. Loss of life estimate

The value applied to the loss of human life and the related physical and mental disability resulting from an accident is known in the literature as the statistical value of the life or the statistical value of preventing fatality (Annex 10).

There are many methods for estimating the value to be attributed to a human life. The most common ones are the human capital method, the willingness-to-pay method, the stated preferences method and the income differential method. Annex 10 and its detailed bibliography examine the variables and assumptions of each method. For the purposes of this feasibility study, we examined the human capital method treated in the studies by Zanola & Moreschi (Annex 10), Liberatore (Annex 11) and ACI (Annex 9), although based on different assumptions. This method seems to come closest to the feasibility study's goal of identifying a method for estimating the cost to society of the exposure of the population to the use of mopeds.

Liberatore (Annex 11) offers an innovative system based on the viewpoint of society's willingness to pay and not on that of the potential accident victim. The method attempts to estimate how much society is willing to pay to avoid the fatal or disabling event.

The next three paragraphs analyse the three studies separately. The number of deaths on which the calculations are based is the minimum for Rome and Milan. It follows that the distribution by age group does not constitute a sample. Applying the methods and parameters adopted in the three nationwide studies, considering the distribution by age group of all the deaths occurring in the year, will yield results more useful as average values and as general considerations. Nevertheless, in both Milan and Rome most deaths occur in the age group 16–35 years, especially 26–35 years, which also presents the highest social costs. Table 39 shows this as the highest income multiplier in the ACI study. This consideration could suggest good reliability in the values given per death.

Human capital method – Liberatore (Annex 11)

In Rome, an estimated 2 392 people were injured and 11 killed during 2000 in moped accidents among drivers, passengers and pedestrians as a result of 2 091 road accidents with mopeds. Liberatore (Annex 11) examined a chosen year and estimated the contribution of a single individual to the per capita gross domestic product for 2000[11]. The per capita income is multiplied by the number of years

[11] It is assumed that the characteristics of the group of people involved in accidents are similar to those of the entire population, especially for employment.

that the person would presumably have lived from the date of the accident to the life expectancy in Italy. Liberatore adjusts the annual income using a discount rate equal to the rate of increase in productivity[12]. Table 37 shows the results. The costs of these deaths in Rome in 2000 were thus estimated to be €9.84 million. This is too low since ISTAT underestimated the number of accidents. The percentage of error is difficult to calculate without correcting for the death and accident rates in Milan or for Italy.

TABLE 37. PRODUCTION LOSS (IN EUROS) RESULTING FROM DEATHS CAUSED FROM ACCIDENTS INVOLVING MOPEDS IN ROME IN 2000 – LIBERATORE

Age (years)	Median age	Life expectancy[a]	Number of deaths	Annual contribution to income (euros)	Total contribution to income (euros)
0–13	7	71.9	0	20 165	0
14–19	17	62.1	0	20 165	0
20–25	23	56.3	3	20 165	3 403 979
26–35	31	48.6	4	20 165	3 916 467
36–45	41	39.0	0	20 165	0
46–55	51	29.8	2	20 165	1 200 374
56–65	61	21.0	1	20 165	424 015
≥ 65	71	13.4	0	20 165	0
Total	–	–	10	–	8 944 836
Corrected total (11 total deaths)[b]					9 839 320

Source: Liberatore (Annex 11) based on data from the WHO European Centre for Environment and Health.

[a] *Life expectancy drawn from the ISTAT mortality tables for the Province of Rome (for 1998), which indicate the life expectancy for each age group and include the probability of dying from causes other than natural ones.*

[b] *The available data cover only 10 of the 11 people killed. The eleventh has been attributed a value equal to the average of the others.*

Human capital method – Department of Economics, University of Turin

The Department of Economics of the University of Turin used the same method as the previous study to achieve results comparable to those of Liberatore (Table 38).

[12] If, for example, in the years to come a country records a 2% increase in per capita gross domestic product associated with economic growth and a simultaneous decrease of 2% in the value of money associated with inflation, the per capita gross domestic product remains constant over time.

The gross production loss attributable to early death from moped accidents was calculated from the age at death and the related life expectancy[13] based on the total years of life lost in accidents. A value was then attributed to each year equal to the average per capita income of the respective provinces (Rome and Milan), to which an average discount rate of 4% and growth rate of 2% were applied. Zanola & Moreschi (Annex 10) decided to consider everyone, regardless of their actual employment situation, as average participants in producing the gross domestic product (Sommer et al., 1999), as the previous study did.

The results thus obtained present a value of €11.9 million for Milan and of €6.6 million for Rome.

TABLE 38. PRODUCTION LOSS (IN EUROS) RESULTING FROM DEATHS CAUSED BY ACCIDENTS INVOLVING MOPEDS IN MILAN AND ROME IN 2000 – ZANOLA & MORESCHI

Milan						
Age (years)	Median age	Life expectancy[a]	Number of deaths	Contribution to national income (euros) per year	Adjusted contribution to income (euros) per year	Total contribution to income (euros)
16–19	18	60.2	3	26 605	15 548	2 808 040
20–25	23	55.4	3	26 605	16 171	2 687 582
26–35	31	47.7	4	26 605	17 248	3 291 001
36–45	41	38.2	2	26 605	18 727	1 430 759
46–55	51	28.9	0	26 605	20 347	0
56–65	61	20.3	0	26 605	22 044	0
Unknown[a]	27.4	51.0	2	26 605	16 391	1 671 854
Total			14			11 889 236
Rome						
Age (years)	Median age	Life expectancy[a]	Number of deaths	Contribution to national income (euros) per year	Adjusted contribution to income (euros) per year	Total contribution to income (euros)
16–19	18	60.2	0	20 569	12 021	–
20–25	23	55.4	3	20 569	12 502	2 077 838
26–35	31	47.7	4	20 569	13 335	2 544 357
36–45	41	38.2	0	20 569	14 478	–
46–55	51	28.9	2	20 569	15 731	909 238
56–65	61	20.3	1	20 569	17 043	345 968
Unknown[a]	27.4	51.0	1	20 569	13 498	661 410
Total			11			6 538 811

Source: Zanola & Moreschi (Annex 10).

[a] *An average of the other deaths was used for deaths for which the age was unknown.*

[13] The study used an average of the values for the male and female populations.

Human capital method – ACI Road Accidents Observatory

The study by the ACI Road Accidents Observatory (Annex 9) provides a table entirely comparable with that of Liberatore. The parameters adopted are: the life expectancy drawn from ISTAT mortality tables for 1995, a hypothetical annual gross domestic product increase of 2.06% and a discount rate of 5.57%, inferred as an average of the period 1987–2000. Table 39 shows the production loss.

The ACI value was €6.8 million versus Zanola & Moreschi's total of €6.6 million. It differs from the Liberatore study, which used different income adjustment coefficients associated with the presumed production potential of the dead person. Annex 9 describes the ACI method of attributing the current value to production loss. ISTAT's erroneous underestimate of accidents in Rome also valid also applies to the figure indicated by ACI.

TABLE 39. PRODUCTION LOSS (IN EUROS) RESULTING FROM DEATHS CAUSED BY ACCIDENTS INVOLVING MOPEDS IN ROME IN 2000 – ACI ROAD ACCIDENTS OBSERVATORY

Age (years)	Number of deaths	Loss of production	
		Current value per person (euros)	Total (euros)
0–15		307 311	–
16–19		478 070	–
20–25	3	641 852	–
26–35	4	824 742	1 925 556
36–45		838 628	3 298 967
46–55	2	632 675	–
56–65	1	263 598	1 265 349
≥ 66		50 339	263 598
Total	10		6 753 470

Source: ACI Road Accidents Observatory (Annex 9).

Society's willingness-to-pay method – Liberatore

Liberatore's study (Annex 11) proposes the estimate based on the society's willingness to pay to avoid fatal or disabling events or to guarantee a lower probability of incidence. In this case, Liberatore considered the obligation to pay for a helmet, this being understood as an expense the society as a whole has decided to sustain to diminish the incidence of fatal or disabling events (Law No. 472/99). The price *C* of the helmet is spent in an effort to lower the probability of death compared with not having a helmet. The following formula derives the value *V* that the society is willing to pay:

$$C \ \Omega \ V(d_n - d_c),$$

The differential ($d_n - d_c$) represents the difference in mortality without a helmet and with one. This is the ratio between moped deaths and mopeds circulating between 1985 (before the 1986 law was passed making helmets obligatory for people younger than 18 years) and 2000 (obligatory helmet use also for those 18 years and older). The cost of a helmet was assumed to be €100 and its lifespan 4 years. It is assumed that the death differential measured is entirely attributable to the use of the helmet. The calculation provides an average value per life of €899 000 which, multiplied by the 11 deaths in Rome, yields a value to society of €9.9 million. This value is comparable to the others illustrated in this section. The assumptions about the helmet's cost and lifespan can be questioned, but the results would still be about the same. Nevertheless, the helmet's lifespan and average cost are inferred from a market survey by Liberatore that often indicates, for example, the presence of two helmets in one family for the same vehicle, one for summer use and one for winter. The method is appealing and could be adopted for subsequent estimates and general conclusions.

Summary of the three studies

Averaging the values found, a loss of €800 000 per human life lost can be calculated for moped accidents. This is an intermediate value between that suggested by Franco Taggi at the Riva del Garda convention of 2001 (Taggi, 2001) and that inferred from the adjusted values indicated by COST 313 (cfr.Table 36). This figure was multiplied by the number of persons killed which, however, is an underestimate.

In order to examine the underestimated number of deaths, reference can be made to the data supplied by the Municipal Police of Rome to the project staff. These data do not distinguish between cause of death by vehicle class, or age of the victim, but they do substantiate the considerable under-reporting, to which the city has been subject (see also the list in Chapter 4 for greater detail):

	Municipal Police	*ISTAT*	*%underestimated*
– total persons injured in Rome	23 014	11 497	50%
– total killed in accidents in Rome	176	99	44%
– persons killed on board mopeds	21	8*	62%
– pedestrians killed	76	2	370%

(*) the number 8 refers to the riders of the moped. The total of 11 deceased in the assessment table is formed by adding 2 deceased in another vehicle plus one struck pedestrian. The number 8 is given because the municipal police department indicates drivers plus passengers as 21 (i.e. without pedestrians and the passengers in other vehicles).

Multiplying the specific value of €826 000 per death by the 21 recorded by the municipal police, the loss of production as a result of death can be placed at:

loss as a result of moped accident deaths in Rome (year 2000) …..€16.8 million

6.2.2. Cost attributable to loss of activity

This section presents the results of the Liberatore (Annex 10) and ACI (Annex 9) studies, since the University of Turin study suggested applying the scales in Table 35. In estimating the cost of the loss of activity as a result of moped accidents, Liberatore applied the human capital method to the estimate of days of missed activity. If the loss in contribution to annual income for 2000 was €20 165, the daily loss was €55.1. For the total days of recovery attributable solely to exposure to mopeds alone, the costs of loss of income in Rome were €1.367 million (Table 40).

The assessment does not consider days of disability following hospitalization. Liberatore thus suggests examining the figure supplied by the National Association of Insurance Companies (Table 23) of 49 days of average recovery time per accident involving a moped and to add this to the days of job disability, assuming only one injured person per accident.

The National Association of Insurance Companies parameter also considers those not hospitalized and can therefore be multiplied by the total number of injured people in Rome. Liberatore's final computation is shown in Table 41.

The absolute value of this figure is also affected by the underestimate of the number of injured people recorded by ISTAT for Rome. Table 41 considers only production loss and not follow-up therapy, drugs, medical tests and examinations or other types of damage.

TABLE 40. HYPOTHETICAL PRODUCTION LOSS (IN EUROS) ASSOCIATED SOLELY WITH RECOVERY TIME FOR ACCIDENTS INVOLVING MOPEDS IN ROME IN 2000

Days of recovery time	Median duration (days)	Number of cases (injured people)	Total days	Daily income contribution lost (euros)	Daily contributions to lost income (euros)
0	0	223	0	55.1	0
1–4	2.5	245	613	55.1	33 746
5–9	7	946	6 622	55.1	364 842
10–14	12	529	6 348	55.1	349 746
≥ 15	25	449	11 225	55.1	618 446
Total	–	2 392	24 808	–	1 366 780

Source: Liberatore (Annex 11) based on National Institute of Health data (Table 26).

TABLE 41. HYPOTHETICAL PRODUCTION LOSS (IN EUROS) ASSOCIATED WITH DAY OF DISABILITY AS A RESULT OF MOPED ACCIDENTS IN ROME IN 2000

Total number of injured people	Days of disability per person	Total days of disability	Productivity loss per day	Total annual loss
2 392	49	117 208	€55.1	€6 458 161
Average cost per injured person				€2 699

Source: Liberatore (Annex 11) based on National Association of Insurance Companies data (Table 23).

ACI study on accident injury

The ACI study (Annex 9) examined the attribution of points of permanent disability and awarded the value established by the Milan Law Court (Tribunale di Milano) to each point. Given that the Milan Law Court assigns points for each year of age, the ACI has considered the average number of points as a value for the age group. Using the WHO data set, the ACI has established three groups of severity of injury and has awarded disability points to each group. Minor injuries were awarded 5 disability points, severe injuries 20 and deaths 100. Minor injuries comprise 83% and severe ones 17% (Table 27). The ACI further reduced these figures by 30% for the minor injuries, given the possible non-attribution to all injuries of identical degrees of minimal disability (5%) and by 70% for the "severe" injuries, to take into account the lower frequency of injury resulting in 20 or more disability points.

Table 42 lists the average values per age group calculated by the ACI based on the tables of the Milan Law Court.

TABLE 42. AVERAGE DISABILITY SCORE BASED ON THE TABLE USED BY THE MILAN LAW COURT IN 2000

Age (years)	Average point value per group			Multiplier adopted for estimates		
	5%	20%	100%	5	20	100
0–13	1 002	2 192	5 511	5 010	43 834	551 060
14–15	963	2 107	5 298	4 816	42 140	529 756
16–19	948	2 073	5 212	4 738	41 462	521 234
20–25	922	2 017	5 070	4 609	40 332	507 032
26–35	881	1 926	4 843	4 403	38 524	484 307
36–45	829	1 813	4 559	4 145	36 265	455 902
46–55	777	1 700	4 275	3 886	34 005	427 497
56–65	726	1 587	3 991	3 628	31 746	399 092
≥ 66	609	1 333	3 352	3 047	26 662	335 181

Source: ACI (Annex 9) based on Milan Law Court data for 2000.

The ACI hypothesis is in accordance with the National Association of Insurance Companies study (Table 23) reporting that, of a sample of 4 603 moped accident claims compensated, 65% of the accidents had an average disability of 3.8%. In fact, ACI has postulated a score of 5 points for 70% of the 83% of the injuries deemed minor.

Table 43 estimates the loss of "social wealth" resulting from moped accidents according to the disability scoring method.

TABLE 43. SOCIAL LOSS (IN EUROS) FROM MOPED ACCIDENTS IN ROME IN 2000 ACCORDING TO THE ATTRIBUTION OF DISABILITY POINTS

Age (years)	% injured per group	Minor injuries			Severe injuries			Total loss (euros)
		70% of 83%	Euros per 5 disability points	Total (euros)	30% of 17%	Euros per 20 disability points	Total (euros)	
0–13	0.46	6.4	5 010	32 026	0.6	43 834	24 598	56 624
14–15	4.24	58.9	3 371	198 648	5.2	42 140	217 966	416 614
16–19	23.28	323.5	3 317	1 073 145	28.4	41 462	1 177 504	2 250 650
20–25	24.77	344.2	3 227	1 110 718	30.2	40 332	1 218 731	2 329 448
26–35	31.19	433.5	3 082	1 335 916	38.0	38 524	1 465 829	2 801 745
36–45	10.32	143.4	2 901	416 097	12.6	36 265	456 560	872 657
46–55	3.33	46.3	2 720	125 898	4.1	34 005	138 142	264 040
56–65	1.38	19.2	2 540	48 707	1.7	31 746	53 444	102 151
66+	1.03	14.3	2 133	30 532	1.3	26 662	33 501	64 034
Total				4 371 687			4 786 275	9 157 962

Source: ACI (Annex 9) based on data from ISTAT, National Institute of Health (Casco 2000 study (personal communication, Franco Taggi and Marco Giustini, National Institute of Health, 2000) and the Milan Law Court.

Table 44 considers the ACI estimates of the emotional damage of the permanent disability resulting from moped accidents by applying a total score of

TABLE 44. QUANTIFICATION OF THE EMOTIONAL DAMAGE CAUSED BY DEATHS IN MOPED ACCIDENTS IN ROME IN 2000

Age (years)	Deaths	Euros per 100 points	Total damage (euros)
0–13		551 060	0
14–15		529 756	0
16–19		521 234	0
20–25	3	507 032	1 521 095
26–35	4	484 307	1 937 230
36–45		455 902	0
46–55	2	427 497	854 994
56–65	1	399 092	399 092
≥ 66		335 181	0
Total	10		4 712 411

Source: ACI (Annex 9).

100 for the disability score to people killed. The calculation for deaths lies outside the estimate of "society's costs" as postulated in section 6.2.1 but is offered by ACI as a method for measuring the intangible familial costs associated with the loss of life. The authors indicate this value as an estimate of the value of the loss of human life as experienced by the family.

The estimate shown in Table 44 is not, therefore, comparable to a production loss but to an estimate of intangible costs such as those proposed by Zanola & Moreschi using the United States Federal Highway Administration scale of values and is thus not considered in the total costs.

Averaging the estimates of the Liberatore (€6.46 million) and the ACI (€9.16 million) studies and assuming that the moped accidents in Rome are underestimated by 40%, the loss from disability resulting from moped accidents in Rome in 2000 was about €13 million.

Loss from disability resulting from moped accidents (Rome year 2000) …..€ 13 million

6.2.3. Overall summary of social costs resulting from moped accidents

To summarize, the overall social costs resulting from accidents involving at least one moped in 2000 in Rome include:

– average health costs per injured person of €975;
– people injured in Rome according to the Rome City Police (Table 11) 6 691;
– estimated direct health costs of . . . . €6.5 million;
– estimated production loss resulting from deaths of . . . . €16.8 million;
– estimated production loss resulting from temporary disability of . . . . €13 million;
– Total estimated social costs for the year 2000 . . . . €36.3 million.

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7. NOISE EXPOSURE

The feasibility study had great difficulty in assessing the impact of mopeds on noise exposure. In reality, such a study would be extremely difficult for noise in general, regardless of the source of noise. Nevertheless, several of the studies found on noise pollution caused by vehicular traffic and mopeds are summarized below.

7.1. Contribution to noise pollution by various vehicles circulating

According to the estimates made based on a model developed by the National Research Council Istituto Motori CNR in 1988, a spark-ignition motorcycle generates noise equivalent to that generated by four automobiles, whereas a truck is comparable to eight automobiles (Di Luca, 1996).

More recent studies conducted by the Regional Environmental Protection Agency of Tuscany indicate that average two-wheeled vehicles emit noise comparable to those of 1.8 automobiles. Trucks and buses emit much more noise: 10 times as much as automobiles (Poggi et al., 2000).

Friends of the Earth Italy (2002) evaluated the external costs of noise pollution. Of these costs, an estimated 9% result from mopeds. This study, however, is concerned with all of Italy and thus considers other means of transport such as aeroplanes and trains as well. It also maintains that the impact of mopeds is greater in the urban setting.

Estimating the overall contribution of various means of transport to noise pollution and to the exposure of the population to noise in general proves extremely problematic for the City of Rome, especially in the absence of an established monitoring system.

7.2. Summary of two noise exposure assessments

This brief summary of studies on exposure to noise pollution in the urban setting is incomplete. On the other hand, this feasibility study is limited to the study of the society's exposure to the use of mopeds.

The legal background in Italy comprises the general policy law on noise pollution (Law No. 447/95) and the Decree of the President of the Ministers' Council of 14/11/1997. The norms subdivide Rome into six different zones, with limits established for each area. The limits are 65 dB(A) during the daytime and 55 dB(A) at night for areas with substantial human activity.

The Regional Environmental Protection Agency of Tuscany (Poggi et al., 2000) extensively monitored the City of Florence, measuring noise levels by area. The study concluded the following.

- On average, the population is exposed to levels 10 dB(A) higher than the limits foreseen by the Green paper on future noise policy of the European Commission (1996).
- The proportion of the population exposed to higher levels is 56% during the day and 100% at night.
- Rome's noisiness has remained constant over time.
- Extended areas with homogeneous noise characteristics cannot be identified.
- The Limited Traffic Zone, if not exclusively reserved for pedestrians, is no quieter than other normal road traffic areas.

The Organization for Security and Cooperation in Europe also considers 65 dB(A) as the acceptable equivalent energy level (L_{eq}) in the urban setting. The L_{eq} was identified to characterize the sounds that oscillate greater than 5 dB, a characteristic of road traffic noise (Di Luca, 1996).

The study concluded that reducing traffic noise by 10 dB(A) would require reducing the road traffic flow by 90% (Di Luca, 1996).

7.3. Situation in Rome

The City of Rome has only measured noise to follow up complaints in specific situations and can therefore not supply systematically gathered data that could allow the contribution of various vehicles to the city's sound pressure levels to be estimated. Although definitive acoustic zoning of the city as foreseen by the regulatory norms has not yet been implemented, temporary zoning is in force. On 23 April 2002, the City government adopted a provision that calls for acoustic zoning, and the City Council's pronouncement is awaited. Once this provision is adopted definitively, the Noise, Air and Water Pollution Unit of the City of Rome expects to launch a sample monitoring system of the various areas of the city using mobile stations. It is hoped that this campaign will provide an in-depth examination of the various sources of noise and the contributions to it by various types of vehicles.

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8. CONCLUSIONS ON THE FEASIBILITY OF A NATIONWIDE STUDY

The feasibility study concludes that a nationwide study on exposure to mopeds in Italy can be performed, and several parameters examined here regarding Rome can be applied generally.

8.1. Possible use of specific parameters

The parameter of the number of mopeds per inhabitant could be applied to the rest of Italy but with some regional adjustments to be defined for each case. The number of licence plates issued by the Department of Motor Vehicles is a good indication of the number of mopeds circulating. This parameter, which is the most immediate and accessible, tends to be overestimated in northern Italy and underestimated in southern Italy. The situation is similar for the number of rider–km.

The conclusions on the phenomenon of the use of mopeds are generally applicable nationwide. Average income and convenience in commuting are very common reasons for using a moped.

The pollution attributable to mopeds, which causes 20% of the CO and 21% of the PM10 measured at urban monitoring stations, is a reasonable point of departure. The assumption of these amounts as input data in subsequent evaluations is a delicate point that will have to be evaluated by people technically competent to assess the validity of the coefficients adopted. Certainly the technicians who deal with emissions and models can review the work proposed by the institutes that have collaborated and can assess the limitations in application. Moreover, these estimates, precisely because they have not been technically validated, do not present confidence intervals but rather constitute an attempt to summarize what can be produced based on the models designed to date and the available data. Based on the quantity and variety of vehicles circulating, the many inhabitants and the complexity of its social fabric, Rome represents a good sample for describing this.

The data on accidents and health effects were drawn from studies conducted on many cities or nationwide. The parameters found are therefore applicable to nationwide estimates. In particular, the assessment of road accident exposure amounting to 83% minor injuries (no hospitalization) and 17% serious injuries (hospitalization and variable recovery time) can be applied to other estimates.

Figures on the specific health effects of accidents and their total cost should be interpreted more cautiously. The accident recording systems and those of hospital admissions are separate and difficult to link.

The feasibility study has identified appropriate parameters for measuring excessive mortality or morbidity among the general population, or even better, the proportion of adverse health effects attributable to the air pollution caused by mopeds. The uncertainty over these estimates (Chapter 5) is articulated in various ways, ranging from clinical and epidemiological ones to toxicological ones and those regarding estimations of real exposure. If urban pollution is definitely harmful, the percentage of responsibility borne by two-stroke engines in worsening health status needs to be studied in greater depth. The conclusions of Chapter 5 therefore need to be interpreted carefully and cannot automatically be applied to other urban contexts.

The opinion of this feasibility study is that estimating parameters for exposure to noise is not currently possible.

8.1.1. Missing data and possible developments for a nationwide assessment

The areas of study related to pollution requiring more in-depth study are:

- the chemical composition of the PM measured by the monitoring stations;
- the composition of the PM emitted in the exhaust of vehicles with two-stroke engines and those with diesel engines;
- the measurement of the correlation between fine PM and other pollutants;
- the measurement of the proportion of urban particles owing to vehicular traffic and the amount of PM emitted by engines compared with other mechanical components such as tyres and brakes; and
- additional study of the possible use of models for the emission and dispersion of pollutants in relation to vehicular traffic flow.

The areas of study related to the effects of accidents requiring more in-depth study are:

- the assumption of a standard system of recording accidents by city police departments, along with digital systems such as those existing in some cities; and
- the setting up of a record-linking system between emergency rooms and the recording of accidents using, for instance, the victim’s tax identification number as a linking device, or more informative admissions charts in hospitals that could, for example, indicate the cause of hospitalization.

8.2. The estimates' critical points and further theoretical observations

The study of the parameters for the social cost of accidents and of the effects of pollution needs to be developed further. There are so many cost models and hypotheses that finding the "truth" for an industrialized society exposed to the use of mopeds is no simple matter. Further, evaluating the benefits deriving from moped use would also be necessary to complete the overall impact assessment.

Assessment of the general population's exposure and the ratio between concentration measurements and emissions factors requires further study. For example, estimating emission factors, average distances travelled by types of vehicles and the total number of vehicles in cities is complex, and the various sources often contradict one another.

Since quantifying the proportion of urban air pollution attributable to mopeds requires many assumptions and adoption of models, coefficients and estimated figures that remain under debate by technicians and experts in this field, this section of the report is subject to review and is especially open to advice and revision. This quantification represents an input of data for health impact assessment; therefore, the figures presented for the burden of disease in relation to pollution could change accordingly in the future.

ANNEXES

Annex 1. List of contacts and sources for rolling stock estimate

WHO	CONTACT	YEAR – I reference	SOURCE basis for total calculation	PUBLICATION and/or SITE	METHODOLOGY	TYPE OF VEHICLE	TERRITORIAL DEFINITION	YEAR OF PUBLICATION	ROLLING STOCK COUNT
Transport Ministry Motor Vehicles Administration Unit Office MOT6	Dr Alessandro CALCHETTI	1993-2000	Rome Provincial Motor Vehicles Office	Archives	Census	mopeds	Province of Rome	Archives updated to 30/4/2001	-1993: 37 026 -1994: 260 217 -1995: 79 715 -1996 : 58 851 -1997: 60 550 -1998: 48 638 -1999: 30 399 -2000: 17 870
Ministry of Transport "Conto Nazionale dei Trasporti"	Dr Gianni Zacchi	1998	ACI	CNT 1999	Rolling stock	mopeds	National	2000	4 100 321
University of Rome "La Sapienza" Inter-University Centre for Environmental Technology and Chemistry		1999	ACI	*Conference on* "The creation of dedicated public transport lanes in the metropolitan area of Rome"	Rolling stock	motorcycles	Rome	2000	600 000
Friends of the Earth	Pier Luigi LOMBARD	March 2001	ANPA (CORINAIR emissions)	The social and environmental costs of travel in the Rome metropolitan area	Annual traffic volumes*	motorcycles and mopeds	Rome	1997	2.80 (10^9 pkm)
Municipality of Rome		28 June 1999	?	Rome General Urban Traffic Plan (PGTU)	?	mopeds	Province of Rome	1998	700 000 (of which an average of 400 000 unit/day used on non-rainy weekdays in Rome urban area)
Municipality of Rome Department VII Travel and Transport Policies		Total Survey	CENSUS	URBAN TRAVEL www.comune.roma.it /dipVII/mobilita	13th general population Census (systematic travel)	motorcycles and mopeds	Rome	1991	Total systematic trips in the Rome municipal area over 24 hours: 65 749
ANIA – National Association of Insurance Companies		1999 Table Sample statistics on the basis of the owner's province of residence	Data from Association Insurance Companies	TABLE	Number of mopeds insured according to province of residence	mopeds	Province of Rome	1999 1997	129 333 (129 233:0.43% =300 542) (samples) 99 564 (registration province)

* *Obtained by multiplying the volumes of national urban traffic (mopeds and motorcycles 31.961 billion passengers/km) by a reduction factor equal to the ratio between the population of the Municipality of Rome (2 653 245) and the entire Italian population resident in cities of more than 20 000 (30 .323 312).*

Annex 1 - continues

WHO	CONTACT	YEAR – I reference	SOURCE basis for total calculation	PUBLICATION and/or SITE	METHODOLOGY	TYPE OF VEHICLE	TERRITORIAL DEFINITION	YEAR OF PUBLICATION	ROLLING STOCK COUNT
ANCMA National Association of Mopeds and Motorcycles		1950-1999		www.ancma.it	PARCO	mopeds	National	1998	7 000 000/5 000 000
ANPA National Agency for the Protection of the Environment		1990-2010	ANCMA data	Moped atmospheric emissions reduction scenarios	Estimate based on the development foreseen in private and public travel, total cars and buses	mopeds	National	2000	2000: 5 351 848
ARPAT Tuscan Regional Agency for Environmental Protection ACI Toscana Service		2000(?)	Field Study	Preliminary elaboration of data obtained from the "Vado Pulito" campaign and of the benzene values measured by ARPAT			Rome	2001	
STA	Engineer DE PALO	1999	- PROVINCE OF ROME (license plates issued) - ANCMA (estimates divided into Conventional and EURO1) - SECTOR ASSOCIATIONS (real number circulating)	Annual report on the air quality of the Municipality of Rome – Year 2000 "Evaluations of pollutant emissions produced by vehicular traffic"	License plates issued (province) = 500 754 80% circulate = 400 603 Registrations before June 1999 are conventional and after 90% are EURO1, applying the Province/Rome conversion factor of 0.96	mopeds	Rome	2000	Rolling Stock 1999 TOT 336 507 CONV 325 029 EURO 11 478 Rolling Stock June 2000 TOT 333 086 CONV 311 979 EURO 21 107
MONNI (Confauto)		1998	C.E.D. of the D.T.T. of the Ministry of Transport and Navigation	Semniar: "MOPEDS: damage and remedies" 10 June 1999	license plates issued	mopeds	Rome	1999	488 706
ACI	Dr PENNISI	1999	ACI	Total Rolling Stock as of 31 December 1999	Calculation based on Ownership, drawn from the public automobile registry (PRA)	mopeds	Province of Rome	2000	208 215

Annex 2. Geographic distribution of two-wheel vehicles*

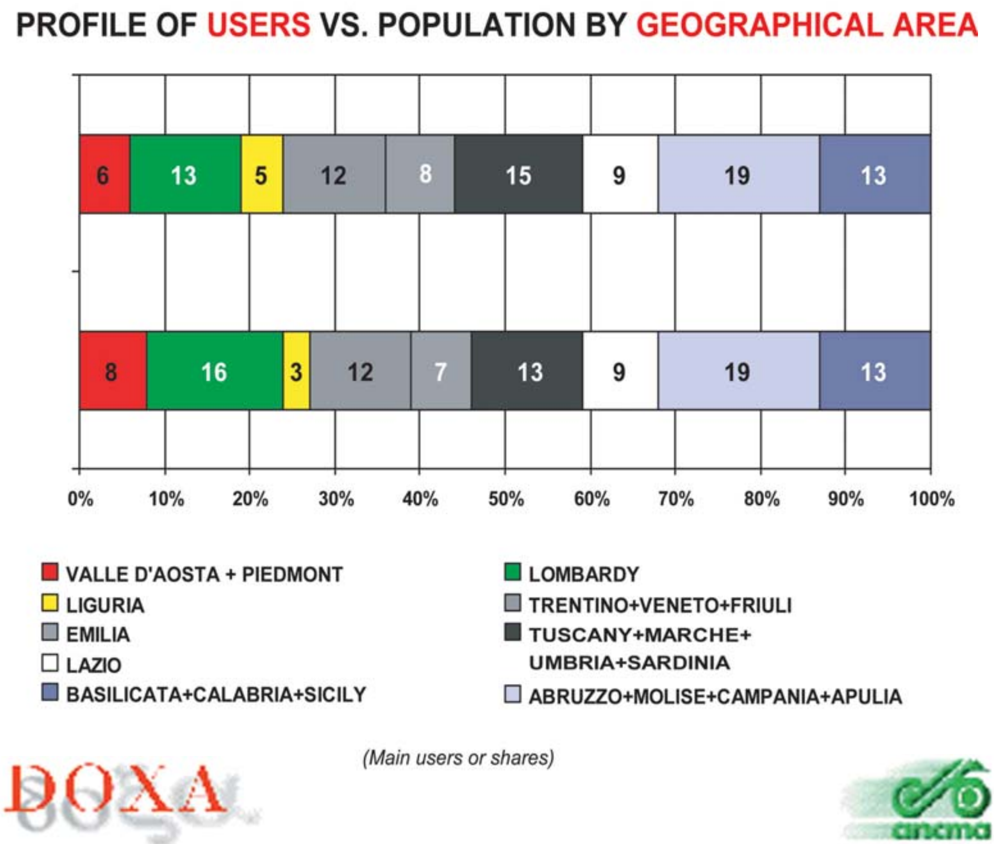

Figure extracted from the November 2001 presentation of the DOXA (Italian Institute for statistical researches and public opinion analysis) - Study commissioned by ANCMA (Italian Association of Motorcycles Manufacturers)

* *Reproduced with kind permission from ANCMA (2001)*

Annex 3. Analysis emissions of two-stroke engines (ISIS, 2001)*

This chapter reviews several studies in order to provide an updated estimate of the specific consumption and emissions factors for two-stroke engine mopeds, with the aim of assessing their overall emissions in Rome for the year 1999.

1. Polluting substances

The principal pollutants present in the exhaust emissions of two-stoke engine mopeds are:

- carbon monoxide (CO)
- volatile organic compounds (VOC)
- nitrogen oxide (NOx)
- particulate matter (PM)
- hydrocarbons (HC)

The emissions of the first three compounds are regulated by Directive 97/24/EC (in force since 17/6/99) which establishes their upper limit values and evaluation methods.

Shown in the table below are the emissions limits for "EURO 1" (97/24/stage 1) and EURO 2 mopeds (97/24/stage 2) according to the ECE 47 drive cycle.

TABLE 1

	CO (g/km)	HC + NO_2 (g/km)
EURO 1 (1999)	6	3
EURO 2 (2002)	1	1.2

Mopeds registered before Stage 1 of the Directive are defined as "conventional".

The following subparagraphs supply a brief introduction to some of the principal pollutants' peculiarities.

1.1. CO

The formulation of CO is associated with the combustion that takes place in the cylinder of the two-stroke motor: as the air/gasoline mixture is poor in oxygen all the carbon present in the fuel cannot be transformed into carbon dioxide.

Given the rich gasoline content in the air/fuel mixture, the two-stroke engine presents high CO concentrations in its exhaust.

* *Reproduced with kind permission from ISIS (Insitute of Studies for the Integration of Systems), 2001.*

1.2. NOx

The term "nitrogen oxide" (NOx) is a conventional term meant to represent the sum of nitrogen monoxide (NO) and nitrogen dioxide (NO_2).

Nitrogen oxide emissions in internal combustion engines are mainly made up of NO; this compound is formed by the combination of oxygen and nitrogen (naturally present in the air) in high–temperature processes. The higher the temperature of the combustion process the greater the NO emissions.

As a result of the lower temperatures reached by their exhaust emissions, the NOx emissions of two-stroke engines are much lower than those of four-stroke engines.

1.3. VOC

The principle mechanism in the formulation of the VOC present in two-stroke engine emissions is the incomplete combustion of the VOC present in the gasoline itself. For this reason the amount and type of compounds emitted do not depend only on the technology of the engine but also on the chemical composition of the gasoline/oil lubricant mixture.

VOC is essentially composed of aromatic hydrocarbons, aldehydes, ketones, alkanes, cycloalkanes, alkynes and polycyclic aromatic hydrocarbons.

1.4. PM

The emission of particles by mopeds is traceable essentially to the presence of unburned engine oil in their exhaust (Palke, 1999) (Santino, 2001).

The PM (defined as portions of exhaust gases trapped in the filter in the form of both aerosols and solid particles) in exhaust emissions is composed of more than 95% unburned or slightly oxidised (non-solid) engine oil, while the remaining 5% is made up of solid carbonaceous and inorganic PM (Palke, 1999).

2. CO emissions

For the assessment of CO emissions (as for all pollutants) reference will be made to several national and international studies; the tables considered for emissions factors for all pollutants are listed in paragraph 9.

2.1. Conventional mopeds (non-catalytic)

The emissions factors obtained following the ECE47 drive cycle in the study in table 7 attributes to conventional mopeds an emissions factor of 9 g per km (g/km) (for two-stroke motorcycles with 125cc engine displacement the CO emissions factor according to the ECE40 drive cycle ranges between 9 and 12 g/km in the 1999 study by Nuti and Capone).

The ECE47 drive cycle presents two essential limitations in measuring emission factors:

The maximum speed reachable is limited to the levels imposed by law.

It does not consider cold-start emissions since the measurement phase beings after 448 seconds from the start of the cycle.

The first point is particularly limiting in terms of mopeds circulating in Italy since the majority have been tampered with (at least the exhaust system) in order to permit speeds much greater than those foreseen by the ECE47 drive cycle.

In order to obviate this problem several studies were taken into consideration (Prati et al. 1999 and Rijkeboer, 1997) that yield emissions on two different mopeds following all the specifications of the ECE47 drive cycle excepting the limitation for maximum speed (in order to account for tampering).

In the Prati et al. study (1999) a CO emission factor of 17.6 g/km is estimated, while the Rijkeboer considers a fluctuation range between 10 and 20 g/km and a proposed emission factor of 15 g/km. The COPERT methodology assumes the value proposed by TNO (Rijkeboer) as average emission factor for conventional mopeds; since this figure proves to be perfectly in line with the emission factors estimated in the Prati et al. (1999) study, the value of 15 g/km is considered as the baseline for this study.

2.2. EURO 1 catalytic mopeds

For the estimate of the CO emission factor for EURO 1 mopeds the baseline value assumed is the emission factor calculated according to the COPERT method, which is equal to 7.5 g/km; this choice is reinforced by what was stated in the preceding paragraph regarding the agreement of the values proposed in COPERT with those estimated in other studies that adopted a "modified" ECE47 drive cycle.

Other values, relatively close to the emission factor adopted, were found in the technical literature for catalysed mopeds:

The Swiss Federal Department of the Environment (Keller et al. 2000) proposed a value of 4.4g/km;

The emission factor measured experimentally by Palke and Tyo (1999), using the ECE40 drive cycle on two catalysed mopeds, fluctuates between 4.7 and 6.6 g/km.

3. NOx emissions

Table (2.9) shows the emission factors proposed by the CORINAIR (2001) inventory (0.3 g/km) while Table (2.8) those of the Swiss Department for the Environment (Keller et al. 2000) (0.01 g/km).

The emission factor offered by Rijkeboer (1997) is equal to 0.03 g/km; this average moped emission factor is adopted (as it was for CO) using the COPERT methodology both for conventional as well as EURO1 mopeds.

The average emission factor for the mopeds examined by the Prati et al. (1999) study (Table 2.1) is also equal to 0.03 g/km.

The emission factor adopted in this study is 0.03 g/km (valid for both conventional and EURO 1 mopeds) since this was the estimate of two independent studies (Prati et al. and Rijkeboer) with a “modified” ECE47 drive cycle certainly much closer to the present situation in Italy.

4. VOC emissions

A study conducted by the U.S. EPA (Lindhiem, 1997) reveals that the non-methane hydrocarbons present in two-stroke engine exhaust equal 99.1 percent of the total hydrocarbons; since methane represents only 0.9 percent of the hydrocarbons emitted in exhaust and considering the uncertainty linked with emission factors estimates, all the factors considered in the literature will be associated in the present study with non-methane volatile organic compounds (NMVOC).

4.1. Conventional (non-catalytic) mopeds

In the case of the NMVOC emission factor reference will once again be made to the studies published by Prati *et al*. (1999) and Lindhiem, which estimate very similar values of 9.2 and 9 mg/km respectively.

In addition, considering the evaporation share of the NMVOC in the ARPA study (2000), an emission factor of 9.3 mg/km is estimated (using the COPERT method).

The present study therefore adopts an emission factor of 9.3 mg/km as it is equivalent to the studies cited and comprehensive of the emission evaporation share.

4.2. EURO 1 catalytic mopeds

After applying the emissions reduction percentage proposed by COPERT for mopeds, a NMVOC emission factor of approx. 4.2 g/km is proposed.

In the study by Palke and Tyo (1999) the NMVOC emission factor measured experimentally according to the ECE40 drive cycle on two catalytic mopeds fluctuates between 4.2 and 4.5 g/km.

The present study thus assumes a EURO1 mopeds emission factor of 4.2 g/km.

5. Emissions for the five major toxic organic pollutants

In the context of gasoline reformulation, the U.S. Environmental Protection Agency (EPA) (U.S. EPA, 1991) established the following organic polluting compounds as being toxic for human health: benzene, polycyclic aromatic hydrocarbons (PAH), formaldehyde, acetaldehyde, and butadiene 1-3.

5.1. Benzene emissions

The S. Fuselli study is a review of several studies on benzene emission factors; Table (2.5) shows how the emission factors fluctuate between 112 and 150 mg/km. This study also displays the emission factor for catalytic mopeds (taken from Nuti M. 1993).

In Prati et al. (1999) the emission factor was estimated by examining the exhaust of 16 mopeds (conventional) and revealed a fluctuation between 41 and 150 mg/km with an average value calculated by us as 111.4 mg/km; these emission coefficients were obtained using commercial gasoline (0.98% benzene and 33.2% aromatic hydrocarbons). Repeating the test with gasoline that had a lower aromatic hydrocarbon content (0.70% benzene and 28.1% aromatic hydrocarbons) yielded an emission factor of between 25 and 127 mg/km with an average reduction of 23% (the reduction of the benzene content was equal to 28% between the two gasoline formulas).

Saija et al. (ANPA, 2000) used the COPERT method to estimate an emission factor for conventional mopeds of 290 mg/km.

The emission factor (for conventional mopeds) proposed for the present study was estimated by means of an averaging of the various values reported by the studies cited and equal to 156.7 mg/km.

The only value available for catalytic mopeds is 16.4 mg/km.

5.2. Formaldehyde and acetaldehyde emissions

F.J. Laimboch (1991) was the only study found for an estimate of acetaldehyde and formaldehyde emission factors. The fluctuation interval for these emission factors is shown in Table (12).

Shown in the table below are the central values of the fluctuation interval assumed by the present study as average representative values for formaldehyde and acetaldehyde emission factors.

TABLE 2

ECE 47 drive cycle	Catalytic	Conventional
Formaldehyde (mg/km)	0.5	15
Acetaldehyde (mg/km)	0.3	5.5

5.3. Benzo[a]pyrene emissions

Benzo[a]pyrene is a polycyclic aromatic hydrocarbon for which some exposure response functions (ExternE) were estimated.

The emission factors estimated (using the ECE47 drive cycle) in F.J. Laimboch (1991) fluctuate within the interval shown in Table 12. The emission factor for non-catalytic mopeds proposed for the present study is 2.15 μg/km (average value for the two mopeds tested). This factor for catalytic mopeds is 0.4 μg/km (central value of the interval examined).

5.4. 1-3 butadiene emissions

The 1-3 butadiene emission factor was obtained from the only study found on emissions of this substance for two-stroke engines (Prati et al. 2000). However, this study estimated an emission factor of 24 mg/km (before catalytic converter) for a two-stroke 124cc motorcycle and not for a moped. Considering the emission factor measured in this study for VOC (4.65 g/km) and relating it to the 1.3 butadiene emission factor, it can be seen that this latter represents 0.267 percent of the VOC emitted.

Considering this percentage valid also for moped emissions and the NMVOC emission factor assumed in this study, an estimated value of 48 mg/km is obtained for conventional mopeds.

Given the estimate procedure and the single source found, this emission factor is to be considered indicative only in terms of magnitude.

6. PM emissions

An initial source of PM emission factors is the D. Santino study (ENEA) which examines the emissions of two mopeds, one conventional and the other EURO1. The emission factors obtained according to the ECE47 drive cycle (both mopeds amply surpassed the theoretical speed of 45km/h during the cycle) were 172 mg/km for the conventional moped and 42.7 mg/km for the EURO1 catalytic moped.

F.J. Laimboch (1991) measured PM emissions for conventional mopeds ("warmed-up" and "cold-start") as well as catalytic ones. The emission factors obtained (ECE47 drive cycle) are shown in Table (11).

Palke and Tyo (1999) evaluated the emissions of 2 conventional mopeds (ECE40 drive cycle). One of them was subsequently equipped with a catalytic converter and emissions were measured before and after. The two mopeds tested differed in terms of distance travelled, in that the first (type "1") had travelled approx. 19 500 km, while the second (type "2") 2 600 km. The emission factors for type "1" non-catalytic mopeds, for type "1" catalytic mopeds and type "2" non-catalytic mopeds was 35.2 mg/km (fluctuation interval from 29 to 43 mg/km), 15.7 mg/km (interval of fluctuation between 29 and 43 mg/km) and 10 mg/km.

The PM emission factor proposed for the present study is 91.4 mg/km for conventional mopeds and 33.9 mg/km for EURO 1 catalytic mopeds.

The value for conventional mopeds was obtained by averaging the sources cited as follows:

- the emission factor estimated by D. Santino *et al.*;
- the cold-start emission factor estimated by F.J. Laimboch (1991) (the initial phase of the ECE47 drive cycle was also considered);
- for the third study an average was taken of the emission factors of the two mopeds tested in order not to excessively underestimate the final result, since one of the two mopeds was practically new (2 600 km travelled) while the average age of the mopeds circulating in Rome is approx. 9 years.

The emission factor for EURO 1 catalytic mopeds was estimated by averaging the values provided by the three studies.

7. Fuel consumption

To estimate moped fuel consumption reference is made to the table below which shows consumption values in g/km taken from several bibliographic sources and the baseline values proposed in this study.

TABLE 3

MOPED Fuel Consumption (g/km)		
Source	**Conventional mopeds**	**EURO 1**
D. Santino et al.	23.7	23.1
M.V. Prati et al. (1999)	27.8	-
COPERT	25	15
Value assumed	25	19

8. Estimate of consumption and air polluting substances emitted in Rome in 1999

This paragraph presents the emission of polluting substances generated by the total mopeds circulating in Rome in 1999; the following data are necessary for an estimate of the overall total emissions:

- the emission factors for all the polluting substances considered;
- the number of circulating mopeds;
- the average annual distance travelled by a moped;
- the division of the total circulating mopeds into the categories "conventional" and "EURO 1".

The emissions factors used in the present study and analysed in the preceding paragraphs are presented in the table below.

TABLE 4

		2T Conventional	EURO 1 (cat.)
CO	g/km	15	7.5
NMCOV	g/km	9.3	4.2
NOx	g/km	0.03	0.03
Benzene	mg/km	156.7	16.4
PM	mg/km	91.4	33.9
1,3 Butadiene	mg/km	48	-
Benzo[a]pyrene	µg/km	2.15	0.4
Formaldehide	mg/km	15	0.5
Acetaldehide	mg/km	5.5	0.3

The number of mopeds (443 171 units) and their average annual distance travelled (6 072 km) were estimated in Chapter 2.

The total annual distance travelled in 1999 was 2 690 958 600 vehicles/km.

The marketing of EURO 1 mopeds began at the end of the first semester of 1999 and thus the total circulating stock is considered as being composed exclusively of conventional mopeds.

The overall emission of polluting substances generated by moped emission in Rome in 1999 is shown in the table below.

Overall gasoline consumption, assuming a specific consumption, is 25 g/km for the year 1999 and equal to 67 274 tonnes.

9. Analysis of the principal bibliographic sources and relative tables

Listed in this section are the tables used in the present study with some observations on them and the bibliographic sources from which they were drawn.

TABLE 5

Distances (vehicle km)	2 690 958 600
CO (tonnes)	40 364.4
NMCOV (tonnes)	25 026
NOx (tonnes)	80.7
Benzene (tonnes)	421.7
PM (tonnes)	246
1,3 butadiene (tonnes)	130.2
Benzo[a]pyrene	0.006
Formaldehyde (tonnes)	40.4
Acetaldehyde (tonnes)	14.8

9.1. M.V. Prati **et al.**, *Regulated and benzene emissions of in use two-stroke mopeds and motorcycles, Istituto Motori CNR e AgipPetroli, SAE 1999*

Sixteen two-stroke mopeds were subjected to dynamometric bench testing. Some of them had been tampered with to boost their top speed to well over the 45 km/h foreseen by the manufacturer. The drive cycle used for testing was based on the ECE47 with the only variation being the lack of a maximum speed (in order to better characterise the real emissions).

Table 6 shows the emission factors of the pollutants regulated by Directive 97/24/EC.

TABLE 6

	CO	NOx	HC	Consumption
Test Results (g/km)	17.6	0.03	9.21	27.8
COPERT II (g/km)	15.0	0.03	9.00	25.0

Two types of gasoline were used (“A” and “B”): type “A” has the typical composition of the gasoline (super) on the market (0.98% benzene and 33.2% aromatic hydrocarbons), while type “B” has a lower percentage of hydrocarbons (0.70% benzene and 28.1% aromatic hydrocarbons).

With type “A” gasoline the benzene emissions of the 16 mopeds fluctuated between 41 and 150 mg/km, while with type “B” the interval was between 25 and 127 mg/km.

9.2. R.C. Rijkeboer, Emission factors for mopeds and motorcycles, report in meet project funded by the European Commission, 1997

The data on moped emissions proposed in the study are subdivided into two classes: the first contains mopeds that respect the ECE 47 normative and the second (non-ECE) mopeds that have been tampered with to enable them to reach speeds above the limit imposed by law.

TABLE 7

	Non-ECE (g/km)	ECE 47 (g/km)
CO	10–20	9
HC	6–12	5
NOx	0.03	0.03
Consumption	20–30	15

9.3. D. Santino, P. Picini, L. Martino, PM emissions from two-stroke mopeds, ENEA, 2001

The test data (dynamometric bench testing) on the emissions and fuel consumption obtained from two mopeds, the first conventional and the second EURO 1.

Both mopeds amply surpassed the speed limit (45 km/h) during the ECE 47 drive cycle.

The PM emission factors measured during the drive cycle are shown in Table 8.

TABLE 8

ECE 47 drive cycle	Catalysed	No catalysed
PM (mg/km)	42.7	172.0
Fuel consumption	23.1	22.7
Oil consumption (g/km)	0.67	0.76

The PM emissions for the conventional moped are closely related to its consumption of oil lubricant.

9.4. M. Nuti, D. Caponi, Piaggio & C. SpA, The development of a propulsive unit for a friendly individual commuting vehicle, International Congress, Detroit, 1999

Data obtained using the ECE 40 drive cycle for two-stroke motorcycles (125cc).

TABLE 9

	HC (g/km)	CO (g/km)	NOx (g/km)
2T conventional (125 cc)	7.5/8.5	9/12	0.02/0.03

9.5. S. Fuselli, Istituto Superiore di Sanità

The study cites several bibliographic sources for the estimate of benzene emission factors (the data are shown in the table below).

TABLE 10

Source	Emission	2-Stroke Conv. mopeds
ANCMA - Nuti m., 1993	Benzene (mg/km)	150 (no cat.) 16.4 (cat.)
Unione Petrolifera	Benzene (mg/km)	112

9.6. F.J.Laimboch, The potential of small loop- scavenged spark – ignition single cylinder two-stroke engine, SP-847, SAE 1991

The study is a bit dated (1991) and refers to mopeds tested between 1982 and 1987, but provides very useful indications on emission factors of many organic compounds and on PM.

The tests were carried out according to the ECE 47 drive cycle.

Table 11 shows PM emission factors; for the catalytic moped a cold-start emission factor was also calculated.

TABLE 11

ECE 47 Drive cycle	Catalysed	No catalysed (cold-start)	No catalysed (warmed-up)
PM (mg/km)	43.3	90.8	58.2

TABLE 12

ECE 47 Drive cycle	Catalysed	No catalysed
Benzo[a]pyrene (μg/km)	0.3 / 0.5	0.7 / 4.5 (0.7/1.4) (2/4.5)
Formaldehyde (mg/km)	0.4/0.6	9/21
Acetaldehyde (mg/km)	0.3	4.2/6.8

Table 12 shows the emission factors for some very toxic organic compounds.

9.7. Keller M., de Haan P. (INFRAS), Emissions polluantes du trafic routier de 1950 à 2020 Complement, Office fédéral de l'environnement, des forêts et du paysage (OFEFP) Berne, 2000

TABLE 13

	Conventional	**EURO 1**
CO (mg/km)	9.3	4.4
HC (mg/km)	3.25	1.1
NOx (mg/km)	0.01	0.01

9.8. Joint EMEP/CORINAIR, Atmospheric emission inventory guidebook, third edition, Copenhagen, European Agency, 2001

TABLE 14

	Conventional	**EURO 1 (reduction percentage)**	**EURO 2 (reduction percentage)**
CO (mg/km)	15	50	90
VOC (mg/km)	9	55	78
NOx (mg/km)	0.03	0	67
Consumption (g/km)	25	40	56

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STA

Annex 4. Contribution by mopeds to urban air pollution*

1. Introduction

The present study constitutes a methodological proposal for the assessment of the contribution by two-wheel vehicles to urban air pollution, following two separate approaches.

The study's first approach is based on the direct measurement of traffic flow. This method allows for the calculation of emissions and then of concentrations owing to the real flow of traffic along a roadway tract, and thus direct comparison with the monitoring station.

The flow of automobile traffic was measured over an arc of ten days, and two-wheel vehicles were surveyed directly. An emissions model was applied for the calculation of CO corresponding to each vehicle category; then, using a dispersion model, the CO concentrations that would be present if the total rolling stock consisted only of automobiles or only of mopeds were measured. These data can be correlated with the concentrations found by the monitoring station set up in the area investigated.

The second approach used the traffic flows calculated by means of the O/D Table of the City of Rome and by the application of planning models that allow for the assignment of traffic flows to each of the city's primary thoroughfares. These flows represent the average traffic on a non-rainy work/school day.

Three air quality monitoring stations were identified in the study, located in heavily trafficked, densely-populated areas. The traffic flow in these areas was examined separately in terms of automobiles, mopeds and motorcycles, and emissions of carbon monoxide were calculated for the categories of vehicle considered.

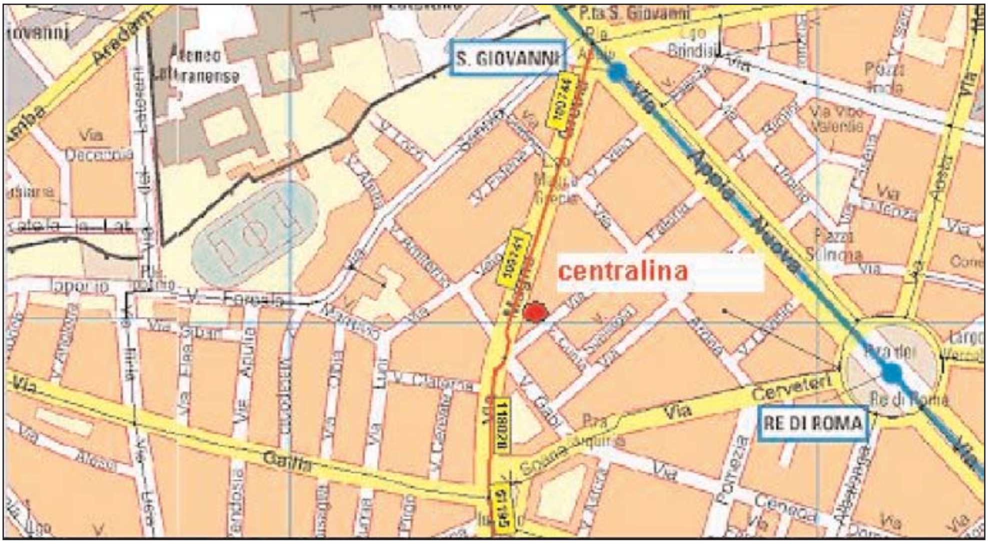
2. Magna Grecia case study

The objective of the study was to calculate the CO concentrations associated only with four-wheel vehicles and mopeds along the roadway "canyon" of Via Magna Grecia. These data can be placed in comparison with the Air Quality Monitoring Station of the City of Rome indicated on the map in Fig. 1.

This roadway tract is particularly suited to an investigation of this sort since traffic flow is measured continuously by means of magnetic induction coils and the data are harvested by the Traffic Control Centre of STA. The presence of the station also allows for the direct comparison of the data calculated by the model and the values measured.

* *Reproduced with kind permission from STA (Rome Mobility Agency), 2002.*

FIG. 1. LOCATION OF THE STUDY AREA



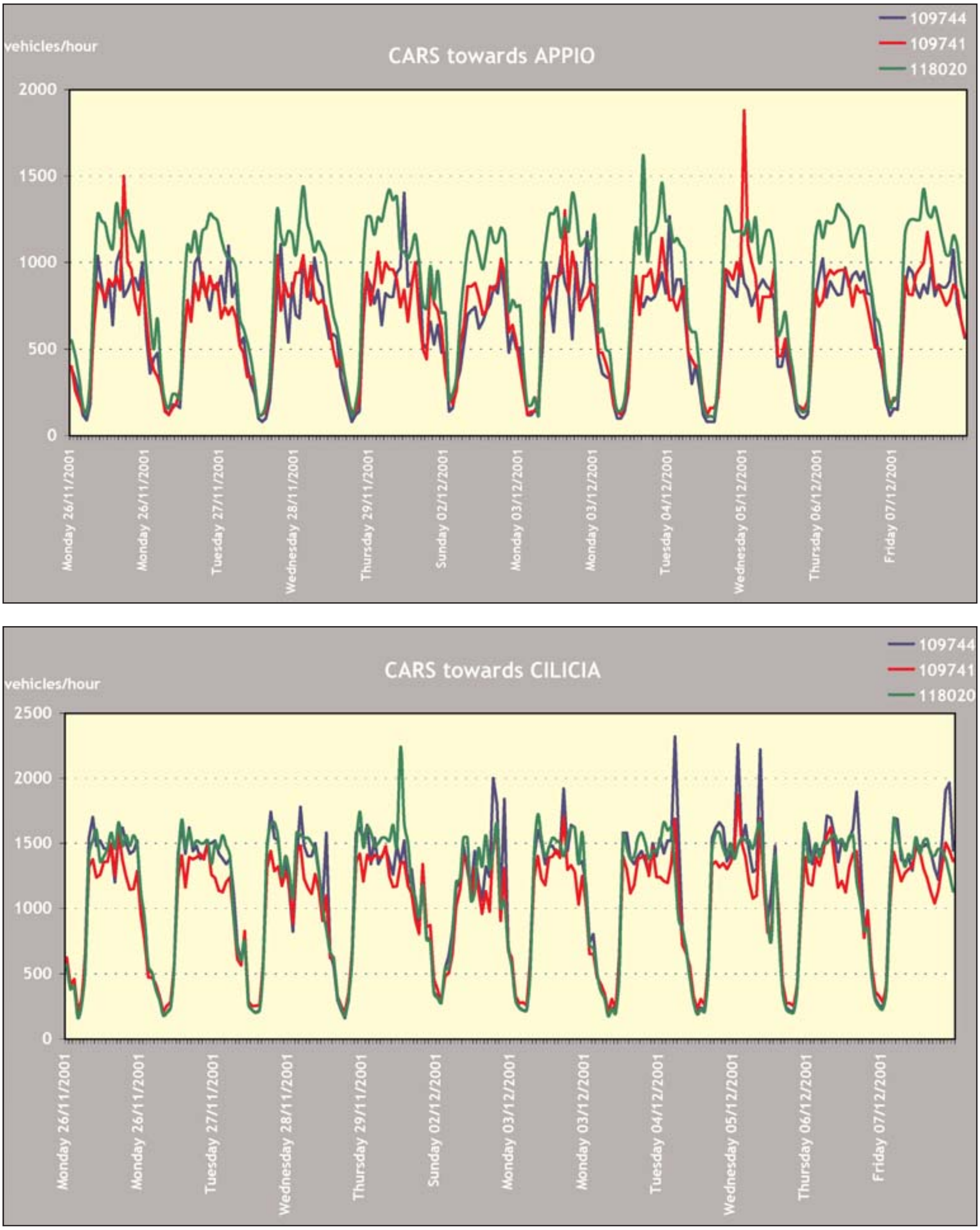
The present study considered the period of time between 26 November 2001 and 7 December 2001, with the exclusion of 30 November and 1 December (days on which traffic data were not reliable). Taking the hourly traffic flows surveyed first emissions were calculated using the TEE method (Traffic Emission and Energetic), and then concentrations, with the application of the English ADMS model (Atmospheric Dispersion Modelling System).

2.1 Traffic flows

Via Magna Grecia is part of a network of roads monitored by STA. Hourly traffic flows for the time interval examined were taken into consideration for the three thoroughfares indicated in Fig. 1.

Analysis of four-wheel traffic reveals a heavy average flow in the Cilicia direction and not in the Appio direction (Fig. 2). Furthermore, no significant reduction in flow was found on Saturdays or Sundays when only a slight reduction and an absence of peak morning and evening hours were noted. The traffic flows were also reworked on the basis of the available data with the aim of estimating flows in relation to several hours during the day (in particular the night-time hours) in which measurements had proved incomplete.

FIG. 2. FOUR-WHEEL TRAFFIC FLOW TRENDS DURING THE TIME PERIOD CONSIDERED



The given traffic-measurement systems do not yield a separate measurement of two-wheel traffic flow. Direct surveys were carried out to identify hourly percentages of two-wheel vehicles out of the total vehicular flow. The Traffic Control Centre has a circuit of video-cameras that survey the heaviest traffic areas, and the one positioned in Piazzale Appio records the vehicle flow on Via Magna Grecia. Data was registered during the five peak hours of the day and later a separate count of two and four-wheel vehicles was done.

This count made it possible to compare both the traffic flows recorded by the magnetic induction coil as well as to calculate the percentage of the vehicular flow associated with two-wheel vehicles. These percentages relative to the five peak hours of the day were integrated with the data relative to the O/D Table of the entire municipal area, yielding, for the time period considered, a two-wheel vehicle flow trend in function of the traffic actually measured, based on statistical investigation (O/D Table) as well as on direct measurement (counts).

On the work/school days of 6 and 7 March 2002 the traffic flow of automobiles and two-wheel vehicles was measured during the 5 peak hours of the day (7.45–8.45; 9.45–10.45; 14.30–15.30; 17–18; 20–21). The counts are shown in Table 1.

TABLE 1. COUNTS CARRIED OUT AT VIA MAGNA GRECIA

DATE AND TIME	TOWARDS VIA CILICIA			TOWARDS PIAZZALE APPIO		
6/03/02	CARS	COMMERCIAL VEHICLE	2-WHEEL	CARS	COMMERCIAL VEHICLE	2-WHEEL
8:00–8:15	404	38	112	311	35	53
8:30–8:45	362	36	143	327	21	87
9:45–10:00	359	35	76	282	25	52
10:15–10:30	362	47	66	264	23	39
14:30–14:45	363	43	61	311	34	67
15:00–15:15	330	34	81	333	30	51
17:15–17:30	361	22	90	366	29	82
17:45–18:00	395	17	97	351	21	112
20:00–20:15	411	8	79	352	9	74
20:30–20:45	349	5	66	339	5	67
10:15–10:30	359	37	89	292	35	70
14:30–14:45	306	42	69	325	35	71
15:00–15:15	361	36	80	329	25	80
17:15–17:30	409	21	109	321	23	112
17:45–18:00	351	20	112	376	24	122
20:00–20:15	353	8	77	349	13	75
20:30–20:45	361	8	56	317	12	77

The average of the counts for the two days, reported at a time interval of one hour, was later compared with the flow of only four-wheel vehicles measured by the Traffic Control Centre, revealing some differences between the flows counted and those measured (Table 2).

TABLE 2. COMPARISON OF FLOWS MEASURED AND COUNTED

TIME	TOWARDS CILICIA			TOWARDS APPIO		
	CARS MEASURED	CARS COUNTED	DIFF.	CARS MEASURED	CARS COUNTED	DIFF.
7:45–8:45	1628	1680	-3%	1228	1388	-13%
9:45–10:45	1485	1599	-8%	1100	1228	-12%
14:30–15:30	1473	1515	-3%	1287	1422	-10%
17:30–18:30	1450	1596	-10%	1330	1511	-14%
20:00–21:00	1425	1503	-5%	1153	1396	-21%

In order to identify the portion of the flow constituted by two-wheel vehicles, a comparison was made between the numbers of two and four-wheel vehicles.

This percentage is variable both in relation to the hour of the day and to the direction of traffic, and results as being between 17 and 30% (Table 3).

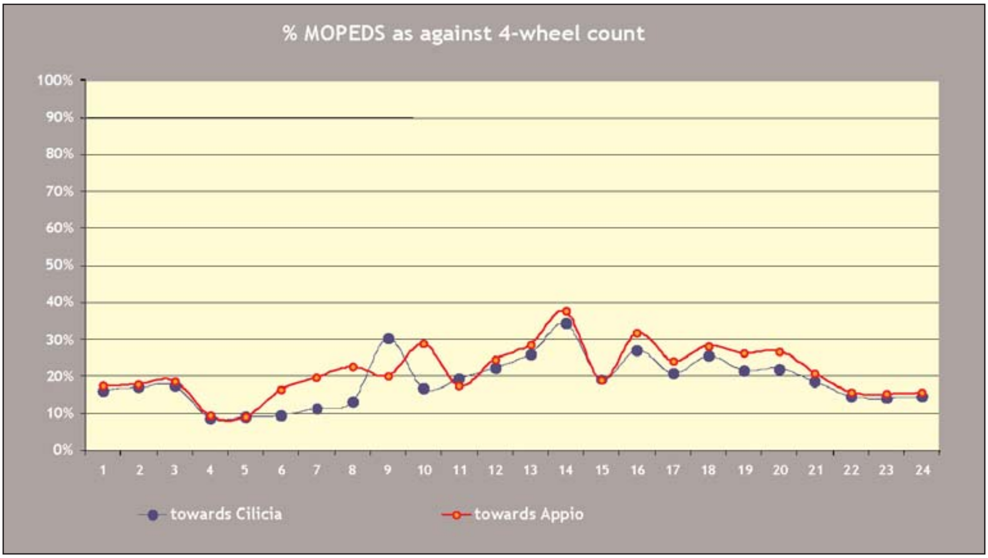
TABLE 3. TWO-WHEEL VEHICLE FLOW

TIME	TOWARDS CILICIA		TOWARDS APPIO	
	WHEEL MEASURED	2-WHEEL %	WHEEL MEASURED	2 WHEEL %
7:45–8:45	510	30%	280	20%
9:45–10:45	308	19%	215	17%
14:30–15:30	291	19%	269	19%
17:30–18:30	408	26%	428	28%
20:00–21:00	278	18%	293	21%

The two-wheel traffic flow trend over the entire arc of the day is calculated by comparing the percentages of two-wheel vehicles yielded in the counts, with those supplied by the O/D Table of the City of Rome in relation to the area in question.

The present study adopted the percentages supplied by the O/D Table during the hours for which counts were not carried out, while the percentages counted at the five peak hours were assumed in an effort to obtain a more realistic picture of the flow of mopeds in periods of heaviest traffic. The final trend of the percentages is shown in Fig. 3.

FIG. 3. PERCENTAGES OF TWO-WHEEL VEHICLES COMPARED TO FOUR-WHEEL VEHICLES FOR EACH DIRECTION



Applying the percentages shown in Fig. 3, to the traffic flow in, and keeping in mind that mopeds constitute approximately one-third of the two-wheel flow, it is possible to estimate moped traffic flow in relation to the roadway tracts considered.

FIG. 4. ESTIMATE OF MOPED FLOW IN VIA MAGNA GRECIA

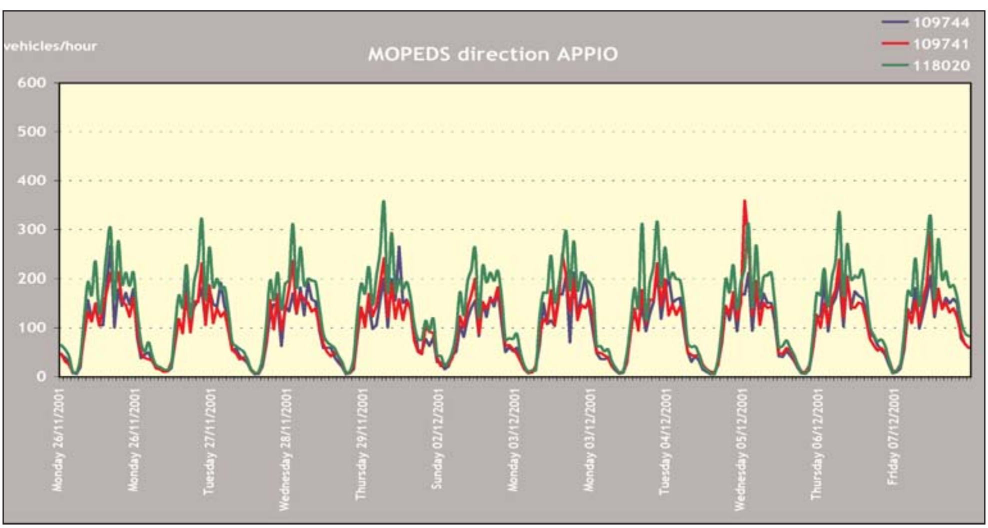
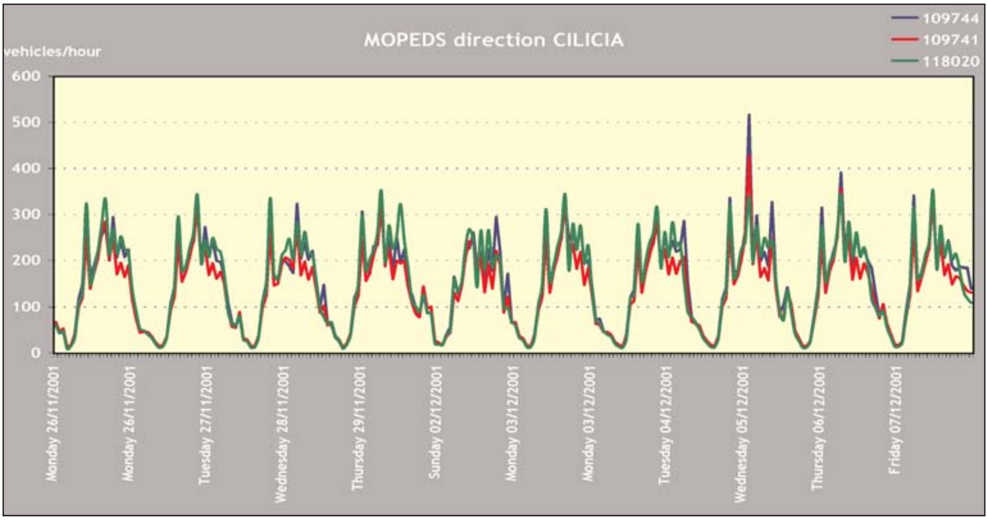


Fig. 4 contd.



2.2 *Emissions calculation*

The TEE model (Traffic Emission and Energetic), developed by ENEA in the context of the European Project ESTEEM, was applied in the calculation of emissions. Hourly CO emission were calculated separately for all four-wheel vehicles and all mopeds. For the purposes of calculating these emissions the total rolling stock of the City of Rome in the year 2000 was divided into the categories envisaged by the COPERT method provided by ACI. The composition of the total two-wheel vehicles of the City of Rome is shown in Fig. 5.

FIG. 5. TOTAL ROLLING STOCK CITY OF ROME

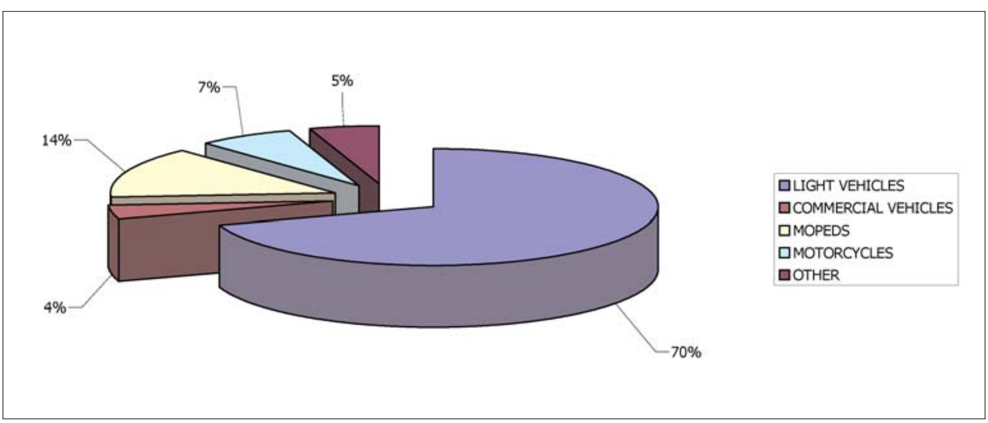
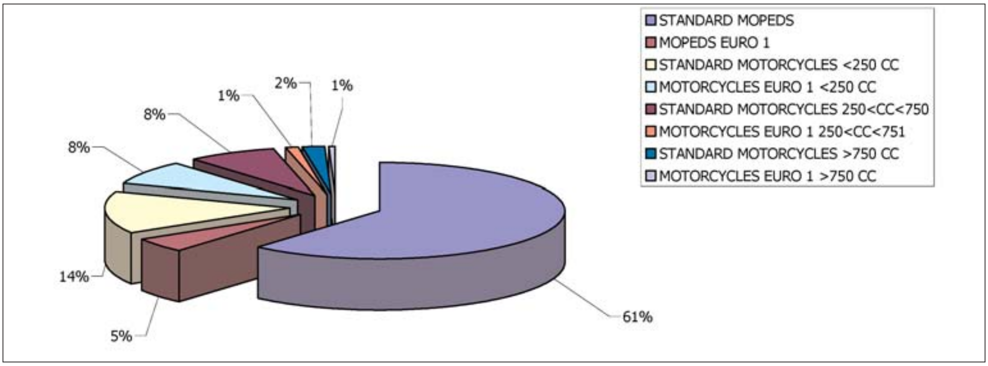


Fig. 5 contd.



CO emissions (gr/km) for the period of the study are shown in Fig. 6.

FIG. 6. CO EMISSIONS FOR CARS, MOPEDS AND COMPARISON OF THE TWO

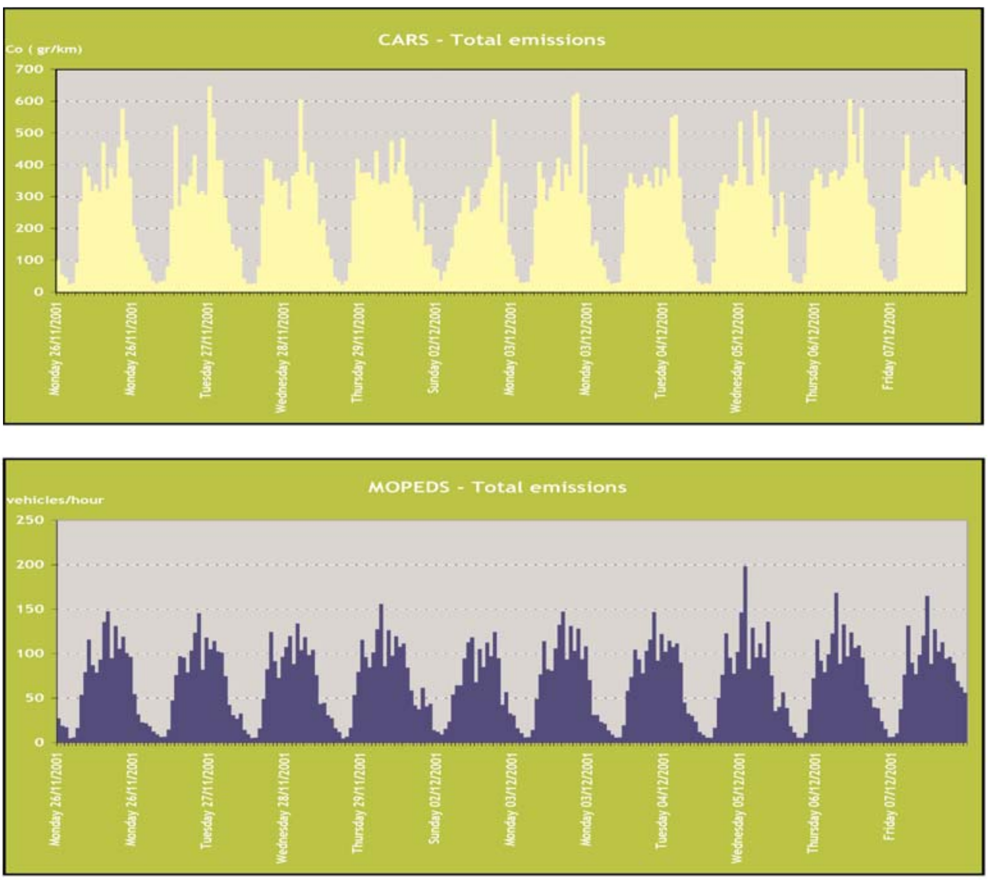
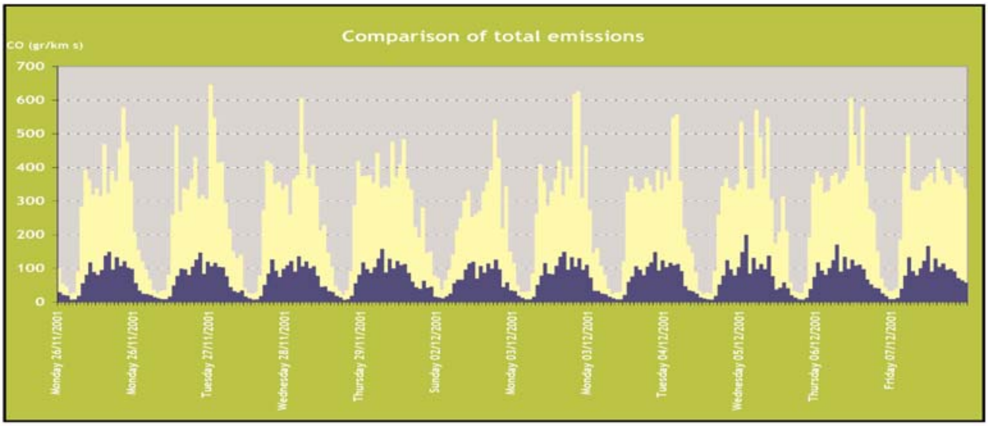


Fig. 6 contd.



The CO emitted by mopeds contributed an average of 20% of total emissions for the entire period of the study.

2.3 *Concentration calculation*

Concentrations were calculated separately for mopeds and four-wheel vehicles. The model used was the English ADMS Urban which permits the calculation of pollutant concentrations associated with linear sources in the urban area, taking into account the presence of eventual canyons.

Fictitious CO concentrations deriving from a hypothetical total rolling stock of only four-wheel vehicles and mopeds were calculated in relation to the separate flows of cars and mopeds. The results obtained are shown in Fig. 7.

FIG. 7. CO CONCENTRATION TRENDS AS GENERATED BY MOPEDS AND CARS

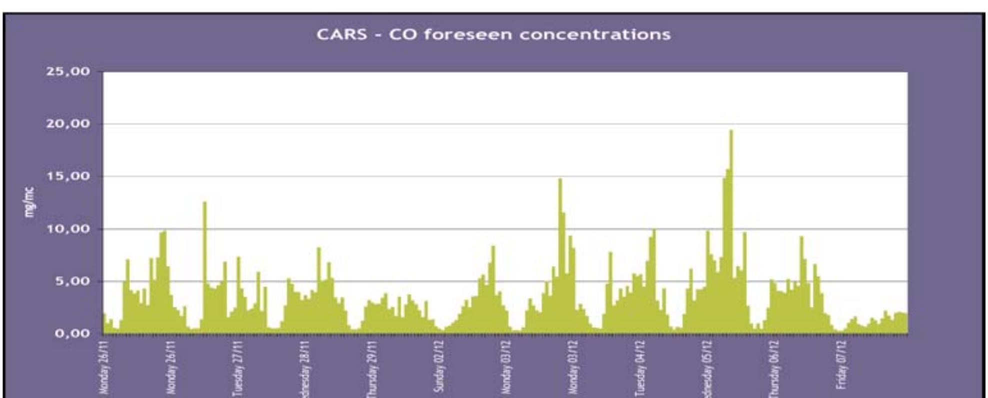
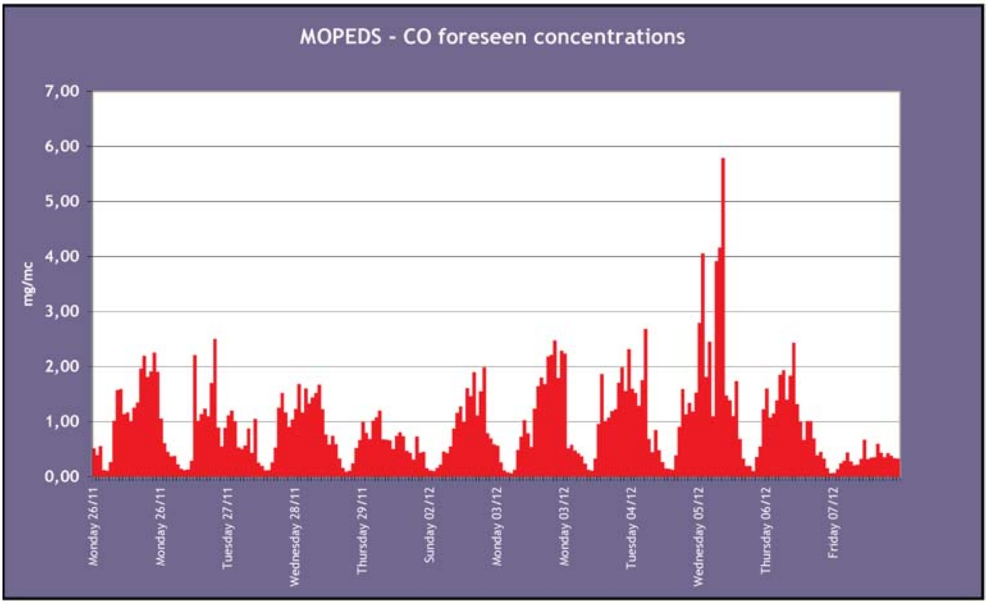
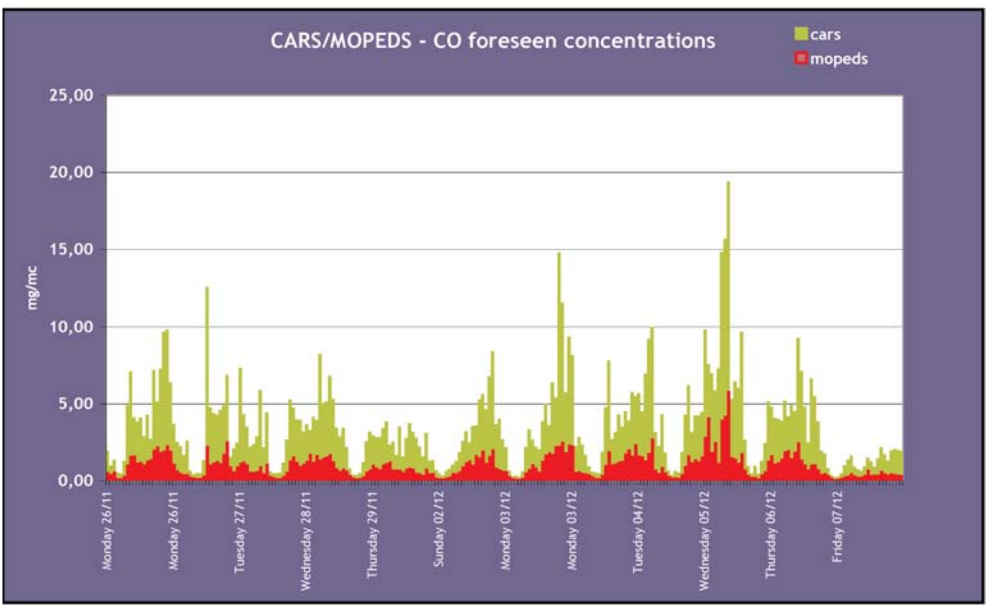


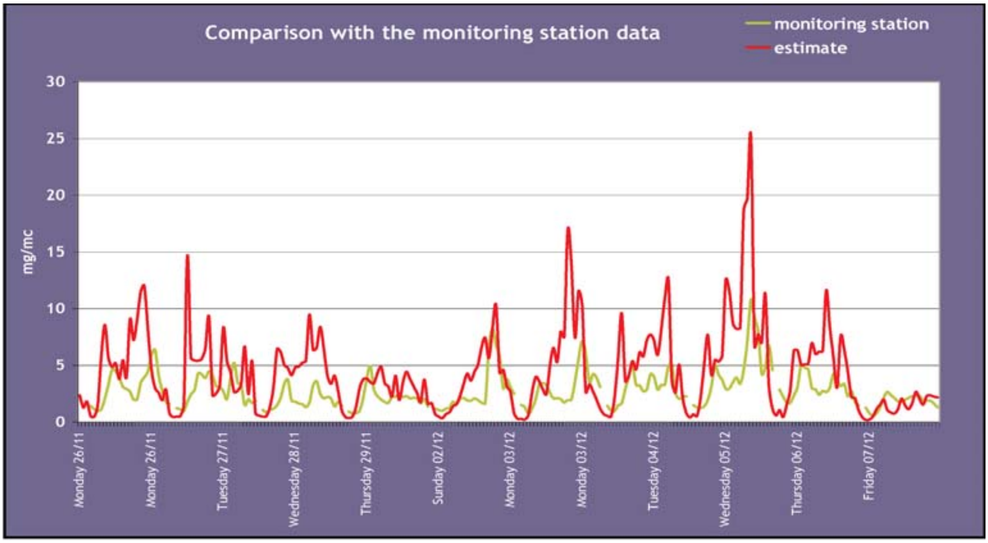
Fig. 7 contd.





The moped-generated CO concentrations for the entire period studied is 21% of the total.

FIG. 8. COMPARISON WITH THE MONITORING STATION DATA



Comparison of the results obtained applying the entire model chain (traffic-emissions-concentrations) and the values measured by the Via Magna Grecia monitoring station in the corresponding period (26/11–7/12/2001) is shown in Fig. 8.

The results obtained with the dispersion model allow for the reconstruction of the concentration trend obtained by the monitoring station. Variations can be seen in the peak hours of the day in which the model tends to overestimate the concentrations, while night-time concentrations result as underestimated. Good results are obtained overall on the predictions of the average concentrations at the 8 hours, or throughout the entire day, in which the variation between the data measured and that estimated is 40% and 30% respectively.

3. Emissions calculation at several air quality monitoring stations

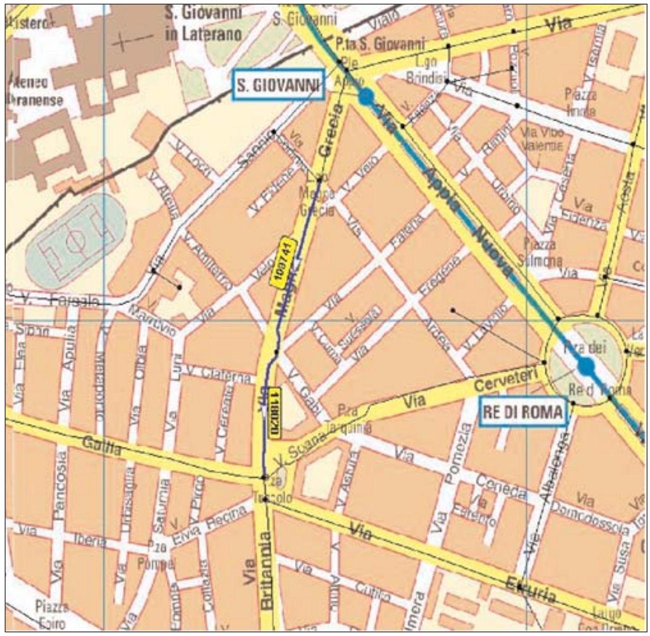
3.1 Traffic flow analysis

For the purposes of comparing the emissions of two and four-wheel vehicles, several roadway tracts in relation to three air quality monitoring stations of the City of Rome were considered: Magna Grecia, Tiburtina and Fermi, located in heavily trafficked and densely populated areas.

The three roadway tracts considered can be seen on the maps in Fig. 9.

FIG. 9. IDENTIFICATION OF THREE ROADWAY TRACTS

MAGNA GRECIA MONITORING STATION



TIBURTINA MONITORING STATION

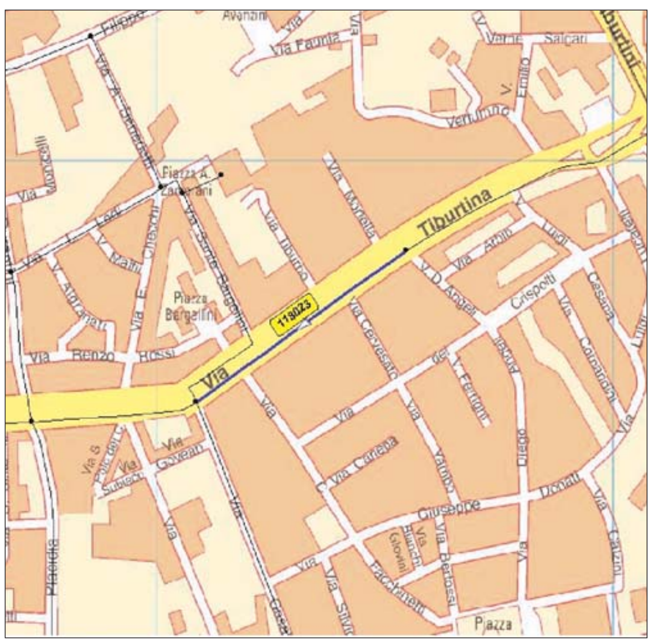
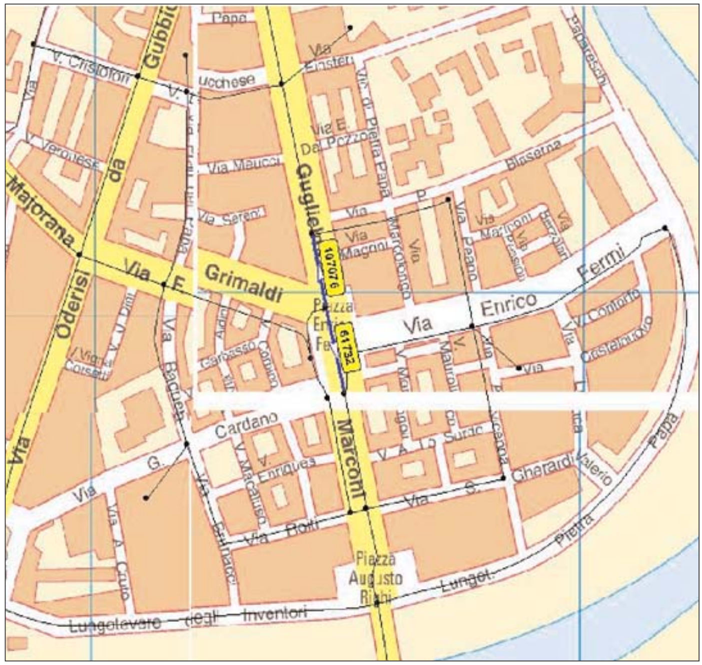


Fig. 9 contd.

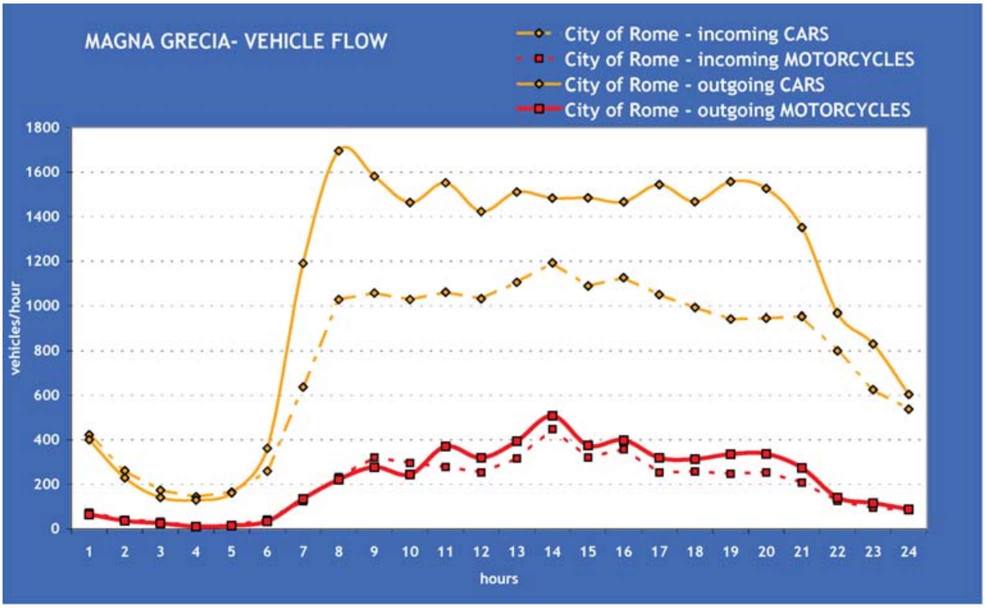
FERMI MONITORING STATION



The integration of the data provided by the Traffic Control Centre of STA and the O/D Table of the entire municipal area, allowed for the reconstruction of hourly flows per roadway tract considered, subdivided in terms of two and four-wheel vehicles. These flow measurements refer to a non-rainy average work/school day.

Fig. 10 shows the traffic flow and speeds for each roadway tract. It is necessary to specify that for motorcycles a speed analogous to that of four-wheel vehicles was assumed in an entirely precautionary manner since data in this area were not available. For some roadway tracts the available vehicle flows correspond to a single direction.

FIG. 10. FLOWS AND SPEEDS



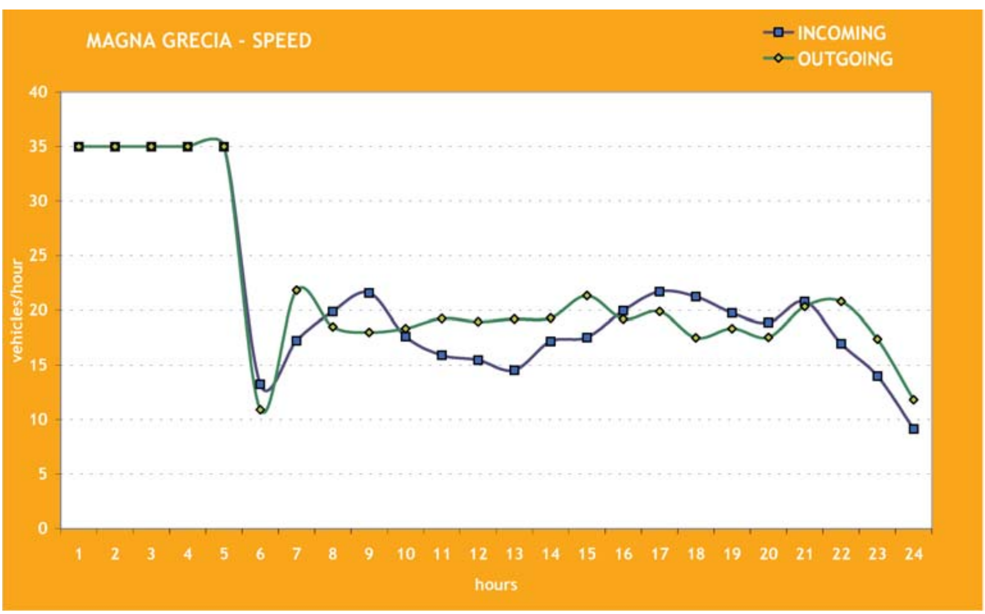
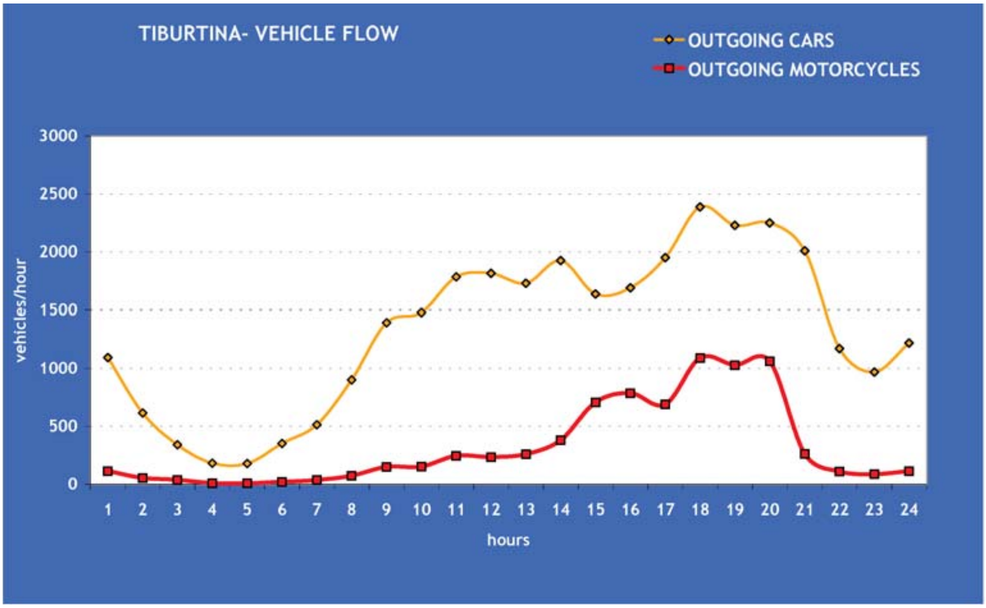
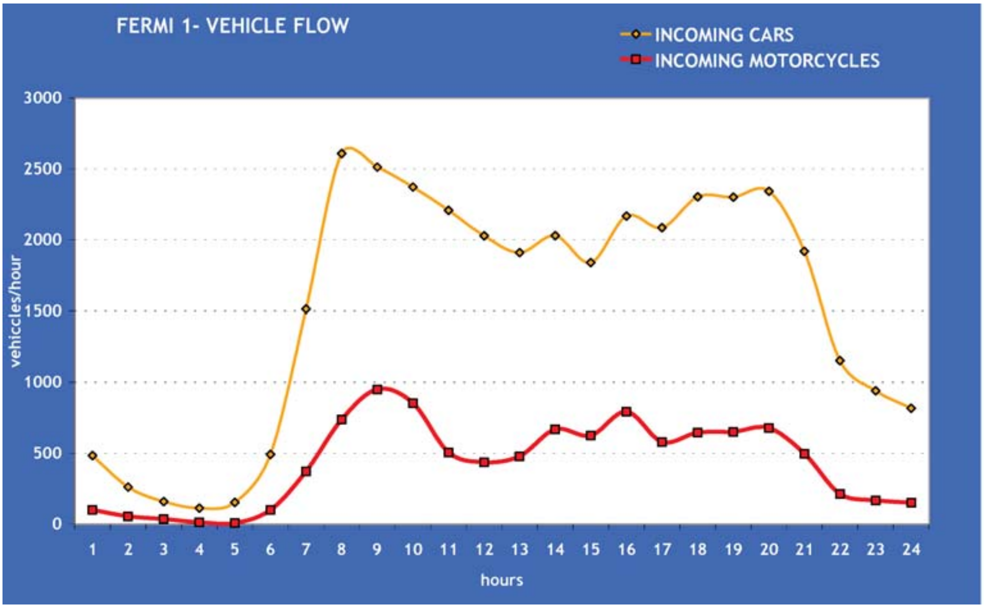


Fig. 10 contd.


TIBURTINA- VEHICLE FLOW
OUTGOING CARS
OUTGOING MOTORCYCLES
vehicles/hour
3000
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
hours


TIBURTINA - SPEED
OUTGOING
vehicles/hour
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
hours

Fig. 10 contd.


FERMI 1- VEHICLE FLOW
INCOMING CARS
INCOMING MOTORCYCLES
vehicles/hour
0
500
1000
1500
2000
2500
3000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
hours

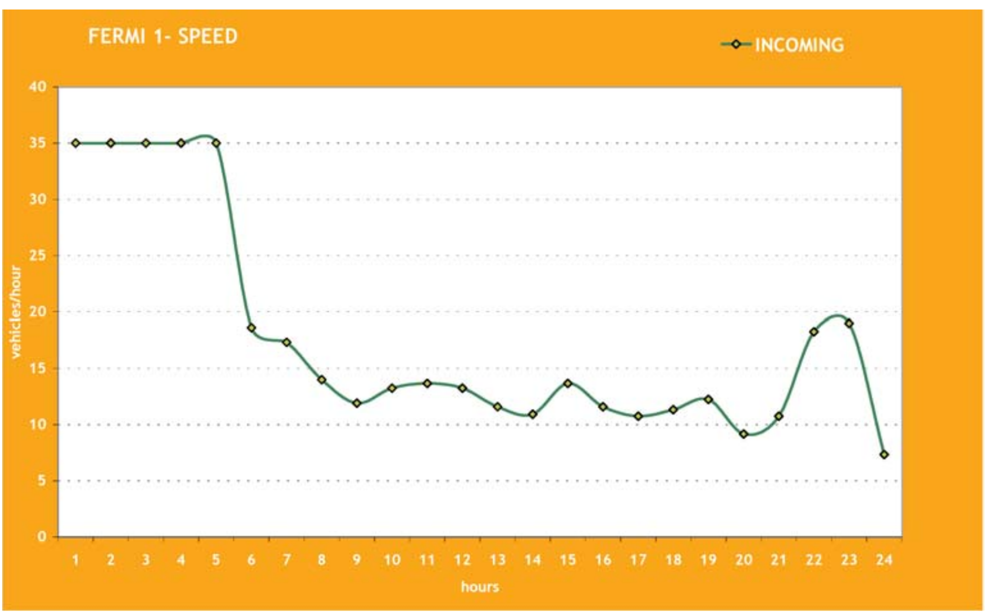
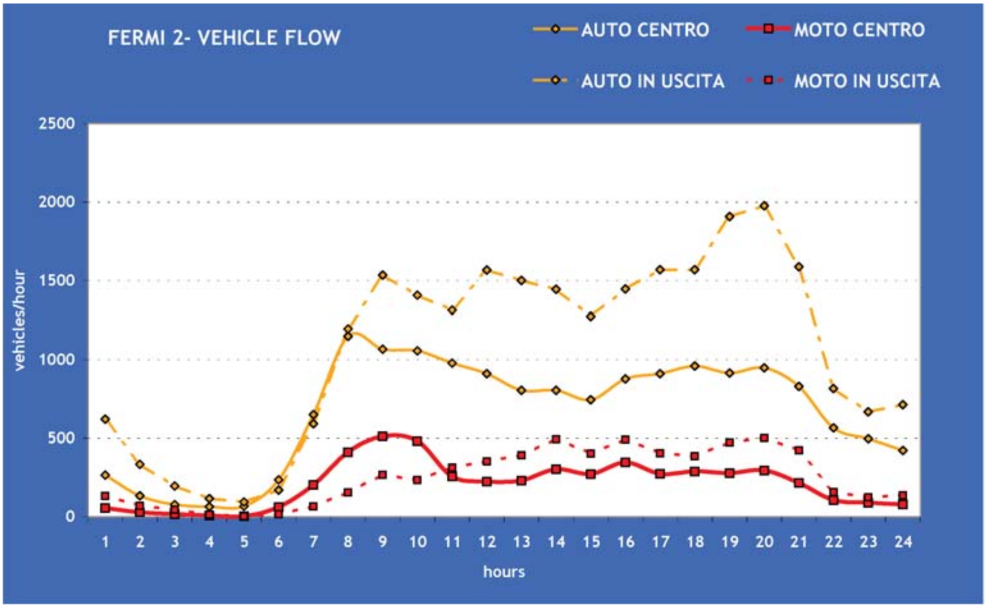
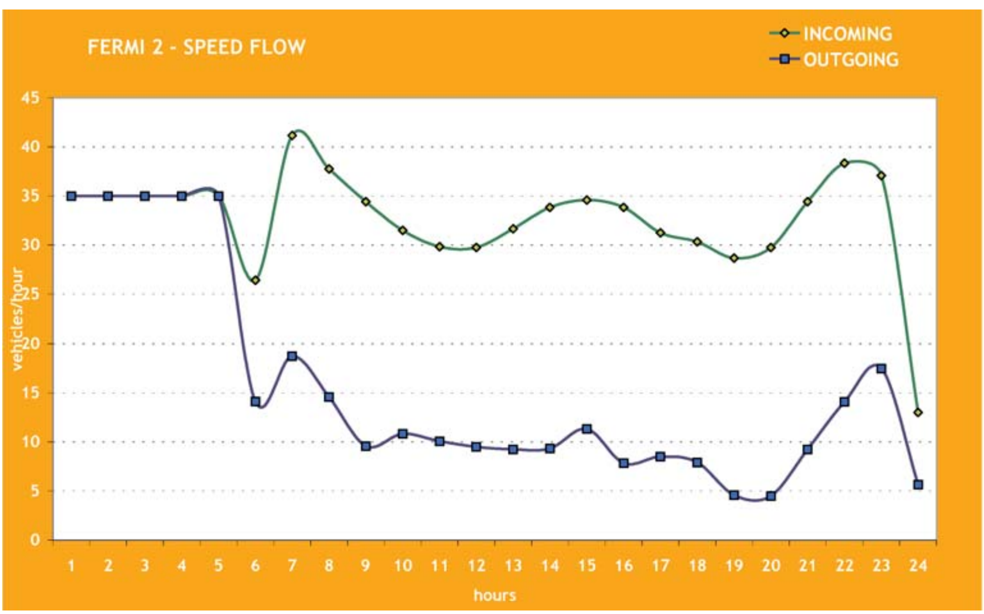

FERMI 1- SPEED
INCOMING
vehicles/hour
0
5
10
15
20
25
30
35
40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
hours

Fig. 10 contd.


FERMI 2- VEHICLE FLOW
AUTO CENTRO
MOTO CENTRO
AUTO IN USCITA
MOTO IN USCITA
vehicles/hour
0
500
1000
1500
2000
2500
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
hours


FERMI 2 - SPEED FLOW
INCOMING
OUTGOING
vehicles/hour
0
5
10
15
20
25
30
35
40
45
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
hours

Analysis of vehicular flow highlights a substantially regular trend during the day-time hours, with relatively constant flows in the period from 7:00 to 20:00 and with more or less pronounced peaks from 7:00 to 9:00 and 17:00 to 19:00.

FIG. 11. VEHICLE FLOW COMPARISON

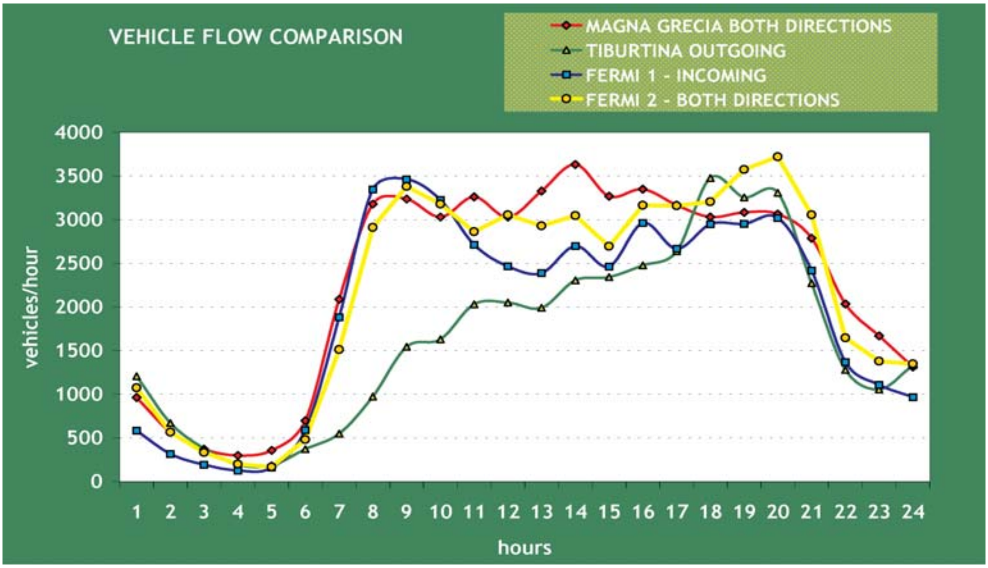
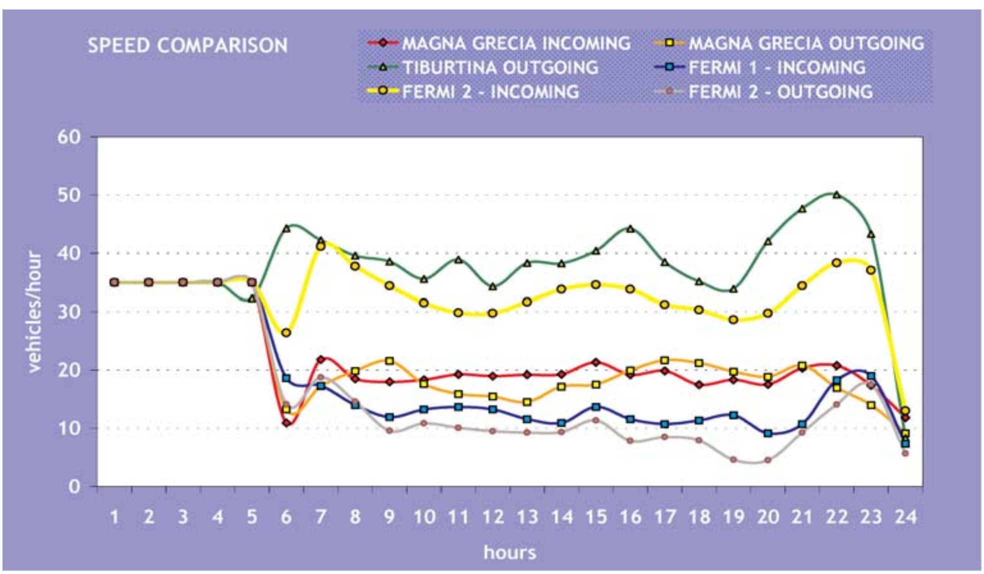


FIG. 12. SPEED COMPARISON



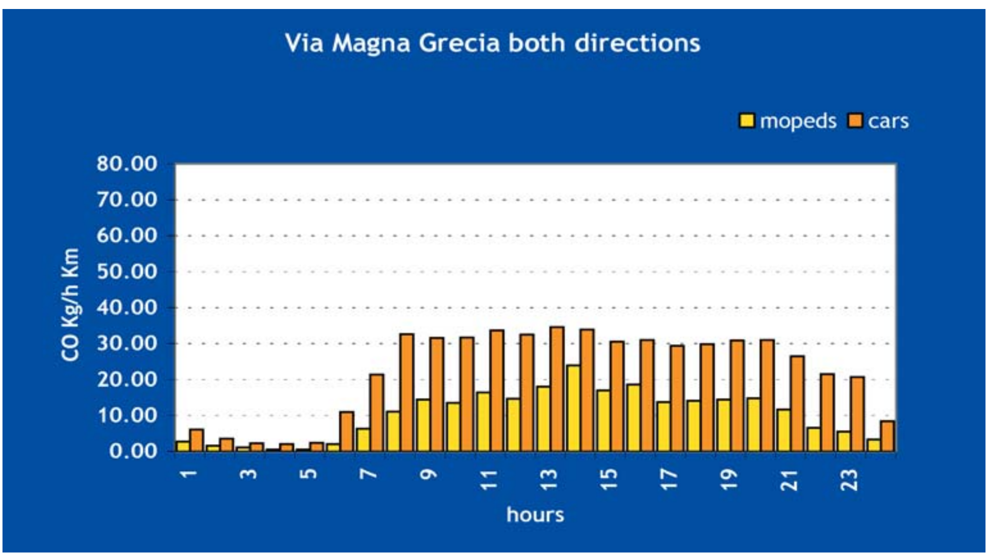
Speed comparison highlights how flows on average are slower at Magna Grecia and Fermi and faster at Tiburtina. Traffic-lights are not operative in the night-time hours and thus do not regulate speed, assumed in an entirely precautionary manner, as of 35 km/h for all the roadway tracts with the exception of Via Tiburtina, in which the characteristics of the road and its high average speeds, led to the assumption of a night-time speed of 50 km/h.

3.2 Emissions calculation

The TEE (Traffic Emission and Energetic) model was used for emissions calculations. CO emissions from four-wheel vehicles and mopeds only were calculated. With regard to traffic flow, keeping in mind the current composition of the total rolling stock, it is reasonable to suppose that the flows are made up of two thirds mopeds and one third motorcycles.

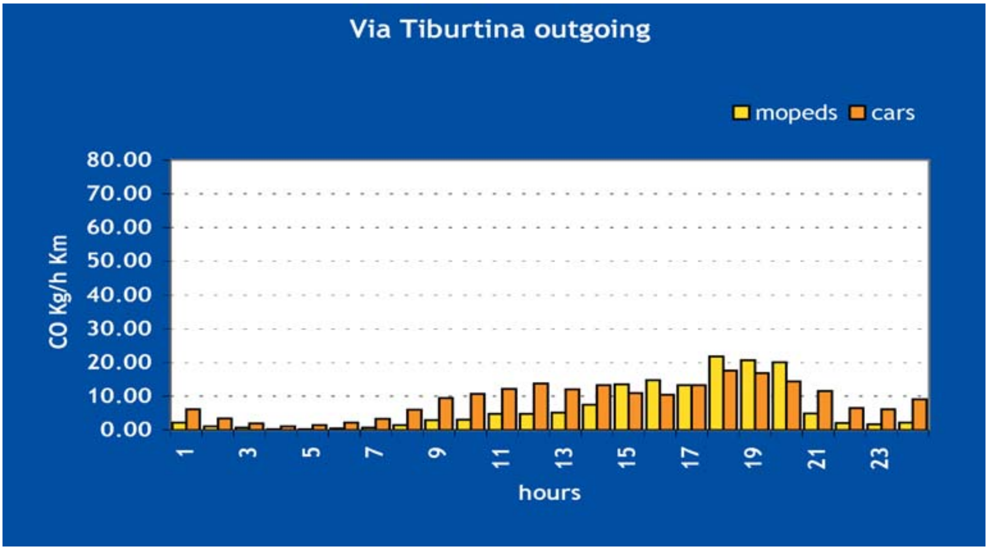
Fig. 13 shows the CO emissions for each roadway tract expressed in kg/h, divided into emissions owing to the flow of four-wheel vehicles and mopeds.

FIG. 13. MOPED AND TWO-WHEEL VEHICLE EMISSIONS



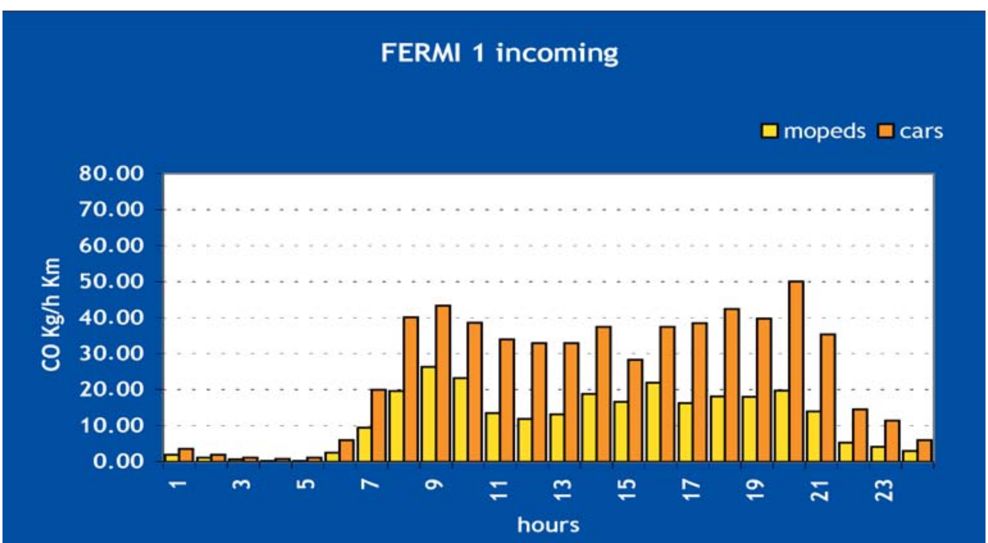
The trend of CO emissions indicates a direct dependence of emissions on traffic flow. Observing the vehicular flow trend (Fig. 11) the stations set up in Via Magna Grecia and Fermi2 show relatively homogeneous flows, while speeds (Fig. 12) are higher at the Magna Grecia station. CO emissions at the Fermi 2 roadway tract are significantly higher for both two and four-wheel vehicles.

FIG. 13 contd.



At all the stations with the exception of Tiburtina two-wheel emissions are lower than four-wheel emissions. An anomalous trend in emissions can be seen at Via Tiburtina, as they are equal to and, in some cases greater (in the evening hours) than, four-wheel emissions.

FIG. 13 contd.



This result is to be attributed to the high number of two-wheel vehicles making up more than one-third of the entire flow, as well as to the fact that that roadway tract maintains a particularly high speed. In order to quantify the contribution to the total daily emissions of two and four-wheel vehicles as compared to flows, a total number of trips for both types of vehicle was calculated along with the total daily emissions for each category. The results can be seen in Table 4.

FIG. 13 contd.

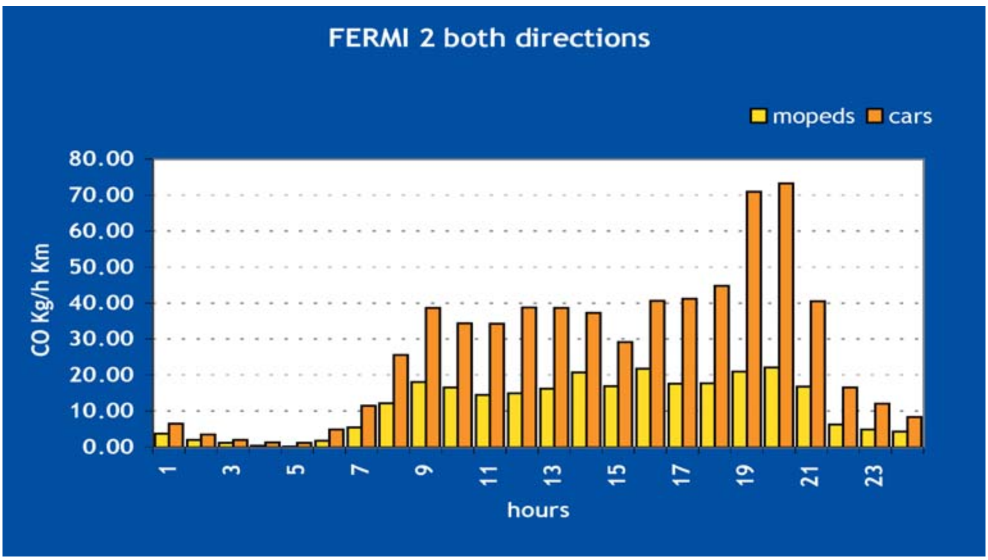


TABLE 4 SUMMARY OF RESULTS

	AUTO/DAY		MOPEDS/DAY		Total (kg/g km)	CO cars (kg/g km)		CO mopeds (kg/g km)		Total (kg/g km)
MAGNA GRECIA	44 765	87%	6 708	13%	*51 473*	593.53	83%	111.84	17%	*651.37*
TIBURTINA	31 807	86%	5 148	14%	*36 955*	212.87	71%	86.00	29%	*298.87*
FERMI 1	36 718	84%	6 880	16%	*43 598*	597.54	84%	113.92	16%	*711.46*
FERMI 2	45 160	85%	7 399	15%	*48 959*	656.23	84%	123.67	16%	*779.89*

Analysis of the results, extended to the entire typical day, reveals that the percentage of daily CO emissions contributed by mopeds is between 16% and 29%, while they represent between 13% and 16% of the total flow.

4. Conclusions

The assessment of emissions associated with vehicular traffic and the estimate of the contribution by mopeds to urban air pollution used two approaches.

The first method was based on the direct measurement of hourly traffic flows on a given tract of roadway for a period of ten days. The application of emissions and dispersion models to real traffic flows allowed for the direct comparison of the data provided by monitoring stations and thus the verification of the reliability of this study method.

The application of the method to the case in question revealed that the ratio between total emissions and those owing to mopeds throughout the period of the study was 20%; this ratio remains essentially unchanged when compared with the CO concentrations due to mopeds alone as compared with the total rolling stock. In fact, the dispersion model used is a gaussian model in which the relationship between the emissions and concentrations calculated is essentially linear.

The emissions and concentrations owing to mopeds consisted on average of 20–21% of the total, while the flow of mopeds compared with the total was approximately 12% for the entire period of the study.

The second approach was based on the use of the O/D Table of the City of Rome and on the application of planning models that allow for the assigning of traffic flows to each of the city's thoroughfares. These flows represent the average traffic on a non-rainy work/school day calibrated, in any case, on the monitoring station network. This approach made it possible to evaluate on a broader spatial scale, taking into consideration four roadway tracts in correspondence with three monitoring stations, and considering the traffic flows corresponding not to a specific time period but to an average traffic flow.

The application of the emission model in this second case study revealed that the contribution of CO from mopeds is approximately 16% of the total emissions and reaches 29% at roadway tracts with higher speeds, while their contribution to total traffic flow (cars and mopeds) is between 13 and 16%.

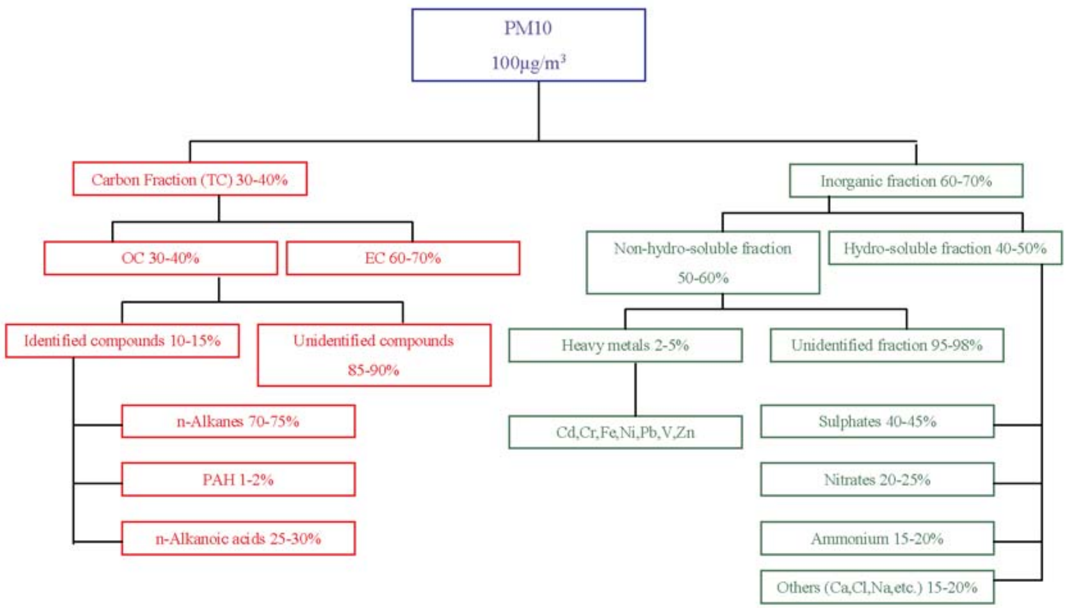
The results obtained by the two approaches result as comparable. In particular, the first method, which requires the availability of real traffic flows, demonstrated the reliability of the dispersion models used by means of comparison with the data collected by the monitoring stations. The second method, applicable in any urban context offering the availability of an O/D Table and a suitably calibrated model for the assigning of traffic flows, allowed for the evaluation of moped contributions to urban pollution on an extended roadway network, without having to make use of a specific time interval.

It is necessary to recall that the studies on two-wheel vehicle emissions are relatively recent, especially when compared with the corresponding studies on four-wheel vehicles, and that the emissions factors are to be considered preliminary and do not consider the mopeds' maintenance level. Futher uncertainty lies in the speeds of mopeds which, for reasons having to do with the models and the scarceness of data, are assumed as equal to those of four-wheel vehicles.

This study has demonstrated that it is possible to estimate the magnitude of urban emissions owing to mopeds, but that the most precise estimates can be only done with more detailed information on two-wheel vehicle flows, kinematics and, above all, emission factors.

Annex 5. Chemical composition of PM10*

Chemical composition breakdown of a PM10 sample



The Avino et al. study analysed and compared the PM10 filtered by two monitoring stations in Rome: one heavily trafficked (Fermi) and the other a background setting in the park of the Villa Ada.

The chart illustrates the organic and inorganic fractions of PM10. The inorganic fraction amounts to 30–40% at the heavily trafficked station and drops to 20–25% in the park; it is composed, in turn, of 60% graphite (EC: elemental, or black, carbon) and 40% complex mixture of hydrocarbons, other oxygenated compounds, alkanes, PAH alkenes and PAH nitrite (OC: organic carbon). EC is defined as the primary pollutant emitted directly in the combustion process. OC has its primary and secondary origins in the mixing of volatile organic compounds and other natural substances such as pollen and vegetal waste as well as bio-genic substances. At the heavily trafficked station the OC/EC ratio varied from 0.57 to 0.91, while in the park it varied from 1.23 to 1.40 (Avino et al. 2001 cfr chapter 3).

* *Reproduced with kind permission from Avino P, Brocco D, Cecinato A (2001). Characterization of carbonaceous PM in the urban area of Rome. In: Brebbia C, Sucharov LJ, eds.* Urban transport VII. *Wessex, WIT Press.*

Annex 6. CO emissions for Rome rolling stock

Vehicles considered[a]	*CO emission factor (g/km)*	*PM emission factor (g/km)*	*Number of total vehicles in Rome*	*% of total vehicles*	*PM/CO ratio per % total*
Conventional light diesel	1.4284	0.2816		1.76%	0.003468
EURO 1 light diesel	0.6767	0.1192	11 491	0.47%	0.000825
EURO 2 light diesel	0.6767	0.1192	16 906	0.69%	0.001214
Conventional diesel cars	1.0237	0.3127	82 820	3.38%	0.010313
EURO 1 diesel cars	0.9032	0.1111	15 175	0.62%	0.000761
EURO 2 diesel cars	0.9032	0.1111	146 198	5.96%	0.007329
Pre ECE gasoline cars	45.1712	0.0630	91 700	3.74%	0.000052
ECE 15/00-01gasoline cars	34.5056	0.0630	59 947	2.44%	0.000045
ECE 15/02 gasoline cars	29.7060	0.0630	51 268	2.09%	0.000044
ECE 15/04 gasoline cars	18.5485	0.0300	539 375	21.99%	0.000356
EURO 1 gasoline cars	5.3568	0.0011	300 836	12.26%	0.000025
EURO 2 gasoline cars	5.3568	0.0011	474 478	19.34%	0.000040
Motorcycles >250 conventional	17.1828	0.0133	52 442	2.14%	0.000017
Motorcycles > 250 EURO 1	19.6257	0.0068	9 510	0.39%	0.000001
Motorcycles < 250 conventional	26.6782	0.1043	73 947	3.01%	0.000118
Motorcycles <250 EURO 1	18.4530	0.0111	40 868	1.67%	0.000010
Average total excluding mopeds **(A)**					0.001539
Mopeds **(B)**	15.0	0.2434	443 000	18.06%	0.002930
Mopeds/total ratio **(A/B)**					**1.904**
Total vehicles considered			2 453 105		
COPERT III emission factors warmed up TNO emission factors					

* Heavy diesel vehicles were excluded from the total since they were not counted by the STA model for the attribution of CO owing to mopeds. STA considered the contribution of CO by this category negligible in the total emitted in Rome, thus simplifying their flow/emissions model.

Annex 7. Total rolling stock particulate emissions in Rome

VEHICLE TYPE	CATEGORY	TOTAL ROLLING STOCK	ANNUAL URBAN DISTANCE TRAVELLED (KM)	PARTICULATE EMISSION COEF. (G/KM)	TOTAL PM EMISSIONS (TONNES/YEAR)	PM QUOTA %
Gasoline-fueled cars	pre ECE	91 700	3 435	0.0630	19.84	1.02%
	ECE 15/00-01	59 947	3 435	0.0630	12.97	0.67%
	ECE 15/02	51 268	3 435	0.0630	11.09	0.57%
	ECE 15/03	62 064	3 435	0.0420	8.95	0.46%
	ECE 15/04	539 375	3 435	0.0300	55.58	2.87%
	91/441/EEC (EURO 1)	300 836	3 435	0.0011	1.14	0.06%
	94/12/EC (EURO 2)	474 478	3 435	0.0011	1.79	0.09%
Total gasoline-fueled cars		*1 579 668*			*111.38*	*5.74%*
LPG cars	conventional	39 654	3 435	0.0400	5.45	0.28%
	91/441/EEC (EURO 1)	6 040	3 435	0.0000	0.00	0.00%
	94/12/EC (EURO 2)	2 445	3 435	0.0000	0.00	0.00%
Total LPG cars		*48 139*			*5.45*	*0.28%*
Diesel-fueled cars	conventional	82 820	3 435	0.4972	141.44	7.30%
	91/441/EEC (EURO 1)	15 175	3 435	0.1766	9.21	0.47%
	94/12/EC (EURO 2)	146 198	3 435	0.1766	88.69	4.57%
Total diesel-fueled cars		*244 199*			*239.34*	*12.34%*
TOTAL CAR EXHAUST					*356.17*	*18.37%*
Friction emissions–cars		1 872 000	3 435	0.0167	107.39	5.54%
TOTAL CARS		**1 872 000**			**463.55**	**23.91%**
Light commercial <3.5t gasoline	conventional	14 174	10 000	0.0400	5.67	0.29%
	93/59/EEC (EURO 1)	3 211	10 000	0.0011	0.04	0.00%
	96/69/EC (EURO 2)	4 533	10 000	0.0011	0.05	0.00%
Light commercial <3.5t gasoline	conventional	43 144	20 000	0.4478	386.40	19.93%
	93/59/EEC (EURO 1)	11 491	20 000	0.1895	43.56	2.25%
	96/69/EC (EURO 2)	16 906	20 000	0.1895	64.08	3.31%
Total light commercial		*93 459*			*499.80*	*25.78%*
Heavy commercial <7.5t gasoline	conventional	364	20 000	0.0400	0.29	0.02%
Heavy commercial <7.5t diesel	conventional	7 114	20 000	0.5858	83.35	4.30%
	91/542/EEC I (EURO 1)	324	20 000	0.3808	2.47	0.13%
	91/542/EEC II (EURO 2)	856	20 000	0.2343	4.01	0.21%
Total heavy commercial		*8 658*			*90.12*	*4.65%*
TOTAL COMMERCIAL EXHAUST					*589.92*	*30.43%*
Friction emissions–light commercial	(including light buses)	93 501	20 000	0.0215	40.20	2.07%
Friction emissions–heavy commercial		8 658	20 000	0.0777	13.46	0.69%
TOTAL COMMERCIAL		**102 159**			**643.58**	**33.19%**

VEHICLE TYPE	CATEGORY	TOTAL ROLLING STOCK	ANNUAL URBAN DISTANCE TRAVELLED (KM)	PARTICULATE EMISSION COEF. (G/KM)	TOTAL PM EMISSIONS (TONNES/YEAR)	PM QUOTA %
ATAC urban buses	conventional	1 632	50 000	1.2624	103.01	5.31%
	conv c/particulate filter	293	50 000	0.8206	12.02	0.62%
	91/542/EEC II (EURO 2)	600	60 000	0.5050	18.18	0.94%
	zero vehicle emission	42	60 000	0	0.00	0.00%
Inter-regional-extra-urban buses	(number of accesses)	67 786	16	1.0182	1.10	0.06%
Tourist buses		42 052	32	1.0182	1.37	0.07%
TOTAL BUS EXHAUST					*135.69*	*7.00%*
Friction emissions - buses		2 525	52 000	0.0777	10.20	0.53%
TOTAL BUSES		**2 567**			**145.88**	**7.52%**
Motorcycles = o > 250 cc	conventional	52 442	6 072	0.0133	4.24	0.22%
	97/24/EC (EURO 1)	9 510	6 072	0.0068	0.39	0.02%
Motorcycles < 250 cc	conventional	73 947	6 072	0.0726	32.59	1.68%
	97/24/EC (EURO 1)	40 868	6 072	0.0111	2.75	0.14%
TOTAL MOTORCYCLES EXHAUST					*54.21*	*2.08%*
Friction emissions - motorcycles		176 767	6 072	0.0084	8.99	0.46%
TOTAL MOTORCYCLES		**176 767**			**48.96**	**2.53%**
Mopeds	conventional	412 149	6 072	0.2433	608.88	31.40%
	97/24/EC I (EURO 1)	31 022	6 072	0.0290	5.46	0.28%
TOTAL MOPED EXHAUST					*614.34*	*31.69%*
Friction emissions - mopeds		443 171	6 072	0.0084	22.54	1.16%
TOTAL MOPEDS		**443 171**			**636.87**	**32.35%**
TOTAL ROME		**2 596 664**			**1 938.86**	**100%**

WHO original figures using ANPA methods, baseline year 2000.

Data sources:

ATAC	ANAV	COPERT	ENEA + LABECO	FITA-CNA
ISIS	LABECO	Romatur	STA	TNO

Notes:

Notes:

COPERT emission factors were calculated at a speed of 18.2 km/h (STA data), except for urban buses for which a speed of 12 km/h was used (ACI data). For the estimate of the warm + cold emissions, applicable according to the COPERT manual only to cars and light commercial vehicles, an average temperature of 15.1° was used, calculated on the data of the Air Force meteorological institute of Rome (1961-1990).

The emission factor for extra-urban and tourist buses was obtained from an average weighted on the composition of the total rolling stock in Italy drawn from ANPA (2000).

The emission factor used for <250cc motorcycles considers that only 10% of vehicles have two-stroke engines.

TNO (whose data are more uncertain than others) indicates identical emission factors for PM10 and PTS; the values assumed for EURO1 vehicles were also assumed for EURO2 vehicles (not present).

Friction emissions (non-exhaust) derive from the consumption of tyres, brakes and road surface; the phenomenon of dust-raising was not considered and reference was made to PM10 emission factors; for buses (excluding electric ones) the TNO emission factors of heavy commercial vehicles were used.

In the absence of specific data, the urban distances travelled by motorcycles were placed as equal to those of mopeds.

ATAC city buses with particulate filter were assigned the emission factor of EURO1 vehicles; today the total ATAC vehicles has changed and amount to 9

For the distances travelled by the various vehicles the data supplied by the various agencies was maintained, and it is upon this that their accuracy relies.

Annex 8. ANIA tables on mopeds accident claims reimbursed*

year */market share of companies participating in the study*	**1998**/*50%*				**1999**/*65%*				**2000**/*77%*			
percentage of reimbursement for injury to person	*55%*				*50%*				*64%*			
Province	**Vehicles insured**	**Number of accidents**	**Accident frequency**	**Average cost (1 000 lire)**	**Vehicles insured**	**Number of accidents**	**Accident frequency**	**Average cost (1 000 lire)**	**Vehicles insured**	**Number of accidents**	**Accident frequency**	**Average cost (1 000 lire)**
NAPLES	41 698	8 083	19.38	3 292	39 420	7 933	20.12	3 518	33 708	4 014	11.91	4 069
CROTONE	2 146	403	18.78	2 461	2 279	341	14.96	3 403	2 885	339	11.75	4 342
NUORO	4 857	664	13.67	2 855	4 978	653	13.12	1 871	5 466	605	11.07	2 606
VIBO VALENTIA	2 302	302	13.12	3 029	2 364	274	11.59	2 661	2 811	287	10.21	3 118
BARI	31 580	4 282	13.56	1 849	38 823	4 715	12.14	2 370	41 572	3 934	9.46	3 280
REGGIO CALABRIA	8 381	1 131	13.49	2 719	9 186	1 001	10.90	3 418	9 395	810	8.62	3 595
FOGGIA	11 153	1 294	11.60	2 390	11 658	1 169	10.03	2 551	13 779	1 187	8.61	2 990
CAGLIARI	18 342	1 999	10.90	2 099	21 184	2 218	10.47	2 220	22 394	1 813	8.10	2 709
BRINDISI	9 994	1 070	10.71	2 821	13 006	1 306	10.04	2 296	13 681	1 082	7.91	2 740
TARANTO	8 875	1 120	12.62	2 528	10 149	1 147	11.30	3 079	13 646	1 053	7.72	2 916
CATANIA	29 424	3 043	10.34	2 904	33 790	3 161	9.35	2 930	35 913	2 724	7.58	4 392
CATANZARO	7 083	773	10.91	2 156	8 016	759	9.47	2 597	9 649	716	7.42	4 037
ROME	**112 281**	**11 278**	**10.04**	**3 146**	**129 233**	**12 285**	**9.51**	**3 643**	**151 032**	**10 868**	**7.20**	**4 160**
SASSARI	10 829	963	8.89	1 997	12 189	1 076	8.83	2 687	13 621	964	7.08	2 868
GENOA	27 753	2 498	9.00	2 246	35 190	2 970	8.44	2 240	38 668	2 648	6.85	2 568
PALERMO	33 905	3 803	11.22	4 302	37 776	3 654	9.67	4 627	40 877	2 796	6.84	4 581
CALTANISSETTA	5 675	679	11.96	1 876	9 910	887	8.95	1 993	11 981	811	6.77	2 893
SIRACUSA	19 405	1 750	9.02	1 671	22 273	1 820	8.17	1 766	24 763	1 594	6.44	2 495
PRATO	11 704	966	8.25	1 942	14 314	1 096	7.66	3 166	16 457	1 041	6.33	3 288
SALERNO	23 916	2 440	10.20	2 927	32 205	2 950	9.16	3 515	36 553	2 305	6.31	3 876
AVELLINO	7 898	693	8.77	2 073	12 112	1 015	8.38	2 700	14 512	914	6.30	3 778
CASERTA	15 051	1 445	9.60	3 455	22 069	1 843	8.35	3 628	24 220	1 520	6.28	4 374
COSENZA	14 878	1 390	9.34	1 927	16 979	1 443	8.50	2 710	17 484	1 083	6.19	3 779
TRAPANI	16 892	1 452	8.60	1 562	23 437	1 912	8.16	2 384	27 944	1 659	6.16	2 426
AGRIGENTO	14 640	1 554	10.61	1 220	20 632	1 820	8.82	1 798	24 112	1 417	5.88	2 489
TRIESTE	11 840	796	6.72	2 401	10 612	632	5.96	3 443	9 834	575	5.85	3 951
POTENZA	6 439	549	8.53	1 520	8 239	652	7.91	1 789	9 761	568	5.82	2 317
MESSINA	18 013	1 869	10.38	3 619	22 810	1 904	8.35	3 776	23 919	1 385	5.79	4 482
MATERA	4 833	433	8.96	1 564	5 285	383	7.25	2 333	5 896	340	5.77	2 772
MASSA CARRARA	12 017	852	7.09	2 351	14 400	1 016	7.06	2 915	15 220	858	5.64	3 989
RAGUSA	12 381	977	7.89	2 117	17 284	1 255	7.26	2 142	17 794	966	5.43	3 078
MILAN	121 551	6 589	5.42	3 099	140 154	7 824	5.58	3 336	144 031	7 759	5.39	3 477
LECCE	23 662	1 578	6.67	2 293	31 229	2 042	6.54	2 816	36 944	1 945	5.26	3 316
LATINA	18 074	1 396	7.72	2 413	23 107	1 571	6.80	3 002	27 199	1 421	5.22	4 050
BENEVENTO	5 869	492	8.38	2 008	9 246	727	7.86	2 741	9 168	466	5.08	3 117
FLORENCE	94 468	6 050	6.40	3 073	101 619	6 144	6.05	3 213	104 441	5 303	5.08	4 261
PESCARA	11 780	782	6.64	2 282	12 928	826	6.39	3 176	14 924	751	5.03	3 108
LIVORNO	31 186	2 100	6.73	3 108	36 124	2 320	6.42	3 476	39 293	1 971	5.02	4 636
IMPERIA	16 590	1 033	6.23	1 785	20 545	1 235	6.01	2 229	20 562	1 019	4.96	3 818
ENNA	4 455	340	7.63	1 049	6 063	386	6.37	1 538	7 192	353	4.91	2 100
LA SPEZIA	11 699	738	6.31	3 563	11 202	624	5.57	3 491	10 707	520	4.86	4 103
PISTOIA	17 348	1 002	5.78	2 840	19 337	1 083	5.60	2 710	20 080	955	4.76	3 571
TURIN	42 783	1 883	4.40	1 992	46 046	2 267	4.92	2 174	52 215	2 467	4.72	2 742
ISERNIA	2 240	104	4.64	1 687	3 246	130	4.00	2 549	3 714	168	4.52	2 909
LUCCA	32 536	1 636	5.03	2 805	35 186	1 707	4.85	4 209	37 152	1 678	4.52	3 830
ORISTANO	4 741	241	5.08	1 966	6 334	362	5.72	2 426	6 940	305	4.39	2 037
BIELLA	5 121	180	3.51	1 862	6 199	257	4.15	3 380	7 312	316	4.32	2 244
CAMPOBASSO	7 019	486	6.92	1 590	9 418	522	5.54	2 215	9 974	428	4.29	2 460
COMO	24 713	993	4.02	2 806	25 894	1 071	4.14	2 721	25 479	1 075	4.22	3 535
CHIETI	15 147	808	5.33	3 194	17 498	826	4.72	2 920	19 235	808	4.20	3 568
BOLOGNA	45 853	2 308	5.03	4 474	47 799	2 413	5.05	5 274	52 200	2 180	4.18	6 784
FROSINONE	15 281	998	6.53	2 269	18 330	1 031	5.62	4 577	21 348	889	4.16	2 521
RIMINI	28 207	1 278	4.53	3 357	28 040	1 250	4.46	5 079	28 406	1 124	3.96	4 711
PISA	33 505	1 607	4.80	2 937	36 607	1 586	4.33	2 950	38 931	1 527	3.92	3 696

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year */market share of companies participating in the study*	**1998**/*50%*				**1999**/*65%*				**2000**/*77%*			
percentage of reimbursement for injury to person	*55%*				*50%*				*64%*			
Province	**Vehicles insured**	**Number of accidents**	**Accident frequency**	**Average cost (1 000 lire)**	**Vehicles insured**	**Number of accidents**	**Accident frequency**	**Average cost (1 000 lire)**	**Vehicles insured**	**Number of accidents**	**Accident frequency**	**Average cost (1 000 lire)**
ANCONA	24 805	1 263	5.09	3 729	26 981	1 292	4.79	2 861	27 338	1 024	3.75	3 138
VITERBO	16 378	745	4.55	1 603	20 553	860	4.18	2 576	24 153	872	3.61	2 340
LECCO	12 671	511	4.03	2 343	15 139	571	3.77	2 378	18 246	657	3.60	5 139
ASCOLI PICENO	14 832	631	4.25	2 472	18 437	778	4.22	3 055	19 480	695	3.57	3 257
SAVONA	24 094	1 049	4.35	1 970	26 358	1 127	4.28	2 442	27 024	966	3.57	3 779
BOLZANO	18 691	695	3.72	1 826	24 084	844	3.50	2 208	26 922	930	3.45	5 174
VERONA	51 994	1 855	3.57	2 608	61 758	2 308	3.74	3 431	64 344	2 217	3.45	3 614
BERGAMO	57 431	2 111	3.68	2 441	68 858	2 645	3.84	3 490	77 743	2 640	3.40	3 920
BRESCIA	64 673	2 691	4.16	3 064	70 164	2 823	4.02	2 530	70 513	2 385	3.38	3 760
REGGIO EMILIA	24 285	753	3.10	3 869	25 686	771	3.00	4 049	27 345	922	3.37	4 165
PARMA	17 689	679	3.84	2 933	24 335	827	3.40	3 485	25 024	837	3.34	3 440
TRENTO	16 101	475	2.95	2 056	22 769	661	2.90	2 897	25 459	851	3.34	3 433
ASTI	6 550	250	3.82	1 800	7 791	292	3.75	1 593	8 522	274	3.22	2 644
TERNI	12 914	616	4.77	1 991	14 369	637	4.43	3 039	15 674	502	3.20	2 431
ALESSANDRIA	14 903	519	3.48	2 885	16 863	542	3.21	2 990	17 391	547	3.15	2 079
FORLI	30 891	926	3.00	2 499	31 858	970	3.04	4 047	30 546	953	3.12	3 856
MACERATA	16 928	606	3.58	2 612	18 433	650	3.53	2 425	18 684	582	3.11	5 688
TERAMO	11 988	434	3.62	2 331	15 007	502	3.35	2 996	15 646	485	3.10	3 560
AREZZO	22 987	800	3.48	2 343	26 635	958	3.60	2 199	26 892	824	3.06	2839
NOVARA	22 338	611	2.74	1 899	24 904	697	2.80	3 626	23 989	732	3.05	2 872
VERBANIA	5 749	230	4.00	2 802	7 651	290	3.79	1 851	9 079	276	3.04	2 300
GROSSETO	19 280	791	4.10	2 725	20 757	774	3.73	5 343	20 610	621	3.01	3 220
VENICE	51 943	1 833	3.53	3 108	58 443	1 873	3.20	3 937	58 392	1 759	3.01	5 538
PADUA	58 452	1 900	3.25	3 423	67 351	2 214	3.29	3 775	67 896	2 015	2.97	3 427
PESARO e URBINO	34 363	1 131	3.29	3 735	38 506	1 296	3.37	2 994	39 472	1 167	2.96	3 945
PERUGIA	37 510	1 322	3.52	3 160	41 530	1 500	3.61	2 680	45 445	1 339	2.95	3 163
CUNEO	17 056	577	3.38	2 894	19 199	680	3.54	2 118	21 739	638	2.93	2 496
VICENZA	49 306	1 357	2.75	2 755	60 932	1 716	2.82	2 924	59 434	1 730	2.91	3 714
PAVIA	23 650	707	2.99	2 640	27 025	809	2.99	2 637	25 753	731	2.84	2 999
RAVENNA	24 451	762	3.12	2 931	24 831	782	3.15	3 334	22 579	637	2.82	3 617
TREVISO	38 550	954	2.47	3 102	47 905	1 271	2.65	3 950	45 820	1 242	2.71	3 977
SIENA	19 788	604	3.05	2 676	21 701	608	2.80	2 580	23 682	637	2.69	3 187
GORIZIA	9 034	240	2.66	2 812	10 544	249	2.36	3 140	10 069	265	2.63	4 538
PIACENZA	9 846	321	3.26	2 740	11 092	318	2.87	3 741	11 561	296	2.56	7 010
LODI	6 513	215	3.30	3 071	7 813	221	2.83	3 374	8 675	210	2.42	3 012
MANTOVA	25 993	559	2.15	2 126	29 451	707	2.40	5 594	29 134	682	2.34	3 425
VERCELLI	8 683	204	2.35	1 889	9 852	241	2.45	2 060	9 572	224	2.34	6 025
CREMONA	19 655	385	1.96	2 479	22 153	489	2.21	2 966	22 234	517	2.33	5 364
SONDRIO	7 830	194	2.48	2 420	8 803	227	2.58	2 346	10 289	239	2.32	2 688
FERRARA	21 350	430	2.01	2 475	26 579	564	2.12	3 128	25 440	590	2.31	6 093
ROVIGO	16 295	361	2.22	2 638	17 277	391	2.26	3 425	16 294	368	2.26	4 157
PORDENONE	16 403	256	1.56	4 810	18 166	338	1.86	3 381	17 191	352	2.05	3 602
UDINE	28 090	514	1.83	2 348	32 447	649	2.00	2 869	31 976	638	2.00	4 825
BELLUNO	7 984	171	2.14	1 635	10 089	206	2.04	2 190	9 521	185	1.94	3 191
Special plates	684	43	6.29	1 550	1 007	53	5.26	1 803	1 012	38	3.75	4 451
Others	12 926	1 157	8.95	3 161	30 394	2 275	7.49	2 809	785	100	12.74	4 167
Total and national average	***2 306 985***	***133 570***	***5.79***	***2 778***	***2 680 271***	***148 514***	***5.54***	***3 155***	***2 800 324***	***129 490***	***4.62***	***3 693***

Annex 9. ACI Study on road accident costs. Methodological note on the tables provided by ACI*

Estimate of production loss due to temporary disability

AGE GROUPS	PRODUCTION LOSS YEAR 2000 (ITL x 1 000)
0–13	595 036
14–15	595 036
16–19	925 673
20–25	1 242 799
26–35	1 596 923
36–45	1 623 810
46–55	1 225 029
56–65	510 396
66+	117 793

LIFE EXPECTANCY (1995 STATISTICS)
GDP INCREASE = 2.06%/YEAR
OFFICIAL BANK RATE = 5.57% (I.E. AVERAGE OF RATES FOR THE PERIOD 1987–2000)

This result was calculated on the basis of three factors:

- rate of employment (ratio of employed persons in each age group to population relative to the same age group);
- daily GDP for each employed person and daily GDP for each inhabitant: one value represents the GDP produced by an employed person and the other by one not employed; it was not possible to calculate this value by age group, a problem that was resolved by weighting the values with the coefficient described in the next point;
- a coefficient explicative of the income level reached by each age group obtained by relating the average income of each age group with the total average income.

Multiplying the employment rate by the income coefficient and then by the daily GDP of each employed person, yields an estimate of the level of income lost

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in the case of an employed injured person. On the other hand, if the injured person were unemployed it would be necessary to multiply the complement of the employment rate by the daily GDP per inhabitant. Adding these two values together a daily production loss is obtained which takes into consideration the possibility of the injured person's belonging to the age group of employed persons. Multiplying the value thus obtained by days of temporary disability yields an estimate of the production loss for that period.

GDP VALUES USED FOR THE CALCULATION OF PRODUCTION LOSS ASSOCIATED WITH INJURED OR KILLED PERSONS		
GDP 2000	billions of £	2 257 066
Employed 2000	thousands	21 080
Inhabitants 2000	thousands	57 189
GDP per employed person (thousands of liras)		*107 071*
GDP per inhabitant (thousands of liras)		*39 467*
Adjustment rate		*5.57*
Reduction coeff. by age group	*up to 30*	*1.015*
	31-40	1.025
	41-50	1.129
	51-65	1.186
	65 -	0.718

Table 31 in Chapter 6: Estimate of health costs for persons injured or killed in road accidents

The DRG fixed rates involving road accident injuries were used for the calculation of this estimate. These rates do not change with variations in age or seriousness of diagnosis, thus the medical cost per injury remains the same and is not subdivided by age group.

The point of departure in determining this value was the percentage of injuries subdivided by type deriving from study 2. It was necessary to use the total percentage and to omit any subdivision by seriousness in as much as the DRG rate does not, as we have already mentioned, consider this parameter. Once the DRG rates regarding road accident injuries were subdivided into the types of injury listed in study 2, an average rate was calculated such that every injured area of the body corresponded with a medical cost. Finally, a weighted average of these rates was taken based on the frequency noted in the above-mentioned study. These same operations were repeated both for the hospitalization and day-hospital rates.

For serious injuries the average global hospitalization cost was added to ambulance and emergency room costs. For minor injuries a cost equal to the average of emergency room and day–hospital costs was considered. In the absence of information on hospitalization before death, only the ambulance and emergency room costs were applied to deceased persons, which resulted in the supposition that all of them were killed on the spot.

The same must be said of rehabilitative therapy both in the case of minor injury and serious injury. In the absence of related data the value could not be calculated.

Table 39 in Chapter 6: Present value of the loss of productivity among deceased persons and those with permanent disability

This estimate applies to both categories (deceased persons and those with permanent disability) as both are considered no longer capable of economically productive activity. The calculation takes into account the GDP, corrected for the long term discount rate, divided by the number of employed persons and by the number of inhabitants respectively, and multiplied by the number of economically productive years lost through death or permanent disability. The average GDP increase during the last 15 years is considered to be 0.194 per inhabitant and 0.192 per employed person. This value has been applied in discounting future lost income.

The adjusted future production loss associated with permanently disabled or deceased persons is obtained by repeating the calculation of the production loss resulting from temporary disability for each year of expected active life (using the GDP corresponding to each year), adjusting with an adjustment rate obtained from an average of the deflated discount rates relative to the last 12 years and, finally, adding together all the years relative to the individual age groups.

Table 44 in Chapter 6: Monetary value applicable to emotional damage as a result of road accident deaths and physical damage to injured persons

To calculate this value reference was made to the table of the Tribunale di Milano [Milan Law Court] which shows the value of the percentage points of disability by age group. In the case of death disability is considered as 100%. The monetary value was then obtained by multiplying the point value in that particular age group by 100.

The same procedure was used for minor injuries which were given 5 points of disability, while serious injuries were given 20 points.

Annex 10. Study of the University of Turin on road accident costs*

1. Road accident costs

The aim of this study is to calculate the costs of road accidents involving mopeds in Rome and Milan. The costs of road accidents concern both the damages suffered by individual citizens as well as those suffered by the society. For the purpose of better estimating the economic impact of these costs it would be useful to separate them into the following four categories [COST 313, 1994]:

(a) *health costs*, represented by the total costs necessary to provide health assistance to persons involved in the accident, which include hospitalization as well as the costs resulting from emergency intervention;
(b) *other real costs*, such as the damage and consequences of repairing vehicles involved in accidents, legal costs and possible funeral costs;
(c) *costs owing to the loss of output*, consisting of the loss of productive work activity owing to accidents; cost of time lost due to accidents; transaction costs such as, for example, the costs of recruiting and training new personnel; four specific circumstances influence the overall sum of these costs:
   - whether the estimates include the work force only or the entire population;
   - whether the costs include gross or net losses;
   - whether future production values are foreseen and at what rate;
   - whether the income, or input, growth rate is expressed, as well as the level of that growth.

(d) *human costs,* which register the pain and suffering of the individual following the accident and reflect the single individual's risk aversion.

The sum of these costs is, however, much different according to whether the outcome is fatal or not. In the case of a fatal outcome, in fact, a value must be attributed to the human life lost, which is a practice that produces a multitude of very different results; accidents limited to injury only are a different case.

The report is arranged as follows: Paragraph 2 contains the analysis of the principal methods used in the literature for calculating the value of a human life. Accidents that do not cause fatal damage are dealt with in paragraph 3. Paragraph 4 illustrates the data used for this ratio for the cities of Milan and Rome. Paragraph 5 and 6 offer respective estimates of mortality and morbidity costs associated with moped accidents in the cities analysed. Finally, several conclusions are drawn in paragraph 7.

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2. The statistical value of human life

The value placed on human life lost and on the physical and psychological disability consequent to accidents is known in the literature as the Value of Statistical Life (VOSL) or the value of the prevention of statistical fatality. There are many methods by which to estimate the statistical value of human life [Jones-Lee, 1989]. In particular, we have cited below those most used in the literature: the human capital method, the willingness-to-pay method, and methods concerning stated preferences and income differentials.

2.1. The human capital method

The human capital method attributes a loss to the society following a death equal to the expected value of the output that the victim would have produced had he not died prematurely.

An alternative method is based on the concept of "net output". This concept considers the fact that a person consumes a large part of what he produces. The value of this expected production is subtracted from the "gross output" value. This approach greatly reduces the value of the life lost, the net output being estimated at approximately 20% in the case of fatality [Hammond, 1981].

An individual application of this method presents various problems, and for this reason it is little used in the literature. In the first place, there is the difficulty in obtaining detailed information on the incomes of persons involved in accidents, on the rates of future development and on the rate of inter-temporal preference to be used in the analysis.

In the second place, even if these data were available the application of the income method (but not that of consumption) could even lead to negative values. In fact, think of all the persons – retired, unemployed, disabled – whose income is lower than their consumption levels. In this case, the value of life would be negative and their death would represent an advantage to the society and not a loss! There would also be unacceptable differences between the value of the life of a man and that of a woman, and between adults and children, and so on, and for this reason "the application of an income derived from the GDP is much more equitable with regard to the real income of the categories of patients involved", even though it is true that the real income "better reflects the real economic burden involved". [Levaggi *et al.*, 1999].

2.2. The willingness-to-pay method

Accepting the fact that the reduction of death risk (and of injury) value includes a multitude of considerations on the part of individuals, the attempt to define *ad hoc* measures was abandoned in favour of a consideration of individual preferences.

The trade-off that takes place between risk reduction and money is registered with the method known as willingness-to-pay (WTP) for the reduction of risk level. The willingness to pay in order to avoid death is given as:

where:

$$\left[\sum_{t=0}^{T} \frac{B_t}{(1+r)^t}\right] A$$

T	=	time of remaining life
Bt	=	benefit deriving from being alive (including non-market benefits)
r	=	rate of inter-temporal preference
A	=	risk aversion factor

This WTP value includes all the benefits of being alive, including a premium for pain and suffering avoided. The use of the individual preference rate renders a discount rate superfluous.

In contrast with the human capital method, the WTP allows for a better evaluation of the various risk attitudes of individuals and the nature of the risk of premature death, in addition to the possibility of evaluating intangible costs, resulting in a generally higher estimate of the social costs associated with premature death [Blomquist, 1979; Jones-Lee, 1989; Persson and Cedervall, 1991; Elvik, 1994; Kidholm, 1995; COST 313].

The WTP is often transformed into VOSL. Assuming that the WTP is expressed as a variation of the probability of the risk of death per single individual, *dz*, these variations are added up for the total of the individuals, *n*, in such a way that n*dz=1, that is that for each group of *n* individuals a statistical life is avoided. It follows that the value of statistical life can therefore be expressed as the sum of the WTPs for all the individuals *n*, VOSL = WTP*n = WTP/dz [Lindberg, 1999].

Naturally the WTP is not without its downside [Tervonen, 1999]. Among the most common criticisms is the risk of identifying individuals' preferences with their choices. In fact, it can happen that these choices are circumstantial, regardless, therefore, of individuals' preferences. Moreover, doubts are raised on the capacity of individuals to have well-defined preferences on marginal changes, as well as to evaluate the nature and magnitude of the risk faced. Finally, the risks of calculated responses to hypothetical questions are well-known.

2.3. The stated preferences method

The stated preferences method proves useful in conjunction with the WTP, as is witnessed by recent developments in research in this direction [Adamowicz et al., 1994; Roe et al., 1996]. The method consists of the observation of how different attributes that characterise some market assets influence the WTP. Analysis, therefore, of products that guarantee increased safety levels allows for a more careful examination of private preferences towards risk [NHTSA, 1996]. Nevertheless, the products in question have characteristics bound not only to safety levels and thus it would be necessary to isolate these from ones that impact only on safety levels.

2.4. Income differentials

Another possible method for the estimation of the value of life lies in income differentials. This method's rationale is based on the fact that high-risk professions should guarantee much higher wages than those guaranteed to lower-risk professions. This wage differential would represent a monetary value applicable to the risk of death.

This measurement of VOSL can, nevertheless, be determined by numerous other factors beyond risk. In confirmation of what can be seen in Table 1, which shows the wage differentials of statistical life, the large differences in values, in fact, are not owing only to the typology of work considered, but also to the nation analysed, as well as the estimation technique which, in turn, impacts on the final VOSL value [Tervonen, 1999].

TABLE 1. WAGE DIFFERENTIALS OF STATISTICAL LIFE (MILLIONS OF POUNDS 1993)

Great Britain	**VOSL**
Malenik (1974)	*0.5*
Veljanovski (1978)	*5.5–7.6*
Needleman (1980)	*0.2*
Marin et al. (1982)	*2.4–2.7*
Geourgiou (1992)	*8.6*
USA	**VOSL**
Coisineau (1988)	*0.8–2.6*
Moore and Viscusi (1988)	*1.2–5.7*
Viscusi and Moore (1989)	*5.4*
Moore and Viscusi (1990)	*10.6*
Kreisner and Leeth (1991)	*0.4*

Source: Tervonen (1999).

2.5. Empirical evidence

Considering the multitude of factors that impact on the individual estimation of the value of human life and the variety of methods used to estimate it, it is not surprising noteworthy differences can be found between the various estimates in the literature. To this end Table 2 shows the values of statistical life taken from several of the principal studies of the last twenty years, adjusted in order to account for the GDP differentials and expressed in Italian liras of 1997. The VOSL value falls between slightly more than 1 billion and almost 8 billion liras!

It is possible to find very different values even within the context of the same project; for example, the COST 313 Project [European Commission, 1994], which was a comparative study on the socio-economic costs of road accidents in Community countries, in which the differences in estimated costs were great and only in part attributable to the income differentials between countries.

TABLE 2. VALUE OF STATISTICAL LIFE IN SOME RECENT STUDIES (BILLIONS OF LIRE 1997)

Sources	Value	Method
Dillingham, 1979	1.017	Meta-analysis
Liu and Hammitt, 1999	1.105	Meta-analysis
Miller & Guria, 1991	1.274	New Zealand, road accidents
COST 313, 1990	1.359	European average, road accidents
COST 313, 1990	1.700	Great Britain, road accidents
COST 313, 1990	2.009	Germany, road accidents
Tielatitos *et al.* ,1999	2.061	Finland, road accidents
COST 313, 1990	2.068	Austria, road accidents
Ball, 1997	2.238	Great Britain, road accidents
Persson, 1989	2.866	Sweden, road accidents
Viscusi *et al.*, 1991	2.866	USA, road accidents
FHWA, 1994	3.194	USA, road accidents
Dillingham, 1985	3.790	Meta-analysis
Viscusi 1993	4.034	USA, road accidents
Martinello and Meng, 1992	4.486	Meta-analysis
Vodden *et al.*, 1993	5.282	Meta-analysis
Jones-Lee, 1985	6.148	Great Britain, road accidents
Leigh, 1995	7.934	Meta-analysis

Source: our elaboration of original data.

TABLE 3. VALUE OF STATISTICAL LIFE IN SOME EUROPEAN COUNTRIES. RESULTS OF THE COST 313 PROJECT (THOUSANDS OF ECU 1990)

Country	VOSL
Austria	1 389
Germany	1 575
Great Britain	931
Netherlands	248
Spain	171
Switzerland	2 166
European Average	*827*

Source: European Commission (1994).

As we have seen, Tables 2 and 3 show very different VOSL values. A partial explanation lies in the different analytic methods, timeframes and baseline populations employed. Nonetheless, this explanation alone does not cover all the reasons behind such marked differences. The fact is that the above studies do not necessarily regard the same typology of costs but, according to the case in question, can include or exclude production and consumption costs, health costs, intangibles, etc.

In an attempt to obtain a more "objective" estimate, even though it may not be founded on the theory of well-being used as the basis for the other assessment methods, the human capital method can be used. As illustrated in paragraph 2.1, the method consists of the estimate of the value of statistical life by means of the calculation of the future output that would be have been produced by the victim had he not died prematurely. Table 4 shows some estimates drawn from the COST 313 project and adapted in order to account for differences in GDP[1].

TABLE 4. COMPONENTS OF THE VALUE OF STATISTICAL LIFE IN SOME EUROPEAN COUNTRIES. RESULTS OF THE COST 313 PROJECT (MILLIONS OF LIRE 1997)

	Gross production loss	Consump-tion loss (2)	Net production loss[2] (3)	Loss of "human value" (4)	Medical and other costs (5)	Total cost per person (6)
Austria	878	*702*	*176*	1 185	4.6	2 068
Germany	854	*683*	*171*	1 153	0.9	2 009
Great Britain	498	*398*	*100*	1 201	1.0	1 700
European average	571	*457*	*114*	787	2.1	1 359

Source: our elaboration of original data.

Although the calculation in this case is based on objective economic magnitudes – production and internal consumption – the results of the estimates still show values quite different from each other.

3. Morbidity costs

3.1. Abbreviated Injury Scale

In the case that an accident is not fatal, the person involved requires health assistance in addition to a combination of other costs, the description of which can be found in the introduction [FMCSA, 2001; Barnett et al., 1999]. The combination of these costs represents a cost directly linked with the injury, which is estimated in consideration of the various levels of seriousness of the injuries.

[1] Other countries not included in the Table show values even further from the European average, Switzerland above it, Holland and Spain under.

[2] The net production loss in column (3) is given by the difference between columns (1) and (2). Nevertheless, in order to avoid a double count the total cost per person includes only the gross loss.

Each injury is assigned an abbreviated injury scale value (AIS) and the injury is assigned to a specific part of the body. In some cases economic evaluations were done according to this scale, such as the three studies whose results are shown in the following table. In the study by the Federal Highway Administration of the USA [FHWA, 1994] the comprehensive cost is estimated, allowing for the internalisation of all the effects of accidents on the entire life of the individual, and a value is estimated for each injury on the various degrees of the AIS scale, attributing a monetary value to eleven components. These include damage to property, loss of workplace and domestic production, health costs, legal and administrative costs and, above all, the costs associated with the pain of a diminished quality of life.

Nevertheless, intangible costs are not always surveyed in this type of study. To this end see Table 5 below which shows the AIS values; the attempt to include intangible costs translates into higher estimates for the Federal Highway Administration (FHWA) as compared with the two subsequent studies.

TABLE 5. ACCIDENT COSTS CLASSIFIED ACCORDING TO THE AIS SCALE (MILLIONS OF LIRE 1997)

Seriousness	Description	FHWA, 1994	MMWR, 1993	Fildes et al., 1998
AIS 1	Minor	6.1	8.8	2.5
AIS 2	Moderate	49.1	38.3	15.3
AIS 3	Serious	184.2	120.3	47.3
AIS 4	Severe	602.0	226.5	89.8
AIS 5	Critical	2 433.7	841.5	290.0
AIS 6[3]	Fatal	3 194.5	1 003.2	460.3

Source: our elaboration of original data.

The AIS scale is an index allowing for the classification of the physical damage consequent to an accident. Nevertheless, it is possible to distinguish injuries also on the basis of the part of the body involved. The Fildes et al. study [1998][4] distinguishes the cost associated with the AIS value for 9 different areas of the body. Using the Fildes estimates and those of the FHWA [1994] it is possible to construct Table 8 containing the comprehensive medical cost for the various areas of the body.

Starting with the AIS classification it is possible to make an even more complex measurement that considers multiple injuries, which was the motivation behind the ISS – the Injury Severity Score. The ISS value is calculated by taking the sum of the squares of the three AIS values for the different areas of the body presenting the highest values, which yields an ISS value that varies from 0 to 75.

[3] The cost associated with the AIS degree 6, equivalent to injuries with fatal consequences, can be interpreted as an evaluation of statistical life.

[4] Used in Table 5 for the calculation of the average cost associated with the AIS value.

TABLE 6. AVERAGE COST PER INJURY ACCORDING TO THE AIS SCALE FOR VARIOUS AREAS OF THE BODY (MILLIONS OF LIRE 1997)

	Seriousness of injury					
Area of the body	**AIS 1**	**AIS 2**	**AIS 3**	**AIS 4**	**AIS 5**	**AIS 6**
external	5.1	37.0	125.1	350.0	635.6	3 194.3
head	7.1	43.6	217.2	862.2	3 813.6	3 194.3
face	7.1	43.6	217.2	93.9	1 265.4	3 194.3
nick	7.1	43.6	217.2	493.9	1 265.4	3 194.3
chest	5.1	37.0	125.1	350.0	635.6	3 194.3
abdomen	5.1	37.0	125.1	350.0	635.6	3 194.3
spinal column	5.1	37.0	292.2	433.5	6 488.5	3 194.3
upper limbs	7.1	64.1	183.8	-	-	-
lower limbs	5.1	64.1	233.4	594.1	1 265.4	-

Source: our elaboration of data from Fildes et al., 1998 and FHWA, 1994.

However, the ISS has some weak points that make it inappropriate for estimating the social costs of accidents. In particular, each individual error present in the AIS index exponentially increases the error recorded by the ISS index; moreover, different types of damage can produce the same final ISS value and hence are not weighted for the various areas of the body injured.

3.2. Components of average accident cost

The classification of costs according to the AIS method is not the only one mentioned in the literature. An alternative approach, widespread in European studies, is that which distinguishes in a less refined manner on the basis of the seriousness of accidents, referring in general to the distinction between sever and minor accident outcomes [Ball, 1997; Tervonen, 1999; Linberg et al., 1999].

Beginning with the results of the COST 313 Project, Table 6 presents an estimate for European countries of average cost by seriousness of the outcome, distinguishing the principal cost components.

The human costs (intangible) have carry a weight of over 60% of the total non-fatal accident costs, while healthcare costs account for a not very important 10%. These estimates are substantially confirmed also by the values of the Department of Transport of the English government (DTLR), which foresee higher human costs and about 8% for health costs.

TABLE 7. AVERAGE COST PER INJURY BASED ON SERIOUSNESS, EUROPEAN AVERAGE (MILLIONS OF LIRE 1997)

	Product-ion loss	**%**	**Health costs**	**%**	**Human costs**	**%**	**Total**	**%**
Minor	1.57	26.8 %	0.62	10.6 %	3.66	62.6 %	5.85	100 %
Severe	27.10	29.0 %	8.30	8.9 %	58.20	62.2 %	93.59	100 %
Death	570.60	42.0 %	2.14	0.9%	786.59	57.9 %	1 359.41	100 %

Source: our elaboration of COST 313 data (European Commission, 1994).

TABLE 8. AVERAGE ACCIDENT COST COMPONENTS, GREAT BRITAIN (1997)

Accident outcome	Production loss	Health costs	Human costs	Total
Minor	17.6%	7.5%	75.0%	100.0%
Severe	12.9%	7.8%	79.3%	100.0%
Death	34.8%	0.1%	65.2%	100.0%

Source: our elaboration of Ball (2000) data.

3.3. Health costs in Italy

The data presented to this point refer to the international situation. In the case of Italy, however, in order to evaluate the costs of accidents born by regional health care systems it is possible to use the rate value associated with the classification of hospital patients based on the DRGs[5] (fixed standard regional hospital rates) [Tosatti, 2000]. This means, therefore, identifying the information relative to accidents that made use of emergency room facilities and rescue intervention associating them with the correct reimbursement rates. Table 9 shows the estimate of average per capita DRG health costs for the year 1993 with reference to initial hospital admission for Emilia-Romagna.

TABLE 9. AVERAGE PER CAPITA HEALTH COSTS FOR INITIAL HOSPITAL ADMISSION 1993 EMILIA-ROMAGNA (LIRE 1993)

Vehicle of the injured person or pedestrian	Crash with						
	Car	Bus	Truck	Two-wheel vehicle	Four-wheel drive	Collision	Total
Car driver	3 845 226		4 582 836		4 010 327		4 008 146
Truck driver							
Two-wheel driver	3 821 918		3 626 471	3 028 474		2 617 461	3 643 642
Passenger in four-wheel vehicle	3 635 027		3 652 300		3 456 275		3 656 718
Passenger on two-wheel vehicle							
Pedestrian	4 697 049						5 184 486

Source: Tosatti (2002).

Unfortunately the results of the application of this method are not very useful. In fact, it should be noted how great a lack there is of healthcare data associated with the remarkable quantity of available technical information (which describe in detail the topology of the accident). Indeed, SDOs do not seem sufficiently

[5] There is also a substantial foreign literature that deals with the estimation of health costs in hospitals using DRGs with reference to specific national situations. See, among others, De Maria et al. (1988), Hendrie et al. (1994), Miller et al. (1993), and Oikkonen (1993).

detailed to detect the weight of hospitalizations per accident subsequent to the initial hospital admission, nor the seriousness and hospitalization history of the injured person per road accident [Tosatti, 2002].

4. The data

The risk of road accident is directly associated with the volume of traffic (level of congestion), the type of vehicle (driver's level of protection, speed, etc.), type of road (changes in viability linked with weather conditions) and the characteristics of the driver (age, behaviour, etc.) [Lindberg, 1999]. Nevertheless, the data available to us do not allow for this degree of distribution.

To estimate the costs of accidents involving mopeds in the cities of Milan and Rome, we were provided with the following data by the Rome office of WHO.

The statistics on the number of persons injured in accidents involving mopeds furnish the number of injured persons including drivers, passengers and pedestrians. In the tables the overall number of cases is treated without distinguishing among the various categories regarding attributed costs.

Table 10. Number of persons injured in accidents involving mopeds (year 2000)

	Milan	Rome
Drivers and passengers	4 556	2 244
Pedestrians	258	148
Total injured persons	4 814	2 392

Source: WHO elaboration of ISTAT data.

To calculate the costs attributable to deaths per age group use was made of the total number and distribution by age group of deaths caused by accidents involving mopeds. In this case as well no distinction was made between pedestrians (whose age was not contained in the statistics used), drivers and passengers.

As was pointed out in the preceding paragraphs, the cost of accidents is largely determined by the seriousness of the health outcomes. Nevertheless, in the absence of a real distribution of injuries on the AIS scale relative to the cities examined, use was made of a percentage distribution deriving from a sample study of 124 accidents and 134 injured persons conducted by the University of Pavia in the context of the MAIDS Project.

TABLE 11. DEATHS BY AGE GROUP (2000)

Age group	Milan	Rome
from 0 to 13	0	0
from 14 to 15	0	0
from 16 to 19	3	0
from 20 to 25	3	3
from 26 to 35	4	4
from 36 to 45	2	0
from 46 to 55	0	2
from 56 to 65	0	1
from 66 and over	0	0
Unknown	2	1
Total	**14**	**11**

Source: WHO elaborations of ISTAT data.

TABLE 12. PERCENTAGE DISTRIBUTION OF PERSONS INJURED IN ACCIDENTS INVOLVING MOPEDS (2000)

Area of the body	Seriousness of injury					
	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	Total
head	9.62 %	3.46 %	1.54 %	1.15 %	1.92%	17.69 %
neck	10.77 %					10.77 %
chest	1.15 %		0.77 %		0.38 %	2.31 %
upper limbs	12.31 %	4.62 %				16.92 %
abdomen	2.31 %					2.31 %
pelvis	0.77 %	1.54 %				2.31 %
spinal column	0.38 %					0.38 %
lower limbs	25.77 %	8.08 %	2.69 %			36.54 %
entire body	10.77 %					10.77 %
total	73.85 %	17.69 %	5.00 %	1.15 %	2.31 %	100.00 %

Source: University of Pavia, MAIDS Project.

Application of the percentage distribution to the total number of injured persons in Milan and Rome yielded the distribution of injuries per AIS and body area in the two cities.

5. The cost of mortality in Milan and Rome

As was pointed out previously, despite the many existing studies there is no baseline value for human life that allows for the assignment of a loss of life value to which everyone can agree. For this reason the cost of accidents involving mopeds varies widely according to whether a "prudential" estimate is chosen or an estimate that attributes a greater value to the risk of premature death.

In the case of accidents involving mopeds the comprehensive cost estimated for Milan varies from slightly less than 15 billion to over 110 billion lire (1997 rates); for Rome the range is from slightly more than 11 billion to almost 90 billion lire (1997 rates).

Table 13. Distribution of injuries per AIS and body areas in Rome and Milan

Milan	Seriousness of injury					
Area of the body	**AIS 1**	**AIS 2**	**AIS 3**	**AIS 4**	**AIS 5**	**Total**
head	463	167	74	56	93	518
neck	518					518
chest	56		37		19	111
upper limbs	592	222				815
abdomen	111					111
pelvis	37	74				111
spinal column	19					19
lower limbs	1 241	389	130			1 759
entire body	518					518
total	3 555	852	241	56	111	4 814
Rome	**Seriousness of injury**					
Area of the body	**AIS 1**	**AIS 2**	**AIS 3**	**AIS 4**	**AIS 5**	**Total**
head	230	83	37	28	46	423
neck	258					258
chest	28		18		9	55
upper limbs	294	110				405
abdomen	55					55
pelvis	18	37				55
spinal column	9					9
lower limbs	617	193	64			874
entire body	258					258
total	1 766	423	120	28	55	2 392

Source: our elaboration of directly gathered data.

Table 14. Value of Statistical Life in some recent studies (billions of lire 1997)

Study	Place	VOSL	
		Milan (14 deaths)	**Rome (11 deaths)**
Dillingham, 1979	Meta-analysis	14.23	11.18
Liu and Hammitt, 1999	Meta-analysis	15.47	12.15
Miller & Guria, 1991	New Zealand, road accidents	17.84	14.01
COST 313, 1990	European average road accidents	19.03	14.95
COST 313, 1990	Great Britain, road accidents	23.80	18.70
COST 313, 1990	Germany, road accidents	28.13	22.10
Tielatitos *et al.* (cit. in Tervonen, 1999)	Finland, road accidents	28.85	22.67
COST 313, 1990	Austria, road accidents	28.95	22.75
DTLR, 2000	Great Britain, road accidents	31.34	24.62
Persson, 1989	Sweden, road accidents	40.13	31.53
Viscusi *et al.*, 1991	USA, road accidents	40.13	31.53
FHWA, 1994	USA, road accidents	44.72	35.14
Dillingham, 1985	Meta-analysis	53.06	41.69
Viscusi, 1993	USA, road accidents	56.48	44.38
Martinello and Meng, 1992	Meta-analysis	62.81	49.35
Vodden *et al.*, 1993	Meta-analysis	73.95	58.10
Jones-Lee, 1985	Great Britain, road accidents	86.07	67.63
Leigh, 1995	Meta-analysis	111.07	87.27

Source: our elaboration of directly gathered data.

As illustrated in paragraph 2, the human capital method consists of estimating the gross production loss attributable to premature death. In the case of mopeds, the production loss was calculated from the age at the moment of death and the relative life expectancy[6], using the total number of years of life lost as a result of accidents. A value was then attributed to each year equal to the average per capita income of the respective province, to which, in the absence of precise data in this regard, and following the indications of the literature [Trawén et al., 2000], an average 4% discount rate and 2% growth rate were applied. Additionally, for reasons of fairness, it was decided that all citizens, regardless of their employment status, would be considered participants in the formation of the gross domestic product [Sommer et al., 1999].

The result thus obtained provides a value of slightly over 6 billion lire for Milan and of approximately 5 billion lire for Rome (1997 rates)[7].

TABLE 15. PRODUCTION LOSS ATTRIBUTABLE TO DEATHS CAUSED BY ACCIDENTS INVOLVING MOPEDS

	Years of life lost	Average per capita income (thousands of liras 1997)	Discount rate	Growth rate	Total expected production loss (billions of liras 1997)
Milan	707	51 515	4 %	2 %	6.31
Rome	486	39 827	4 %	2 %	4.88

6. Social and health costs in Milan and Rome

The use of estimates based on the AIS (Abbreviated Injury Scale) makes it possible to obtain estimates of the total social cost of accidents involving mopeds that take into account the various seriousness levels of injuries. Beginning with the distribution of the accidents examined, it can be noted how the majority of costs are attributable to the most serious accidents whose outcome is not fatal (AIS 5), and which, despite the low number of events, have an almost 50% impact on cost.

In the case of Milan, the estimates yielded values of between 70 and slightly less than 412 billion lire (1997). The same estimate for Rome yielded a comprehensive cost of between approximately 35 billion to slightly more than 204 billion lire (1997).

[6] In the absence of data on the gender of the deceased, an average of the male and female population was used.

[7] If it is considered that production loss, according to the calculation of the COST 313 Project, is about 42% of the total cost (Table 7), it is possible to estimate a comprehensive cost of 15 billion for Milan and approximately 11.6 for Rome, values not far from the lower limit of the estimates published in the literature (Table 14).

TABLE 16. ESTIMATE OF TOTAL SOCIAL COSTS OF ACCIDENTS IN THE CITIES OF MILAN AND ROME (BILLIONS OF LIRE 1997)

Seriousness of injury	Number of cases	FHWA 1994[8]	MMWR, 1993	Fildes et al., 1998
Milan				
AIS 1	3 555	21.84	31.21	11.42
AIS 2	852	41.87	32.63	16.68
AIS 3	241	44.41	28.98	14.62
AIS 4	56	33.71	12.68	6.443
AIS 5	111	270.0	93.41	41.23
Total	4 815	411.9	198.9	70.56
Rome				
AIS 1	1 766	10.85	15.50	4.43
AIS 2	423	20.79	16.20	6.47
AIS 3	120	22.12	14.43	5.68
AIS 4	28	16.86	6.34	2.52
AIS 5	55	133.80	46.28	15.95
Total	2 392	204.41	98.76	35.04

Source: our elaboration of directly gathered data.

Starting from the total social costs it is possible to estimate the total social costs for the various areas of the body utilising the values proposed by FHWA[1998] and by Fildes and Cameron [1998]. Since the percentage distribution of injured persons is the same for Milan and Rome, obviously the distribution of costs is also the same, and is characterised by the fact that the most significant number of injuries are those to the head. This predominance is to be attributed both to the fact that these injuries are numerous and, at least in the sample considered, also tend to be more serious than others and consequently more costly.

To estimate the costs born by the regional health services deriving from emergency room and hospitalization costs it is necessary to identify the rates employed for the individual treatments provided.

In the case of hospitalized patients, the lack of hospital discharge charts on injured persons which assign a DRG rate for each individual injury, turns the estimate into a simple approximation of the real hospitalization costs born by the regional health services. This essentially means attributing an average DRG value to each area of the body injured. To obtain the number of persons hospitalized per body area injured, Table 13 considers all the injuries classified as AIS 3,4 and 5, and more than 50% of those classified AIS2. In this way the total number of persons hospitalized is equal to 17% of the total injured, a percentage similar to

[8] It must be remembered that the FHWA (USA) considers all the possible costs associated with the accident (comprehensive cost), hence the much higher value.

that of the University of Pavia study results. The DRG rates were then grouped by body area[9], excluding the DRG associated with particularly complex pathologies which, if considered, would heavily influence the final value of the estimate[10]. Finally, the average of the rate per homogeneous group was applied to the number of hospitalizations estimated.

On the other hand, in the case of subjects not hospitalized, we used the reimbursements guaranteed on the basis of the Triage Code of the Lazio Regional Council. In particular, subjects with AIS 1 injuries were assigned a white code, while 50% of the subjects were given an AIS 2[11] classification and assigned a green code. The results of this estimate are shown in Table 18[12].

TABLE 17. TOTAL SOCIAL COST PER BODY AREA FOR MILAN AND ROME (BILLIONS OF LIRE 1997)

	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	Total
Milan						
entire body	2.05	0	0	0	0	2.054
head	2.57	5.69	12.55	37.70	2769	335.4
neck	2.88	0	0	0	0	2.882
chest	0.22	0	3.61	0	9.427	13.26
abdomen and pelvis	0.59	2.13	0	0	0	2.723
spinal column	0.07	0	0	0	0	0.075
upper limbs	3.29	11.11	0			14.41
lower limbs	4.93	19.47	23.69	0	0	48.09
Total	16.62	38.41	39.85	37.70	286.3	418.9
Rome						
entire body	1.02	0	0	0	0	1.02
head	1.28	2.83	6.27	18.85	136.9	166.20
neck	1.43	0	0	0	0	1.43
chest	0.11	0	1.76	0	4.46	6.33
abdomen and pelvis	0.29	107	0	0	0	1.36
spinal column	0.04	0	0	0	0	0.04
upper limbs	1.64	5.51	0			7.14
lower limbs	2.45	9.66	11.66	0	0	23.78
Total	8.26	19.06	19.69	18.85	141.4	207.30

Source: our elaboration of data from Fildes et al., 1998 and FHWA, 1994.

[9] The Lazio Regional Council DRG rates for the year 2000 applied to both cities.

[10] As partial confirmation of this choice, see the study by the Istituto Superiore di Sanità [Casco 2000] which reports the ISS injury distributions relative to the sample analysed, which show a limited presence of serious cases of multiple injury.

[11] Note that 50% of the subjects with AIS 2 were inserted among the subjects hospitalized.

[12] It should be underlined that Table 18 is not comparable with Table 17, which does not include only the costs of hospitalization but the comprehensive cost of the accident.

TABLE 18. ESTIMATE OF THE TOTAL COSTS OF EMERGENCY ROOM TREATMENT AND HOSPITALIZATION (BILLIONS OF LIRE 1997)

	Milan		Rome	
	Emergency room costs	Hospitalization costs	Emergency room costs	Hospitalization costs
head	62.1	2 147	30.9	1,068
neck	41.4		20.6	
chest	4.5	219	2.2	106
abdomen and pelvis	23.0	267	11.4	134
spinal column	1.5	343	0.7	170
upper limbs	80.7	1 672	40.0	826
lower limbs	157.6		78.3	
entire body	41.4		20.6	
total	412.0	4 647	204.8	2 304

TABLE 19. TOTAL COST OF HOSPITALIZATION BASED ON DRG RATES WEIGHTED FOR SERIOUSNESS (BILLIONS OF LIRE 2000)

	Milan	Rome
head	2 276	1 130
chest	225	108
abdomen and pelvis	152	76
upper limbs	265	131
lower limbs	1 046	517
total	3 966	1 964

Nevertheless, Table 19, even in light of the hypothesis upon which it is constructed, must be taken as indicative of the overestimate of the total cost per area of the body born by the national health system based on the average rates per homogeneous group (Table 18). In this regard the values in Table 18 are potentially overestimated overall while, as regards the costs of head and chest injuries alone, they result underestimated.

Therefore, the estimate of the costs born solely by regional health services presents values much lower than the social ones (Table 17), but in this regard it is necessary to recall, once again, that these latter are comprehensive costs of which health costs represent only a modest amount (Tables 7 and 8).

7. Conclusions

The road accidents that take place annually in the member countries of the European Community kill approximately 45 000 people and leave more than 1.5 million injured (1999 figures).

Apart from the humanitarian aspects of the reduction in road deaths and injuries, there is noteworthy pressure being placed by the society to reduce the social and health costs of these accidents. In this regard the estimate of these costs is the necessary premise to achieving an efficient allocation of scarce resources.

The aim of this study has been to evaluate the costs of mortality and the social costs of accidents involving mopeds, in addition to providing an estimate – necessarily partial as a result of the quality of the data available – of the costs born by the national health system.

Given the multitude of methods in the literature used to estimate costs, we have decided not to present an unequivocal evaluation of them, but to present different values according to the baseline technique. As for the comprehensive costs owing to premature death, using the WTP we obtained an estimate of between slightly more than €8 million and 58.8 million for Milan and between €5.9 and 48.1 million for Rome (year 2000). Use of the human capital method produced significantly lower figures. In fact, the production loss following premature death is equal to slightly more than €3.2 million for Milan and of approximately €2.7 million for Rome (2000 figures). Nevertheless, departing from the production loss, if a comprehensive cost is calculated we obtain a value equal to €8 million for Milan and 11.6 for Rome – figures not far from the lower limits previously indicated.

In terms of the estimate of total social costs, use of the AIS index yields values of between €37.4 million and approximately €220.4 million in the case of Milan, according to the estimates used, while for Rome the comprehensive cost lies between €18.7 million and slightly more than €109.1 million (2000 figures).

The study presents an estimate of the costs born by the regional health services related to emergency room treatment and hospitalization. The lack of individual diagnoses that would allow for the exact attribution of DRG reimbursement rates for hospital services, and the exact assignment of a Triage Code in the case of emergency room treatment, hinders the reconstruction of society's burden. Nevertheless the estimate, even given the limitations deriving from it, indicates a value of approximately €2.7 million for Milan and slightly more than €1.3 million for Rome (2000 figures). Finally, a subsequent elaboration allowed us to underline how this estimate appears to be skewed both by an underestimation of the costs attributable to head and chest injuries as well as an overestimation of the costs of pelvic and upper and lower limb injuries.

The present study represents an initial attempt to estimate the costs of road accidents involving mopeds. Nonetheless, a certain caution is necessary in drawing general conclusions from the estimates presented as a result of the nature of the data at our disposal and the random nature of some costs. In this regard we would underline the need for further studies focused specifically on the Italian situation.

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Annex 11. Study of P. Liberatore on the value of fatalities*

1. Premise

Disabilities and deaths caused by accidents involving mopeds are associated with various other damages to the individuals involved and to those around them: these are, above all, "emotional" damages but also include financial damage associated with hospital expenses, vehicle repair costs, increased insurance premiums, etc.

Further, it would be legitimate to say that the entire society suffers a loss with the death or disability of any of its members. The use of mopeds as an alternative to the automobile, in fact, constitutes a risk to which society is exposed (independent of its benefits in terms of time savings and traffic decongestion), which can be measured and attributed monetary value using conventional economic techniques.

One part of this economic evaluation consists of reconstructing the direct expenses sustained by the State/Society (hospital costs, material damage repairs, police services, etc.). A second part, not so easily ascribed monetary value but equally important, concerns the social costs associated with the loss of human life or the inability of injured persons to work. This second measurement is the object of the present study and is obtained through the assignment of a monetary value to the life and health of persons involved in moped accidents. Since this is a matter of assets "external" to the market and not subject to sale or acquisition, it will be necessary to make use of variables or parameters capable only of approximating their value.

The data utilised relate directly to accidents involving mopeds in Rome during the year 2000. Two different approaches are used: the first makes use of the concept of the "human capital" of each individual, determining its value in terms of the lost contribution to society's overall wealth; the second is based on the cost that the State/Society appears willing to pay in order to guarantee its members greater safety, that is a reduced number of deaths.

2. Baseline data

The estimates are based on the 2 392 persons injured and 11 killed (drivers, passengers and pedestrians) as a result of 2 091 road accidents involving mopeds in Rome in the year 2000 (which is more than 23% of the total of all road traffic accidents).

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TABLE 1. ROME – YEAR 2000 – NUMBER OF DRIVERS AND PASSENGERS INJURED AND KILLED IN ACCIDENTS INVOLVING MOPEDS, BY AGE GROUP

Age group	injured		killed	
0–13	10	*0.4%*	0	*0.0%*
14–15	90	*4.0%*	0	*0.0%*
16–19	497	*22.1%*	0	*0.0%*
20–25	555	*24.7%*	3	*30.0%*
26–35	702	*31.3%*	4	*40.0%*
36–45	242	*10.8%*	0	*0.0%*
46–55	85	*3.8%*	2	*20.0%*
56–65	34	*1.5%*	1	*10.0%*
65+	29	*1.3%*	0	*0.0%*
total	**2 244**	***100%***	**10**	***100.0%***

Source: MAIDS study.

A second data set concerns the impact of accidents on the injured persons' normal activity (in this case both of drivers and passengers as well as pedestrians), i.e., the number of days of hospitalization assigned to them (Table 2).

TABLE 2. ROME – YEAR 2000 – NUMBER OF DAYS OF HOSPITALIZATION ASSIGNED TO PERSONS INJURED IN ACCIDENTS INVOLVING MOPEDS

days of hospitalization	injured persons	
none	223	*9.3%*
from 1 to 4	245	*10.2%*
from 5 to 9	946	*39.5%*
from 10 to 14	529	*22.1%*
15 and over	449	*18.8%*
total	**2 392**	***100%***

Source: WHO European Centre for Environment and Health.

From the information contained in Table 2, a uniform distribution of hospitalization days can be hypothesised for each of the 5 age groups (thus, respectively, 0, 2.5, 7 and 12 days for the first four and for the last group an indicative value of 25 days), yielding an average stay in hospital of 10.4 days.

Finally, a study conducted on a sample of 4 603 cases (source: WHO – European Centre for Environment and Health, Rome) indicates 49 days as the average duration of inability to work resulting from moped accidents; in this study, this period is attributed to persons hospitalized for at least one day, and includes the stay in hospital.

3. Estimate of social costs based on human capital

3.1. Basic elements of the method

Among the numerous methods proposed in the literature for the economic assessment of human life and health, the approach based on the concept of each individual's "human capital" has been the most widely applied and accepted. This method attaches monetary value to the expected future income of individual members of society: the "economic loss" associated with an individual involved in an accident is determined by estimating the contribution to the overall wealth that he, starting from the time of the accident, will never (in case of death) or will not temporarily (in the case of disability following injury) provide, and which therefore society loses. For each individual, this contribution is represented by the person's "own" proportion of wealth, therefore by his own income and production[1]. This is a matter then of reconstructing the future annual income and daily income of each member of the society killed or injured, and of summing them, respectively, up to the probable age at death and/or up to the resumption of activity: the value thus obtained constitutes the loss of human capital loss associated with moped injuries and deaths, i.e. the income lost to society.

For any particular year, an estimate of the contribution of an individual to the national income for that year is obtainable from the ratio between this aggregate and the sum of persons who contribute to its formation. In this study, the Gross Domestic Product (GDP) at market prices (an accounting aggregate calculated annually by ISTAT and presented in the national economic tables) is assumed as income in Italy, the figures for which are available for the baseline year 2000. The individual contribution to income for the year 2000 is obtained from the ratio between the GDP and the year's average population[2] (yielding a value of approximately €20 165); the daily contribution is obtained by further dividing the year by 366 days.

3.2. Application of the method to deaths

In order to estimate the value today of foregone future income, i.e. to determine its current value, we need to make assumptions about factors that during the

[1] In fact, instead of income some authors prefer to speak of the production capacity, and hence of expected future production for individuals and of production contribution loss for the society. In quantitative terms this is the same aggregate, considering that, in national accounting, the production (GDP) and income of a country coincide and are both classic indicators of its "wealth".

[2] It is assumed, that is, that the characteristics of the total individuals involved in accidents have the same structure as the entire Italian population, particularly concerning employment.

next 5 to 6 decades, will determine the real value of the currency. With the aim of simplifying the estimates, the per capita GDP set was reconstructed assigning the value attributed for the year 2000 to the years from 2001 on, based on the idea that the discount rate to be applied for the adjustment can be considered as equal to the rate of development of each individual's capacity to produce income – i.e. productivity[3].

The probable age at death is drawn from the mortality tables elaborated by ISTAT for the province of Rome (for the year 1998) which indicates, for each age *x* the average number of years that an individual can expect to live (i.e. his "life expectancy").

The results are shown in Table 3 below.

TABLE 3. ROME – YEAR 2000 – ECONOMIC QUANTIFICATION OF SOCIAL COSTS ASSOCIATED WITH DEATHS IN ACCIDENTS INVOLVING MOPEDS (€)

Age group (years)	Median age (x)	Life expectancy (*ex*)	Number of deaths	Annual contribution to income (€)	Total contribution to income (€)
0–13	7	71.9	0	20 165	0
14–19	17	62.1	0	20 165	0
20–25	23	56.3	3	20 165	3 403 979
26–35	31	48.6	4	20 165	3 916 468
36–45	41	39.0	0	20 165	0
46–55	51	29.8	2	20 165	1 200 374
56–65	61	21.0	1	20 165	424 015
65+	71	13.4	0	20 165	0
total	-	-	**10**	-	**8 944 837**
Adjusted total (11 total deaths)					**9 839 320**

Source: elaboration of data from WHO European Centre for Environment and Health.

Since we had the age at death for only 10 of 11 fatalities, a value was attributed to the eleventh equal to the average of the others. Thus calculated, the social costs associated with the 11 deceased persons amount overall to €9.84 million.

[3] It can be hypothesized, for example, that if a country registers an increase in the per capita GDP in the coming years equal to 2%, associated with economic growth, and at the same time a decrease of 2% in the value of its currency associated with inflation, then the per capita GDP will remain constant over time.

3.3. Application of the method to hospitalizations and temporary disabilities

More immediate and less affected by background assumptions is the calculation of the social cost of hospitalizations and temporary disabilities, based on the lost daily contribution to the overall income associated with periods of hospital stay or convalescence; for the year 2000 this contribution was obtained by dividing the year by 366 (yielding a value of €55.1).

An initial estimate of social costs for temporary disabilities can be performed by imagining that the hospitalizations are distributed uniformly among the various age groups (which is the same as saying that they are concentrated in the median age group); assuming an average length of hospitalizations of the "15 and over" group equal to 25 days, obtains the results described in Table 4.

The overall social costs for the year 2000 associated with hospitalizations amount to €1.37 million.

TABLE 4. ROME – YEAR 2000 – ECONOMIC QUANTIFICATION OF SOCIAL COSTS ASSOCIATED WITH HOSPITALIZATIONS FOR ACCIDENTS INVOLVING MOPEDS (€)

Length of hospital stay (days)	Median length of stay (days)	Number of cases (injured persons)	Total days	Daily contribution lost (€)	Daily contribution to lost income (€)
none	0	223	0	55.1	0
from 1 to 4	2.5	245	613	55.1	33 746
from 5 to 9	7	946	6 622	55.1	364 842
from 10 to 14	12	529	6 348	55.1	349 746
15 and over	25	449	11 225	55.1	618 446
total	**-**	**2 392**	**24 808**	**-**	**1 366 780**

Source: elaboration of data from WHO European Centre for Environment and Health.

Nevertheless, this estimate is incomplete. In reality, the injured person remains unable to work (and therefore does not produce income, meaning that he does not contribute to the society's wealth) not only during the time he is hospitalized, but also during his subsequent convalescence. It is, therefore, more correct to refer to the 49 total days of temporary disability indicated by the WHO European Centre for Environment and Health, which are applied to the 2 169 injured who have been assigned at least one day of hospitalization; social costs increase significantly on the basis of this second approach (see Table 5) and are equal to approximately €5.86 million.

TABLE 5. ROME – YEAR 2000 – ECONOMIC QUANTIFICATION OF THE SOCIAL COSTS ASSOCIATED WITH INABILITY TO WORK DUE TO TEMPORARY DISABILITY OWING TO ACCIDENTS INVOLVING MOPEDS (€)

Indicators	**€**
Total number of injured persons	2 392
Number of injured persons hospitalised (**A**)	2 169
Average time unable to work (days) (**B**)	49
Total days of recovery (**C = A*B**)	106 281
Daily contribution loss (€) (**D**)	55
Total lost daily contribution (€) (D*C)	**5 855 599**

Source: elaboration of WHO European Centre for Environment and Health data.

4. Comparative estimate based on the cost of a helmet

An alternative to the "human capital" method estimates the value of human life by means of individuals' or the State/Society's "willingness to pay" in order to guarantee a lower probability of death or injury. In some cases, this willingness to pay can be identified by means of the cost an individual chooses (or is obliged) to sustain in order to ensure his own safety; reference will be made in the present study to the costs deriving from society's choice of making helmets obligatory for all moped riders over the age of 18[4] by means of State law n. 472/99.

The theoretical premise is based on a fundamental principle: if it is believed opportune to spend a certain amount of money on something, then indirectly that thing is attributed a value equal to or greater than the sum paid for it, otherwise the expense would not be undertaken. Therefore, since purchasing a helmet reduces the probability of dying, the cost sustained can represent the individual's willingness to pay for this reduction, or better, the lower limit of this value[5].

In fact, the price of a helmet can not necessarily represent the cost that single individuals – characterised by different risk aversions – are willing to pay; it does, however, represent that considered adequate by society, which is, moreover, the requirement of the present study. By means of the law, society has revealed the appropriateness of spending the price *C* of a helmet in order to

[4] The helmet has been obligatory for all riders under the age of 18 since 1986.

[5] The first formulation of this method was proposed by O. Chillemi in 1994; used in place of the obligatory helmet was the residential automatic circuit-breaker [known as the "life-saver"], made obligatory by law no. 46/1990.

reduce the probability of death from its original *dn* (probability of death without helmet) to *dc* (probability of death with helmet), i.e. raising the probability of survival from to $(1 - d_n)$ to $(1 - d_c)$.

The general formula for this hypothesis is the following (see Paragraph 6):

$$C \leq V\ (d_n - d_c),$$

from which it is easy to see that the value *V* assigned by society to safety (and consequently to life) is at least equal to the ratio between *C* and *(dn–dc)*.

On the basis of the results of a study conducted in 2001 on the price lists of four of the main manufacturers of motorcycle products[6], it is possible to assume an average cost of €110[7] for an approved and completely safety-guaranteed helmet, with an average life-span of four years (data necessary to determine the cost sustained in a single year). The *dn* and *dc* values are obtained from the ratio between deaths on mopeds and the total number of mopeds circulating, respectively, in 1985 (when the helmet was not yet obligatory for anyone and was used very little by riders), and in the year 2000 (immediately after the law making the helmet obligatory for drivers and passengers): we assume that the reduction in the probability of death is entirely attributable to the use of the helmet[8].

The value of a single anonymous life, obtained from the ratio between the average cost of a helmet and the probability differential of death, can be calculated as €899 000; making reference to the 11 deaths analysed in this study, the overall cost borne by society for deaths per year amounts to approximately €9.89 million: this is a very similar value to that obtained with the human capital method.

In reality, we are well aware that this second estimate, founded on hypotheses completely different from those used for the first one, offers relatively low results and is thus difficult to "accept" in conceptual and ethical terms. While with the human capital method the social cost was calculated in "economic" terms as the individual's missing contribution to the total income, in this case

[6] Ascione, (2001); the cases are Nolan, Lem, Agv and Bieffe.

[7] This is significantly lower than the real average price, but is certainly sufficient for the purchase of a safe helmet; higher prices are not associated with greater safety as much as with features such as aesthetic appeal, brand-name, model, internal aeration, presence of a visor, etc.

[8] In all probability other factors have helped to lower the mortality rate: for example, the technological advances that have made mopeds safer, or the numerous awareness campaigns encouraging prudence; these are factors whose weight is difficult to calculate and is, in any case, negligible as compared with that of the helmet, and which are not considered here for simplicity's sake.

direct reference is made to human life as such, which should have a very high value in absolute terms – one, in any case, much higher than that of the lost monetary contribution.

5. Summary

The present study is aimed at estimating the annual social costs as a result of road accidents involving mopeds, through the attribution of a monetary value to the life and health of persons involved in moped accidents; the empirical data upon which it is based refer to accidents taking place in Rome during the year 2000.

Table 6 shows the principal results obtained with the human capital method. The social costs associated with 2 091 moped accidents in Rome over the year 2000, i.e. the exposure of society to mopeds, amounts to a total cost of approximately €15.7 million, of which €9.8 million are linked with the 11 deaths and €5.9 million with the inability to work as a result of the temporary disability of the 2 392 injured persons. On average, therefore, considering both deaths and accidents resulting in temporary disability, each accident involving a moped has a cost to society of slightly less than €7 506.

TABLE 6. ROME – YEAR 2000 – SUMMARY VIEW OF THE ESTIMATE OF THE COSTS BORN BY THE SOCIETY AS A RESULT OF 2 091 MOPED ACCIDENTS (€)

	Deaths	Injured persons (temporary disability)	Total
Number of cases	11	2 932	-
Total social costs	9 839 320	5 855 599	15 694 920
Social costs per accident	-	-	7 505.9

Source: elaboration of data from WHO European Centre for Environment and Health.

The results obtained for deaths are confirmed and supported by a second estimate of social costs which, while based on totally different hypotheses and parameters, reaches very similar results. It attributes an economic value to human life by attributing to those persons who die, society's willingness to pay for increased safety, which is expressed by means of the choice of the State/Society to make helmet use obligatory.

Greater detail on the methodological set-up, hypotheses formulated and calculation procedures are presented in the following paragraphs.

6. Some further considerations

Quantifying the life and health of an anonymous individual in economic terms is a complex and risky operation, whatever the approach chosen. Apart from the ethical doubts associated with the difficulty in considering life solely as an economic "asset" just like any other that contributes to forming the wealth of society, it is necessary to confront the difficulties associated with putting a market price on something so entirely external to the market and not subject to the classic laws of supply and demand.

6.1. The human capital method

From the theoretical point of view, in the case of damage to health, the most effective and well-used evaluation methods refer to a "dominant decider" and, instead of basing themselves on the mere sum of the preferences expressed by single individuals, adopts as significant the point of view of a superior decider, usually the State/Society (public decider).

Among the methods using the dominant decider, the most diffuse is the "human capital" method, also known as the "adjustment of lost income" or the "gross product". The method is based on the idea that the value of an individual for the society, i.e. the loss born in case of the death of one of its anonymous members, is represented by the adjustment of the individual's expected future income, which corresponds to his contribution to society's wealth – i.e. to the GDP.

The classic formula of the human capital evaluation $P\vartheta$ on the basis of expected future income (Mishan, 1974) can be expressed as:

$$P_\tau = \sum_{t=\tau}^{\infty} Y_t p_\tau^t (1+r)^{-(t-\tau)}$$

where Y_t is the individual's gross income foreseen for the *t-th* year (with the exception of income from the individual's ownership of other assets), is the probability that the individual has in the current year of remaining alive in the *t-th* year and *r* is the discount rate[9].

The estimation method in this study greatly simplifies the formula: the individual's probability of survival at various birthdays, from the year of the accident (the current year= ϑ#2000) to that of his natural death, is "summarised" by his life

[9] The method is not immune to criticism: the main ones regard the low or nil value indirectly attributed theoretically to individuals excluded from the production process, such as the elderly, disabled, etc.

expectancy *ex*, while no discount rate is applied to adjust expected future income, with the idea that this is compensated by an equal production growth rate.

Chosen to represent the wealth of the society was the GDP of Italy at market prices for the year 2000, whose most recent reconstruction is proposed in ISTAT's quarterly economic tables, IV quarter 2001 (published on 8 March 2002) and is equal to €1 164 766 million. The per capita income is obtained by dividing this value by the average Italian population in 2000, taken from the average of the sum of the population on 1 January 2000 (57 679 895) and the population as of 31 December 2000 (57 844 017); the daily value is obtained by further dividing by 366.

The life expectancy at various birthdays, as already specified, is taken from the most recent mortality tables available for the province of Rome and referring to the year 1998; it was then hypothesised that the moped riders in question were residents of the province of Rome and that they follow the same mortality laws.

Finally, as regards the social costs associated with injury, the only specification concerns the choice of data relative to the days of temporary disability (49 days) in calculating the daily income lost, instead of the data regarding the average recovery time, which is explained by the fact that the missing contribution to society's wealth takes place over an entire period of disability and not only during a brief hospital stay.

6.2. Willingness to pay for safety

A group of social cost estimation methods alternative to those with the dominant decider are based on the expense to be born for the reduction of health risks, or of the probability of death, which are often represented by a "willingness to pay" expressed directly (in interviews or questionnaires) or indirectly. Of course, these estimates have the advantage of adhering more to real choices or behaviours than do the methods with a single superior decider; but it is precisely this greater adhesion to individual choices and behaviours, that is to a, by definition, subjective willingness to pay, that constitutes the method's weak point: rarely are individuals consistent over time and homogeneous amongst themselves in their choice of allocating their resources; in fact, it is more frequent that the value implicitly attributed by one individual to a certain asset (in this case human life) differs by orders of magnitude from that implicitly attributed by another individual.

This problem can be overcome by referring to the willingness to pay manifested by the entire society (for example, by means of the creation of a law), thus linking to the theoretical assumptions of methods with the dominant decider. The method of reconstructing the value of human life presented in paragraph 5 is founded on these considerations, and refers to the previously cited estimate carried out by O. Chillemi in 1994.

In general terms, a society's belief that it is opportune to impose upon M individuals a per capita expense *C* in order to reduce the expected number of deaths from *n* to *n-1* (i.e. the probability of death from *n/M* to *(n-1)/M)* is seen to attribute to the life saved a value *V* at least equal to C^*M. The probabilities of death being d_n and d_c, the lives saved result $M\ (d_n - d_c)$, and the formula for this hypothesis becomes:

$$C * M \leq V * M(d_n - d_c), \text{ that is}$$

$$C \leq V(d_n - d_c),$$

which is independent from the numerator *M*.

If instead the formula is rewritten in terms of survival probability:

$$C \leq V(1 - d_c) - V(1 - d_n),$$

expense *C*, the probability for survival of each individual rises from $(1 - d_n)$ to $(1 - d_c)$: before undertaking the expense *C* the value of life *V* was associated with a "weight" equal to the probability of survival $(1 - d_n)$; after its purchase *V* is associated with a greater weight, equal to $(1 - d_c)$.

In the present study, the probabilities of death d_n and d_c, relative, respectively, to the years 1985 and 2000, are obtained from the ratio between the number of deaths resulting from moped accidents (published by ISTAT in its road accident statistics[10]) and the number of mopeds circulating, for which reference was made to the estimate by the National Association of Mopeds, Motorcycles and Accessories (ANCMA)[11].

The average price of a helmet, on the other hand, estimated at approximately €110, was divided by by the average number of years of use (4), with the aim of considering the annual cost born by individuals for their safety. For the sake of simplicity, in this case as well, no discount rate was considered in the calculation.

[10] A matter of 658 deaths in 1985 and 522 in 2000, considering both moped drivers and passengers. Since the law took effect in the month of March 2000, the probability of death for the year 2000 is slightly overestimated.

[11] 5 850 000 mopeds estimated 1985 and 6 375 000 mopeds estimated in 2000. ISTAT/ACI also publish a reconstruction of the number of mopeds circulating in various years which is, however, sorely underestimated – as the two agencies admit (slightly less than 4 million units in 2000) – since it considers only the mopeds registered at the Motor Vehicles Department and for which the circulation tax is regularly paid.

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Annex 12. Estimate of road accidents based on emergency facility visits*

This annex is an initial description of injuries resulting from road accidents for the resident population of Rome, by means of the analysis of regional emergency facility (I and II level emergency wards, emergency room) visits and of subsequent hospitalization.

1. Data sources

Use was made of the emergency health information system (SIES) with reference to emergency facility visits in the year 2000, for a record total count of 1 980 343. For the study of hospital admissions following road accidents, use was made of the hospital discharge information system (SDO) data for 2000 and for the first 9 months of 2001.

Both information systems are directly under the administration of the public health agency.

2. Road accident selection criteria

The data used regarding 1 980 000 emergency facility visits in 2000 were drawn from the information system up until 30 September 2001, selecting visits where the "injury circumstance" variable, which is always and only filled out in cases of injury, cited "road". Selected from these were all those with primary or secondary injury diagnoses (ICD codes 9 CM 800-959), excepting the diagnoses of foreign body in orifice other than eye or remote after-effects of injury. Visits not resulting in diagnosis were discarded, with the exception of diagnoses with a greater probability of immediate complications such as neck injury and intra-cranial hemorrhage. Excluded from the total count visits thus obtained were hospitalizations for problems clearly in contrast with road accidents such as "planned hospital admission", "fever", "intoxication", etc. Hospitalizations dated before 1 January 2000 and after 31 December 2000 were also excluded, along with multiple admissions presumably consequent to the same episode, using the same criteria for the definition of multiple admission: two or more hospitalizations of the same patient (identified by the same name, surname and date of birth), on the same or consecutive days.

Selected from the admissions thus obtained were those associated with patients residing in Rome and Fiumicino. Regarding emergency room visits, we noted how the percentage of Rome residents who make use of emergency facilities outside of

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Rome is 9.1%, while the percentage of residents outside of Rome who use emergency facilities in Rome is 13.4%.

3. Linkage for the study of hospitalization resulting from road accidents

Patients who made use of an emergency facility were identified in a search-by name, surname and date of birth-of the hospital discharge archives of 2000 and of the first 9 months of 2001, regardless of the outcome of the visit. The linkage criterion was then loosened, searching also for two identical entries and a typing error in one. In order to be considered as generated by the emergency facility visit the hospital admission had to have the same date as that of the discharge from the emergency facility +/- one day. For all hospitalized patients resulting as having been transferred the subsequent hospitalization was searched on the basis of the same criteria: name, surname and date of birth. The linkage criterion was then loosened, searching also for two identical entries and a typing error in one, and date of admission the same as that of discharge from the previous hospital +/- one day; this operation was repeated to cover all hospitalized patients resulting as having been transferred.

4. Analysis

A Poisson distribution for visits per facility per month was adopted in order to estimate coverage. To obtain the number of expected visits, the moving average of five months - the month itself, two before and two after – was calculated for monthly visits per emergency facility. Excluded from this average were months with zero, one or two visits. A minimum acceptability threshold was calculated for the number of visits equal to the average minus two Poisson standard deviations. Months with zero, one or two visits and those under the threshold were replaced with the moving average. For emergency facilities that had not sent in data for 2000, expectations were considered equal to the average visits expected from other facilities of the same geographical area, except hospitals complexes.

The body area variables (classified as head, neck, limbs, other) and injury type were attributed on the basis of clinical diagnosis.

The resident population used for the calculation of the rates is that of ISTAT 2000.

5. Comment

The total incidence of emergency facility visits is 2 726 out of 100 000 inhabitants. The number of deaths resulting from road accidents is 47 [this number includes the dead arrivals and Emergency Room deaths (30), as well as persons who died during the hospital treatment subsequent to emergency facility visit; this data set does not contain those killed at the site of the accident].

As regards body area, more visits for limb injuries are recorded, followed by neck, head and other (abdomen, chest and multiple). In a separate analysis of several injuries it can be noted, in particular, that the median age for head injury (28) is lower by approximately three years than all the other injuries combined (median age males = 20, female = 32); this can be influenced by the lower average age of motorcycle and moped drivers and the greater probability that accidents with these vehicles will result in head injury.

Fractures are associated almost exclusively with the limbs, and osteo-articular injuries are those mainly of the neck, known as "whiplash", typical of automobile collision (peak between 20 and 29 years).

Cuts are very low in frequency, and peak with those to the heads of children. The median age for this type of injury is very low, which could be the result of the greater frequency of this type of injury among motorcycle drivers.

Contusions follow the same trend as that of the total visits, with the exception of the very low frequency of contusions to the neck.

Abrasions are less represented numerically. A peak is seen among the very young, 15–19 years of age, and the body areas most affected are the limbs and abdomen/trunk.

6. Cost estimate

We traced cases of 12 069 hospitalizations following an emergency room visit as a result of a road accident. Some of these episodes consisted of up to six consecutive admissions.

Episodes followed by hospital admission	Average cost per episode	No. of hospitalizations	Average cost per hospitalization	Total count cost
	(£ x 1 000) 5 061.09		(£ x 1 000) 4 735.79	(£ x 1 000) 61 082 244
12 069	(€) 2 613.8	12 898	(€) 2 445.8	(€) 31 546 346

FIG. 1. DATA SET SELECTION CRITERIA

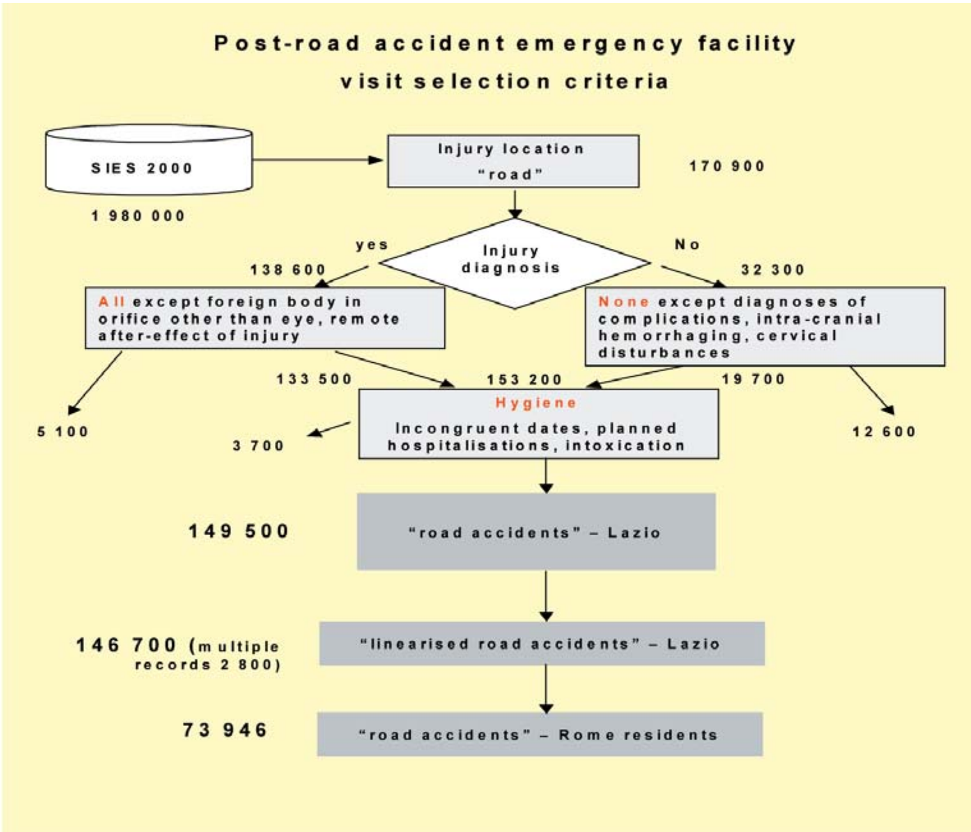


TABLE 1. COVERAGE CALCULATION

Rome E.R.s (15 institutes hospital agencies)		
Monitored	Expected	Coverage by 15 institutes non-hospital agencies
34 876	45 517	77%
Hospital Agencies Rome		
Monitored	Expected	Coverage by hospital agencies
37 679	39 297	96%
Total for Rome		
Monitored	Expected	Total coverage Rome E.R.s
72 555	84 814	86%

FIG. 2. INCIDENCE BY GENDER AND AGE GROUP

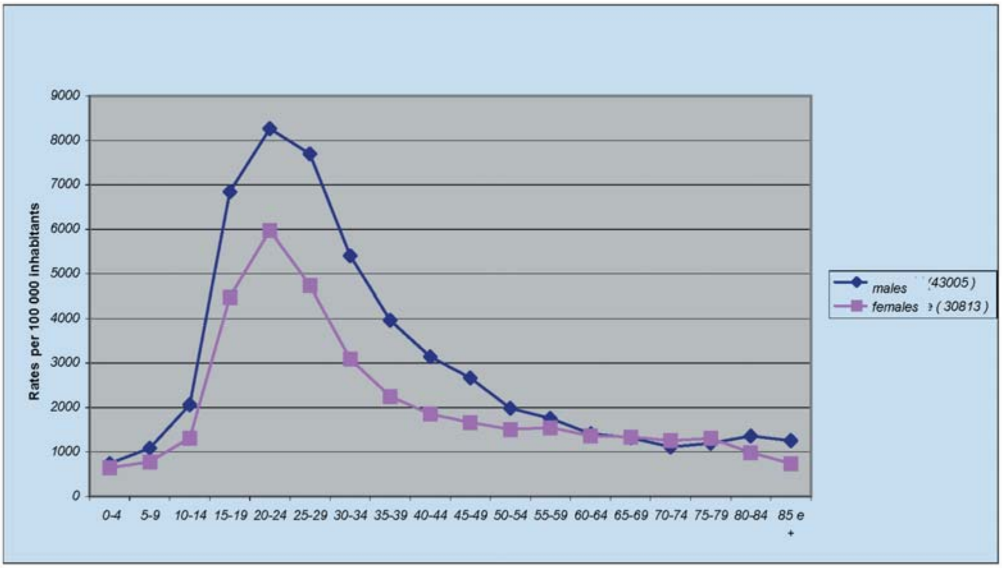
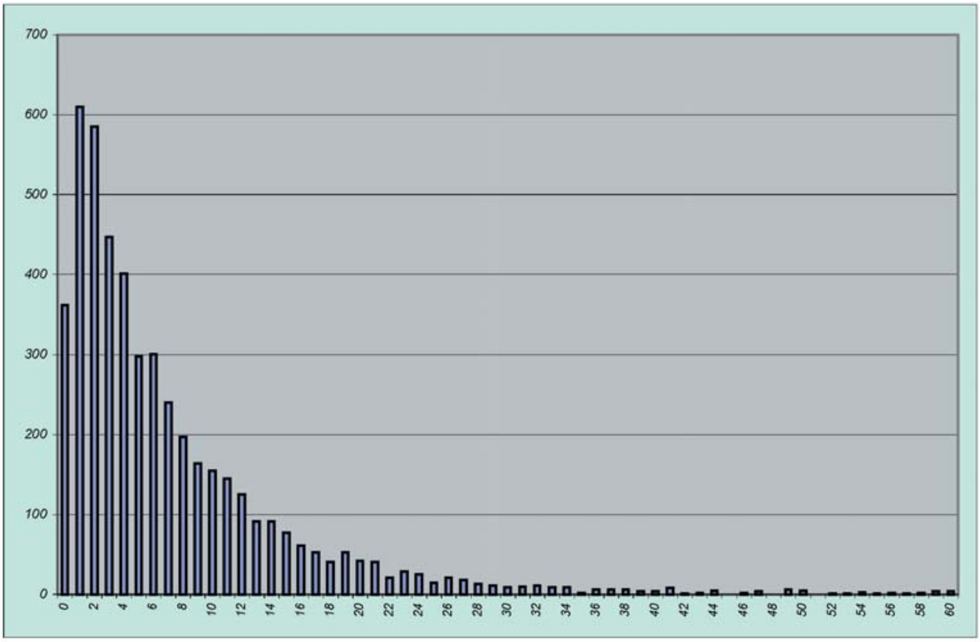


TABLE 2. OUTCOME OF EMERGENCY FACILITY VISIT

Outcome	No.	%
Dead arrivals + site deaths	30	0.04
At home	63 442	85.8
Hospital ward	4 340	5.9
Transfer to other hospital	384	0.5
Refused hospitalization	5 510	7.5
Refused hospitalization	240	0.3
Total	73 946	

FIG. 3. DURATION OF HOSPITALIZATION



Average: 8.11
Standard deviation: 12.64
Maximum: 260
Number of cases with more than 60 days treatment: 45

TABLE 3. IN HOSPITAL MORTALITY AND DEATH RATE

Mortality	Values
Deaths	47
In-hospital mortality	1.7 per 100 000 inhabitants/year
Death rate	0.06%

FIG. 4. INCIDENCE OF VISITS BY AGE GROUP AND BY AREA OF THE BODY INVOLVED IN THE INJURY

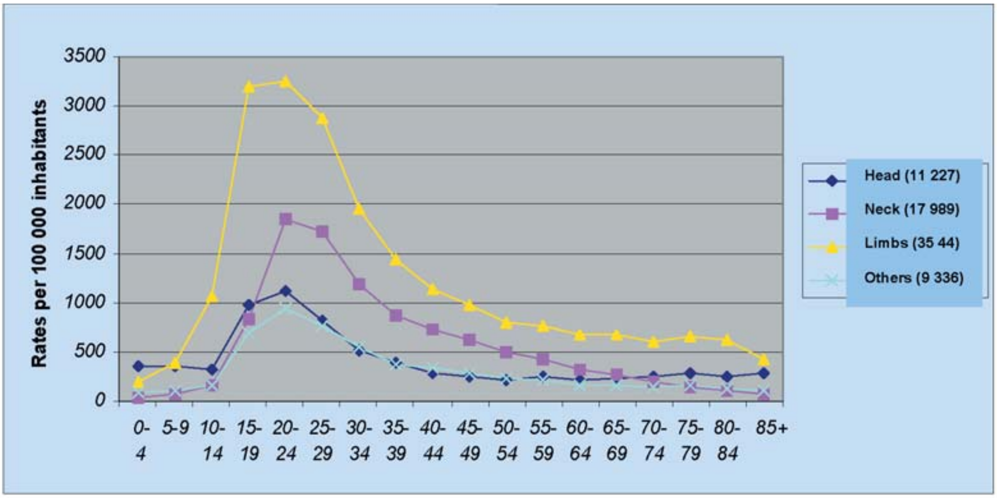


FIG. 5. INCIDENCE OF HEAD INJURY BY AGE GROUP

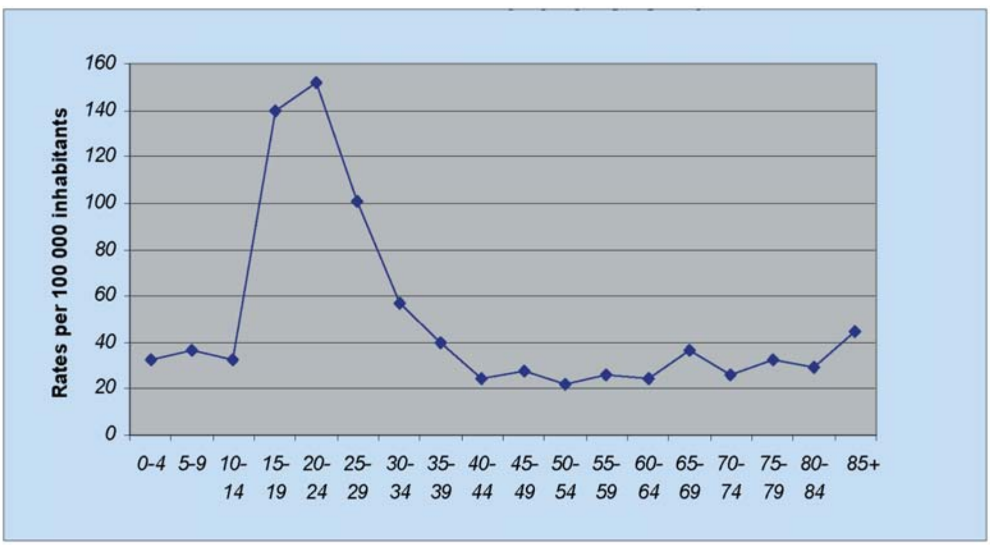


FIG. 6. INCIDENCE OF FRACTURE BY AGE GROUP

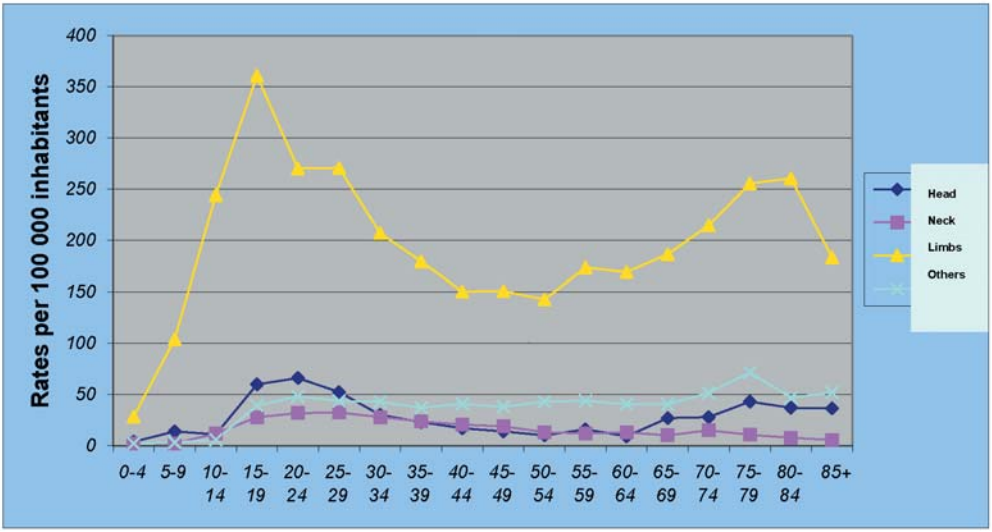


FIG. 7. INCIDENCE OF OSTEO-ARTICULAR INJURY BY AGE GROUP

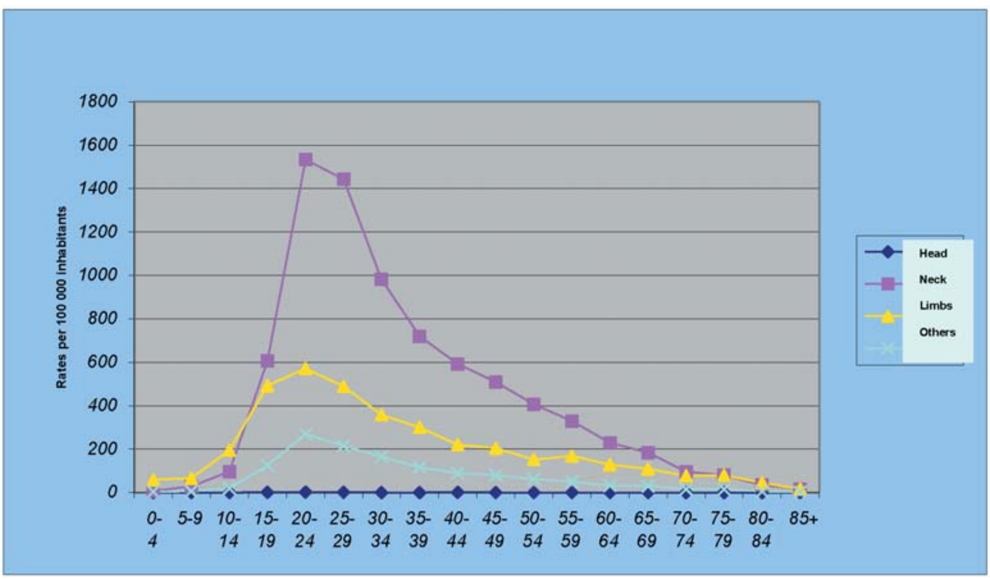


FIG. 8. INCIDENCE OF CUTS BY AGE GROUP

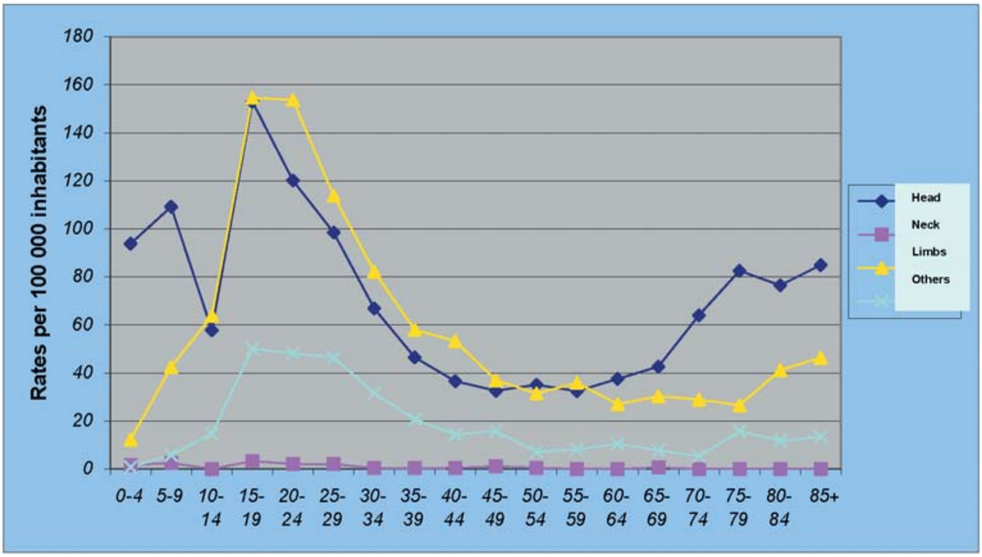


FIG. 9. INCIDENCE OF CONTUSIONS BY AGE GROUP

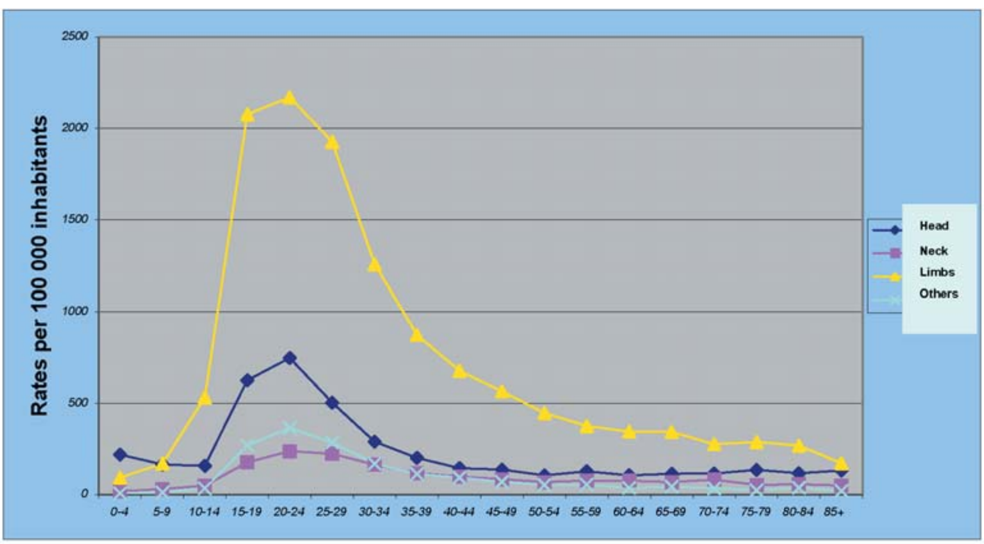
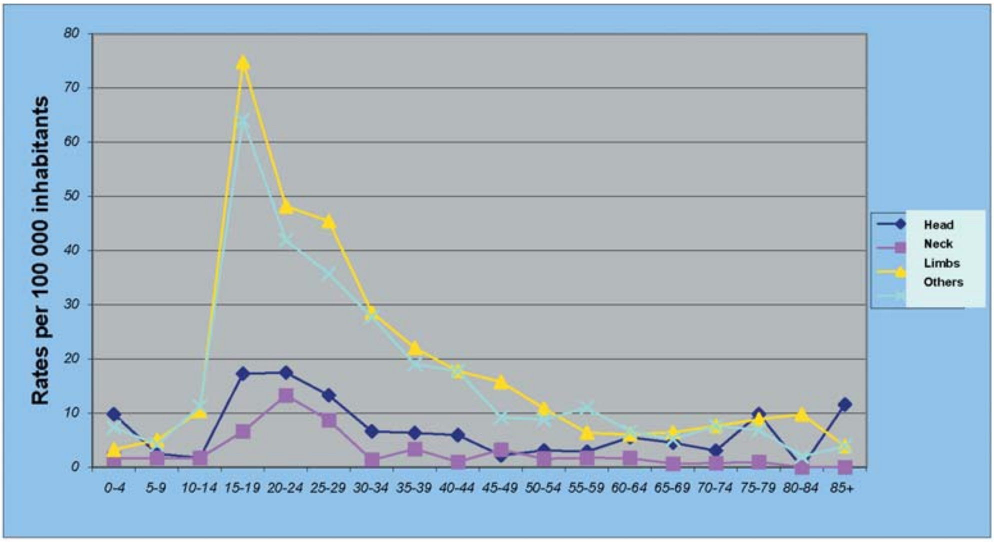


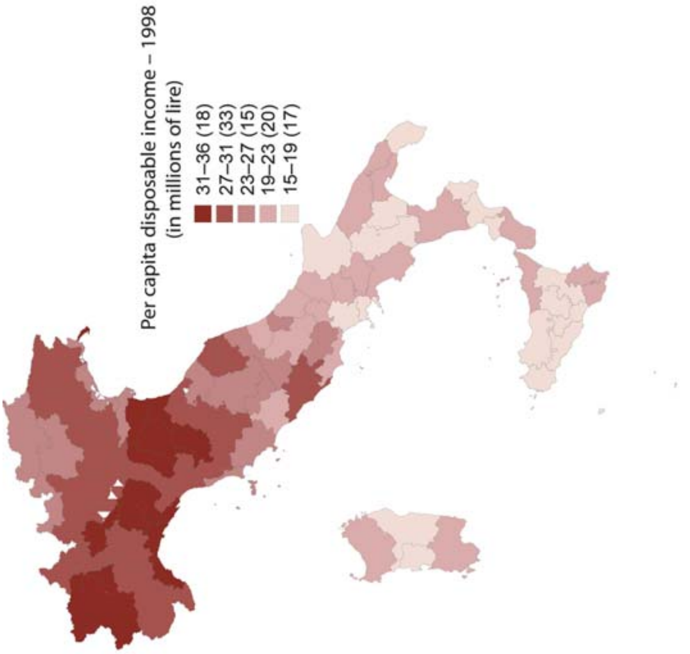
TABLE 4. TYPE OF INJURY BY BODY AREA INVOLVED

Injury type		Body area				Total
		head	neck	limbs	other	
Coma	Total count	1			26	27
	% by injury type	3.7			96.3	100.0
	% by body area	0.0			0.3	0.0
Contusion	Total count	6 371	2 852	21 273	2 879	33 375
	% by injury type	19.1	8.5	63.7	8.6	100.0
	% by body area	56.5	15.9	60.2	30.8	45.1
Foreign body in natural orifice	Total count	800				800
	% by injury type	100.0				100.0
	% by body area	7.1				1.1
Cut	Total count	1 775	23	1 603	521	3 922
	% by injury type	45.3	0.6	40.9	13.3	100.0
	% by body area	15.7	0.1	4.5	5.6	5.3
Fracture	Total count	717	488	5 235	1 048	7 488
	% by injury type	9.6	6.5	69.9	14.0	100.0
	% by body area	6.4	2.7	14.8	11.2	10.1
Internal injury	Total count	22	7		427	456
	% by injury type	4.8	1.5		93.6	100.0
	% by body area	0.2	0.0		4.6	0.6
Osteo-articular injury	Total count	8	14 291	6 310	2 330	22 939
	% by injury type	0.0	62.3	27.5	10.2	100.0
	% by body area	0.1	79.4	17.9	25.0	31.0
Blood-vessel injury	Total count	72		5	15	92
	% by injury type	78.3		5.4	16.3	100.0
	% by body area	0.6		0.0	0.2	0.1
Poorly defined	Total count	1273	196	270	1 584	3 323
	% by injury type	38.3	5.9	8.1	47.7	100.0
	% by body area	11.3	1.1	0.8	17.0	4.5
Crushing/amputation	Total count			60	6	66
	% by injury type			90.9	9.1	100.0
	% by body area			0,2	0.1	0.1
Abrasion	Total count	183	81	532	473	1 269
	% by injury type	14.4	6.4	41.9	37.3	100.0
	% by body area	1.6	0.5	1.5	5.1	1.7
Burn	Total count	44	1	55	21	121
	% by injury type	36.4	0.8	45.5	17.4	100.0
	% by body area	0.4	0.0	0.2	0.2	0.2
Nerve damage	Total count	11	50	1	6	68
	% by injury type	16.2	73.5	1.5	8.8	100.0
	% by body area	0.1	0..3	0,0	0.1	0,1
Total	Total count	11 277	17 989	35 344	9 336	73 946
	% by injury type	15.3	24.3	47.8	12.6	100.0
	% by body area	100.0	100.0	100.0	100.0	100.0

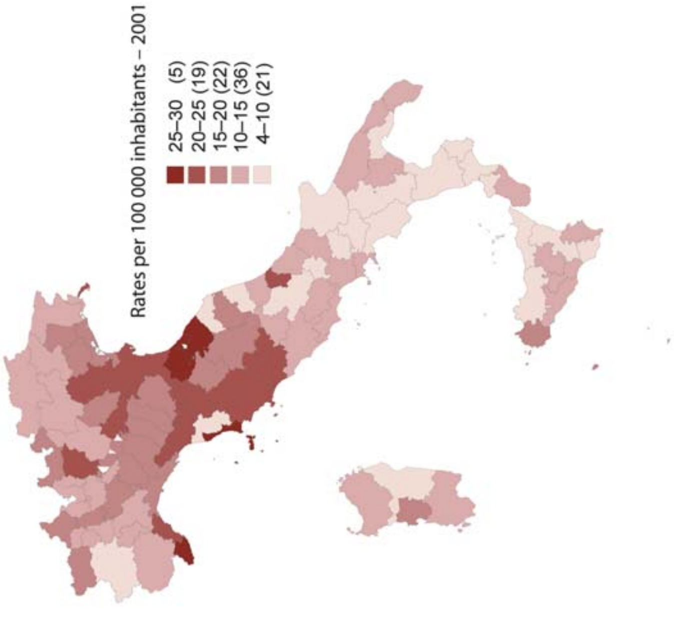
FIG. 10. INCIDENCE OF MINOR INJURIES BY AGE GROUP



Annex 13. Distribution of number plates and of disposable income by province in Italy



Source: WHO elaboration of data from Istituto Tagliacarne - 2002.



Source: WHO elaboration of data from ANCMA 2002.

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