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Research project

Impacts of mobility on greenhouse gases emissions in the Brussels-Capital Region:

A case study with dynamic ecological economic modelling for regional planning

REPORT

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CONTENTS

Summary of the Project

Objectives:

The aim of the study is to analyse the greenhouse gases (GHG) and other air-pollutant emissions from urban mobility for the case study of the Brussels-Capital region. The assessment is based comparing business-as-usual scenarios, and the ones of the Regional Mobility Plan (Plan "IRIS"), with a reference to the framework of the Kyoto Protocol on Climate Change.

Strategy:

For the purposes of such analysis a system of integrated models has been proposed, including:

1) Urban development analysis, including population and employment dynamics, based on indicators of economic development by main sectors of activities and respective demand for labor resources;

2) Mobility model, providing scenarios of road traffic in the region, according to different origin-destination matrices, generated on the basis of the different urban development scenarios. For transportation network analysis the recent version of TRIPS package is used, which provides powerful tools for assignment and graphical presentation;

3) A model linking mobility and air pollution. The focus is mainly on global pollution (CO_2, CH_4, and also like N_2O, O_3), tropospheric ozone-forming pollutants (NO_x, VOC, CO), and local pollutants (PM, SO_2). Also consumption of non-renewable fuels with respective and emission is analysed. COPERT methodology (versions II and III) was used for calculation of the emission functions per kilometre driven, taking into consideration climate conditions, private cars fleet composition with specific speed profiles, as well as new European/Belgian regulations on vehicles (COPERT III). The emissions are calculated spatially on the transportation network as a function of the assigned traffic intensity, average speed on each link, and length of the trip (which allows considering proportion between cold start and hot emissions).

Results:

The software was developed to link the mobility model, road traffic assignment with TRIPS package, and emissions calculations. Different scenarios for the year of 2005, based on mainly the assumptions of the Plan "IRIS" are considered, assessing the environmental impact of actual policy in regional and urban planning and possible measures in order to reduce the air pollution.

The concept and preliminary results of the study have been discussed at two international conferences (Safonov P., Favrel V., and Hecq W., 2000a, 2000b)[*)], and a paper is being prepared for publication.

[*)] Abstracts of the presentations are enclosed.

Introduction

The earth's climate has been evolving continuously over many millennia. The last two centuries, however, have witnessed the development of the greenhouse problem, which threatens to change climate in an unprecedented manner. Greenhouse gases (GHG) in the earth's atmosphere allow incoming solar radiation to pass through relatively unimpeded, but partially absorb and re-emit outgoing infrared terrestrial radiation. This natural process raises the earth's average temperature from –18 ºC to +15 ºC, and is hence, vital for life on earth.

Since the Industrial Revolution, however, anthropogenic activities have been increasing the atmospheric concentrations of greenhouse gases beyond their natural levels, resulting in the enhanced greenhouse effect. This causes an increase in global temperatures, which is known as global warming. This warming can be amplified through positive feedbacks, such as increases in water vapour, or reduced through negative feedbacks, such as increases in stratospheric aerosols. The sum of all these potential changes is referred to as climate change.

The emissions of the greenhouse gases from transportation in Belgium, and especially in the Brussels area, are observed as a major and increasing factor of environmental pressure. This is linked to a growth of economic activity, especially in the tertiary sectors, which require more and more offices, and thus commuting. In the frame of Kyoto Protocol on Climate Change (1997) a target of 7.5% reduction of GHG emissions by the year 2010 (from the level of 1990) is an accepted Belgian obligation, for which feasibility and implementation measures should be assessed.

Road traffic in the Brussels-Capital Region has continuously been increasing during the last decade. The reasons of this trend lie mainly in the urban exodus, the growth of employment in the Brussels area and its peripheral region, and the constantly increasing population motorization rate. Recent studies (IRIS, 1993) predict the complete saturation of the road network before the year 2005 in the Belgian capital.

The assessment of the impacts of this road traffic on the environment in general, and on air quality, in particular, helps not only to evaluate the actual situation but also to assess the possible effects of measures towards a more sustainable transport system.

Today it is generally accepted that transport policies alone will not achieve a sustainable level of fuel consumption and emissions. A consensus is also emerging that it is necessary to co-ordinate land use changes with transport measures in order to achieve an environmentally and economically sustainable transport system.

Transport and land-use have to be considered as an integrated system. But, as Lobe P., Duchâteau H. (1998) advise, in many urban areas this system resembles a spiral of urban decline, caused by potentially vicious interactions of this system at an urban level.

Solutions to road transport derived pollution such as catalytic converters and road pricing and even improved public transport do not properly tackle the problem: **the demand for transport** itself needs to be managed rather than try to satisfy a thirst that can never be quenched: urban planning can assist this management process.

This present study is undertaken in the Centre for Economic and Social Studies on the Environment (CEESE) of Université Libre de Bruxelles (ULB). It is aimed at modelling and analysis of the air-pollution from urban mobility in the of Brussels-Capital region.

Recognising the importance of different environmental impacts of mobility (such as problems of noise, vibration and smell, which would stay outside the framework of this study), this project is focused on the assessment of air pollutants (CO_2, CH_4, NO_x, VOC, CO, PM, SO_2) and the consumption of non-renewable fuel.

As part of the «Sustainable mobility in the Brussels-Capital Region» project, financed by SSTC, CEESE-ULB is currently developing a methodology for the assessment of the physical effects and external costs caused by air pollution generated by road traffic in an urban area. While considering the impacts of air pollution (e.g. in terms of building deterioration, health effects, climate change, etc.), the general approach associates to traffic a sequence based on the five following steps: human activities, emissions, immissions, physical impacts and external costs. This is the classical approach namely used in major studies such as ExternE (European Commission, 1995) for the assessment of externalities in the energy sector and which has recently been updated for its application to the transport sector.

Within this project an *integrated model* is being synthesised for analysis of influence of urban development and transport policies on the mobility of people in a metropolitan area, and respective air-pollution resulting from this mobility.

After introducing the problem of greenhouse gases and climate change and surveying recent state of related issues of urban development and mobility, this report presents the main concept of such integrated models system. The methodology is described for the emission calculations for the transportation model. Road traffic emissions are assessed using both the COPERT methodology (Ahlvik et al, 1997) and traffic data for the Brussels-Capital Region.

In the framework of recent project we have designed a model that allows the assessment of the traffic contribution to air pollutant emissions in the Brussels-Capital region. Several scenarios have been calculated for the road traffic situation in 2005, reflecting the basic assumptions of the Regional Mobility Plan (Plan IRIS, 1993-1997).

1. Road Transport and Climate Change: The Problem Definition

"The world's scientists tell us that man-made climate change is one of the greatest environmental threats we face today. They are warning us that global temperatures will increase, sea levels will rise, and droughts, floods and storms will become more frequent and severe. There is mounting evidence that they are right. 1998 is set to be the warmest year on record, surpassing the previous record which was set only last year [1997]."[1]

1.1. Greenhouse effect and climate change

Let us shortly explain the mechanism of what is called "greenhouse effect", using the Figure 1.1 below, and how it causes climate change (Ledley et al., 1999).

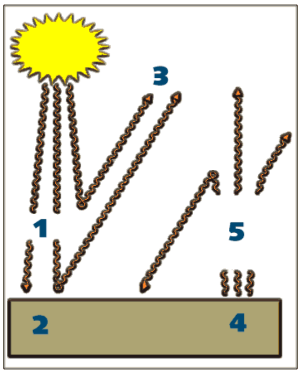


Figure 1.1.
Greenhouse effect

The heat on earth comes from the sun (1). That heat is partly absorbed by the earth itself (2), but a substantial part is reradiated also, into space (3). The heat absorbed is reradiated by the earth as infra-red radiation (4). Infrared (IR) active gases ("greenhouse gases"), principally water vapour (H_2O), carbon dioxide (CO_2), and ozone (O_3), naturally present in the Earth's atmosphere, absorb thermal IR radiation emitted by the Earth's surface and atmosphere and in turn reradiate it in the form of heat (5). These gases thus ensure that a considerable part of the heat from the sun remains within the atmosphere after all. To some extent it works in the same way as a greenhouse: the heat of the sun can come in, while the gases ensure that the stored heat remains inside. The atmosphere is warmed by this mechanism and, in turn, emits IR radiation, with a significant portion of this energy acting to warm the surface and the lower atmosphere. As a consequence the average surface air temperature of the Earth is about 30° C higher than it would be without atmospheric absorption and reradiation of IR energy.

This phenomenon is popularly known as the “greenhouse effect,” and the IR active gases responsible for the effect are likewise referred to as “greenhouse gases.” The rapid increase in concentrations of greenhouse gases since the industrial period began has given rise to concern over potential resultant climate changes.

The principal six greenhouse gas concentrations that are covered by the Kyoto Protocol on Climate Change (1997) are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and also hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafloride (SF6).

[1] John Prescott, in foreword to UK Climate Change Programme consultation, 1998.

A good indicator for the situation in Belgium are the emissions of carbon dioxide (CO_2): indeed, in 1994 that gas accounted for approx. 82% of greenhouse gas emissions. Between 1990 and 1994 CO_2 emissions increased by approx. 6.3%. If no measures were taken, the emission of CO_2 would continue to rise, as is indicated in the table below.

Table 1.1. Evolution Carbon dioxide-emissions in Belgium, without control measures

1990	100%
2000	112%
2005*	119 %
2010	123 %
2015*	128 %
2020*	133 %

* These figures only relate to the CO_2 emission through energy consumption (including transport)

Much of the recent debate on transport has been devoid of environmental consideration. But given our responsibilities towards environmental protection, such an approach is partial and unacceptable. Transport has been perhaps the most high profile environmental issue in Belgium over the past decade. And if one thing has come out of these years, it is that if we do not tackle traffic growth then we will be unable to tackle transport's impact on climate change and on urban air pollution.

1.2. Motor vehicle exhaust gases and their emissions into the atmosphere.

The main greenhouse gases associated with the transport sector are: direct GHS - carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), and indirect GHGs (ozone precursors) oxides of nitrogen (NO_x), non-methane volatile organic compounds (NMVOCs), and carbon monoxide (CO).

However, it is important to study the complex phenomena or air-pollution from transport, since often measures leading to decrease of some of them lead to increase of the others.

Thus, in this section we give description to some most important air-pollutants from the road traffic, focusing on the types of damage they cause and possible measures of their emissions reduction.

Carbon dioxide (CO_2) and carbon monoxide (CO)

Combustion of all fossil fuels produces carbon dioxide, the main greenhouse gas. Incomplete combustion of carbon compounds results in the production of CO. Once in contact with adequate supply of oxygen CO becomes oxidised to CO_2. This gas is mostly sourced from spark ignition engines (petrol) and this is more likely to be produced when vehicles are decelerating or idling. Motor vehicle traffic is the main source of this gas in the environment.

Methane (CH_4)

Human activities have led to large increases in CH_4 emissions and there is now about 2½ times as much of this greenhouse gas in the atmosphere as there was 200 years ago. Global emissions of CH_4 from wetlands, ruminant animals, rice paddies, and other sources, like transport continue to increase atmospheric concentrations. Once in the atmosphere, CH_4 is slowly oxidised, over a period of about 9 years on average, to produce CO_2. In the last 20 years CH_4 growth rates have decreased, but they have also become highly variable from year to year and the reasons for this are not yet clear.

Nitrous oxide (N_2O)

Road transport is a significant but minor source of nitrous oxide (about 10% of all Belgian emissions) along with other oxides of nitrogen. Under normal atmospheric conditions it is oxidised rapidly to nitric oxide. Nitrous oxide is non-toxic to humans; however it is different than other oxides of nitrogen in that it is a greenhouse gas. Emissions of nitrous oxide increase with the use of catalytic converters on cars, and levels are increasing at the rate of 0.3% per year.

Nitrogen oxides (NO_x)

The term nitrogen oxides is used to refer to both *nitric oxide* (NO) and *nitrogen dioxide* (NO_2), although there are other oxides of nitrogen. Nitrogen oxides are produced with the combustion of nitrogen and oxygen, forming nitric oxide. Generally, the higher the combustion temperature, the greater the amount of nitrous oxides produced. Nitric oxide, the initial product, combines with oxygen to form nitrogen dioxide. As the formation of nitrogen dioxide takes place fairly rapidly, nitrogen dioxide is regarded as being more important in terms of its human health effects.

Nitrogen dioxide is a reddish-brown gas and which gives the city smog its colour. Globally, nitrogen oxides resulting from human activity are only 8% of naturally produced nitrogen oxides which are formed by bacterial and volcanic action and lightning. However urban levels of NO_x can elevate this concentration by several hundred times under certain atmospheric conditions. Nitrogen dioxide, when washed out of the atmosphere by rain combines with water to form nitric acid, one of the sources of acid rain and tropospheric ozone O_3.

Modelling studies have shown that the hourly mean concentration of nitrogen dioxide would frequently exceed the EC standard of 200 µg/m3 near any road carrying more than 10 000 fast moving vehicles an hour if these are mostly not fitted with catalytic converters.

Under conditions of bright sunlight and clear air, nitrogen oxides react with hydrocarbons to produce photochemical smog. Photochemical smogs contain a wide variety of organic compounds that are harmful to a varying degree. In still air conditions, the photochemical smog concentrates over its source. However as the amount of nitrogen oxides and hydrocarbons increase so the secondary pollutants are produced a long distance away from their original source.

(Tropospheric or Ground level) Ozone (O_3)

Ozone is produced when sunlight reacts with nitrogen dioxide and radicals derived from hydrocarbons (VOCs). The worst pollution episodes are caused by vehicle pollution. When ozone levels are over 100 ppb (200 µg/m3) human reactions are irritated eyes, nose and throat, coughing, chest pain and nausea.

Volatile Organic Compounds (VOCs)

Volatile Organic Compounds are hydrocarbons and their derivatives produced from the burning of fuel and from the evaporation of fuel and halogenated compounds derive from the manufacture and maintenance of vehicles and aircraft. Benzene is probably the most important VOC from transport, 78% from petrol engine exhaust and 9% from diesel exhaust. No safe level of Benzene is known, although it is generally recommended that the standard should be 5 parts per billion (ppb) per running average, to be reduced to 1 ppb at a later date. Catalytic converters when working properly can remove up to 90% of VOCs.

Particulates

Particulates (particulate matters - PM) are a complex mixture of solid and liquid matter, from road dusts and industry and burning of coal or incineration. Secondary particulates are those formed by reactions with other pollutants, and can be formed by the transformation of gaseous emissions such as oxides of sulphur and nitrogen and VOCs.

A major source of particulates are diesel exhausts. During last decades emissions of black smoke increased significantly related to the growth in road traffic. There is increasing concern over the health effects of Particulates. Road tyres and brakes also contribute Particulates and produce asbestos, chrome, nickel, copper, zinc, cadmium, cobalt and aluminium. No control over these emissions can be gained by catalytic converters.

Sulphur dioxide (SO2)

The contribution by transport to total sulphur dioxide emission is relatively small, as the major sources are combustion of coal. However, emissions can be significant in certain localities such as in harbour areas or in traffic congested streets with a high proportion of diesel fuelled vehicles. Sulphur dioxide is particularly harmful when in concentration with smoke particles or nitrogen dioxide. Acid deposition can affect vegetation as well as damage buildings.

1.3. Catalytic Converters - A solution to car pollution?

Catalytic converts increase fuel consumption and therefore carbon dioxide emissions by 3 to 10%. In cities, catalytic converters are of little effect as most journeys are below 5 km, and the catalytic converters are not effective until the exhausts have warmed up. It is predicted that in catalytic converters will reduce vehicular emissions up to 2006. From that time emissions will increase in line with the growth in vehicle use. However, there is considerable variation in the emission performance of cars fitted with catalytic converters. A German government survey found, for instance, that half of the cars monitored failed to meet relevant emissions limits, particularly for carbon monoxide. Cars with high mileage and those driven at high speeds perform very badly. UK experience has shown that catalysts are being damaged or are failing at a higher rate than predicted. One manufacturer has suggested that a car will on average need a new catalyst every three years.

1.4. Belgian Climate Policy

There is now widespread acceptance that we must make serious commitment towards tackling climate change through reducing greenhouse gas emissions. The Kyoto Protocol, agreed in December 1997, indicated a global governmental acceptance that climate change was happening, and that it was likely to have serious implications unless measures were taken to combat it. Despite the Belgian Government's clear commitment to greenhouse gas reduction, however, other European states (e.g. Germany, Austria and Denmark) are leading the way on emission reduction, with more challenging reduction targets, using shorter timescales for action.

The evolution of the greenhouse gas (GHG) emission reduction target is one of the key characteristics of climate policy in Belgium. In 1991, the federal Government took a decision to adopt as the national target a 5 per cent reduction in energy-related carbon dioxide (CO2) emissions between 1990 and 2000. In 1994, this target was reiterated by the federal and regional governments and the National Programme for Reducing CO2 Emissions (NPRE) was prepared by a number of working groups, including a Transport group, an Energy group, a CO2 Tax Policy group and a CO2 Science Policy group with the aim of achieving this target. Finally, under the EC burden-sharing agreement, the target agreed for Belgium calls for a 7.5 per cent reduction in the total of all six gases covered by the Kyoto Protocol for the first commitment period of 2008-2012.

The National Communication 1 (NC1) clearly indicated that the implementation of the National Programme for Reducing CO_2 Emissions (NPRE) alone will not be sufficient to reach the national target, as almost half of the necessary reduction in emissions was expected to come from the combined carbon/energy tax. However, this tax has never materialised in Belgium. Furthermore, other measures envisaged in the NPRE have not been implemented, while those implemented have failed to deliver the effect expected (renewables, energy efficiency and natural gas). As a result, emissions have continued to grow. In 1996, they reached 128,550 Gg CO2 according to the recent inventory, against 115,800 Gg in 1990 (121,100 Gg adjusted emissions) given in the NC1, which indicates that it would be unrealistic to expect the 5 per cent reduction target to be reached before 2000. The attention of policy-makers was geared to the post-2000 period and that a new Policy Plan for Reduction of GHG Emissions, due by the end of 1999, was expected to lay down in a single framework all the policies necessary to achieve the target under the Kyoto Protocol. Another plan prepared in 1999 was the Sustainable Development Policy Plan, in which climate change was one of the key issues.

In the NC2 the total methane (CH_4) emissions in Belgium were projected to decrease by about 22 per cent in 2005 compared to the 1990 level, reflecting the decrease in emissions from agriculture and waste. In contrast, N_2O emissions were expected to increase by 16 per cent over the same period. This increase was attributed to the growth in emissions from transport, the share of which in total N_2O emissions was expected to increase from 3 per cent in 1990 to 16 per cent in 2005.

The total GHG emissions of Belgium for 1990 were estimated at 136,895 Gg of CO_2 equivalent in the recent inventory submission, which is equal to the figure reported in the NC2 and is approximately 2 per cent higher than the estimates in the NC1. The difference stems from revisions of CO_2 estimates only. CO_2 is by far the most important gas in Belgium, with emissions estimated at 114,033 Gg in 1990, or 83 per cent of the total emissions. This was followed by CH_4, which made up 9.7 per cent, and N_2O, which accounted for the rest. Between 1990 and 1996, total emissions grew by 7.2 per cent to reach 146,820 Gg, a growth primarily attributed to the growth of CO_2 emissions by 9.2 per cent and N_2O emissions by 14 per cent, while CH_4 emissions declined by 7.3 per cent.

1.5. Greenhouse gases and Transport in Belgium

Across the Belgium the transport sector is responsible for about 20% of CO2 emissions (Fig 1.2), of which about 85% comes from road traffic. The transport sector has seen one of the fastest growth in emissions in recent years. But the transport sector also offers some of the most clear possibilities for controlling emissions - but only so long as traffic levels can be brought to sustainable levels. Recent shifts in transport policy have acknowledged that greater fuel efficiency, cleaner vehicles and change in public attitudes towards transport are required in an attempt to control emissions from transport.

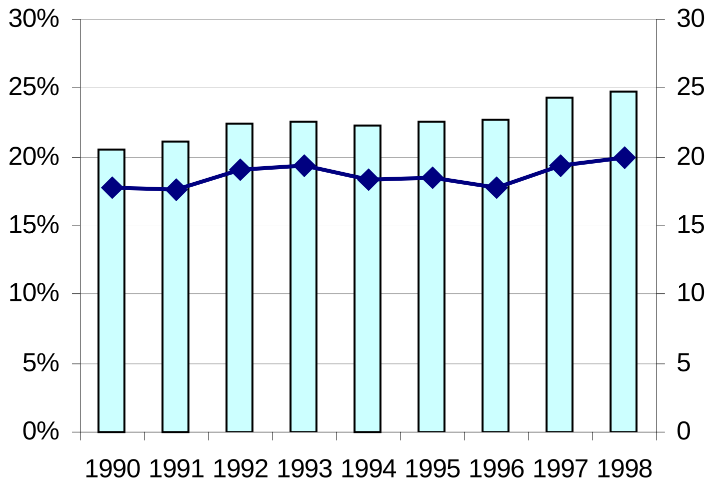


Figure 1.2. CO2 Emissions from Transport in Belgium
(line - % to total emissions; histogram - absolute values in thousand Gg)
Source: UNFCCC, FCCC/IDR.2/BEL, 27 July 2000

As in many other EC countries transport was an important and growing source of emissions in Belgium, and virtually half of the measures envisaged in the National Programme for Reducing CO_2 Emissions (NPRE), including economic instruments, regulations and physical planning, targeted emissions originating from this sector. These measures were implemented by different levels of government, with the primary objective of solving some urgent problems of the local environment, such as traffic congestion, air pollution, and noise. They were applied only partly and the effect achieved was lower than expected, but apart from that, as of 1993, Belgium has seen a slight decrease in transport energy intensity. Even so, Belgium has one of the highest road densities in the EC and road transport continued to grow in absolute terms, with almost unit elasticity between the GDP and the number of cars. At the same time, rail transport declined.

Measures targeting passenger transport in the NPRE mainly aimed at promoting public transport and at reducing the traffic in city centres and commuting by car. By imposing strict monitoring of speed limits and by changing price and tariff policy, the NPRE planned to influence both the overall efficiency of transportation and the consumption patterns.

In the context of the price and taxation policy, in order to discourage the use of cars for professional purposes, limits were set on the deduction of transport costs from professional income and higher taxation was imposed on private use of company cars. The use of public transport was also encouraged by giving exemptions to employer-paid public transport costs. Moreover, as of 1998 the use of bicycles for commuting was stimulated. To counterbalance the drastic reduction in VAT on car sales from 33 per cent to 19.5 per cent, a new tax on new cars was introduced in 1992, and in 1993 it was extended to second-hand cars. The tax level depends on the car age and engine power, and was believed to be an effective tool to push consumer choice towards smaller and less polluting cars. Finally, in 1995 the Eurosticker (Eurovignette) was introduced, as a levy on the use of the road network by heavy goods vehicles (12 tonnes upwards).

Taxes on gasoline and diesel oil in Belgium have risen steadily during the 1990s, virtually offsetting the impact on consumers of declining world oil prices. In 1996, additional excise taxes were imposed on gasoline, which brought Belgium into the group of EC countries having the highest level of motor fuel taxation. Simultaneously, an excise compensation tax was levied on diesel cars, which countervailed the lack of a similar increase in the excise taxes on diesel fuel. As a result, in 1999, taxes made up 78 per cent of gasoline prices and 66 per cent of diesel fuel prices.

The motor lobby argues that because emissions from cars are falling that manufacturers are dealing with toxic emissions problems, and there is no need to implement traffic reduction in order to reduce emissions. They argue that the focus should instead be on gross polluters and on buses and lorries, which they claim to be more polluting.

But while emissions may be falling nationally, they are not falling fast enough to meet the Government's air quality targets.

As for the relative emission shares of cars, lorries and buses, official emissions inventories show that, for most pollutants in most urban areas, the car is the main source, although in areas where there is still heavy industry this can also be a major factor. A bus with an average load is much less polluting per passenger than an average load car. Buses can be made less polluting through use of low sulphur diesel, which greatly reduces particulate emissions, and conversion to gas-powered vehicles, which reduce pollution still further. In the longer-term, electric-powered buses and taxis may be required.

The essential fact of air pollution issues in urban areas is that in order to achieve real improvements in air quality that reductions in traffic volumes are necessary. Improvements to petrol and diesel engines cannot in themselves provide all the solutions to air pollution problems. An integrated approach is required to change the demand for mobility and modal choice.

At regional level, the planning aspects of transport policy were given great importance, which is also the case of the Brussels-Capital region.

2. Modelling Urban Development, Mobility and Air Pollution: State of the Art

This section presents the approaches and models, which provide the methodological basis of the construction of the models system for the Integrated socio-economic-environmental analysis of urban mobility, further described in section 3.

2.1. Integrated land-use and mobility modeling

There exist several approaches and models, which allow for integrated analysis of three-fold process: land-use, mobility, and pollution.

Recent study is implemented with the Professional Transport Planning Package (TRIPS, 1999), which includes possibilities of advanced demand modelling, based on information about residential areas and main economic activities in the region (using LOGIT models). TRIPS has both road and public transport modules and is open for any exentions, which makes it a powerful and rather flexible tool for integrated mobility analysis. TRIPS was used for the development of the Brussels Regional Mobility Plan (Plan IRIS, 1993-1997), and thus it is instrumental to carry out extended analysis using already developed data bases and transport modelling techniques.

Another model in land use-transport modelling forr the Brussels metropolitan area (Lobe P., Duchâteau H., 1998) was developed within the framework of the ESTEEM research project to analyse the consequences of implementing different scenarios in urban planning (in particular the influence of a RER introduction). The model is based on the TRANUS software (T. de la Barra and B. Perez, 1998). The TRANUS provides an intermodal transport model of passengers' transport system, and an integrated land-use/transport model able to simulate the impacts of land-use policies on transport and the impacts of transport policies on land-use. Its structure comprises two main components: a land use sub-model and a transport sub-model, which interact dynamically.

Many other approaches and models/packages are known (AMERSFORT, BOYCE ET AL, CALUTAS, CATLAS/NYSYM/METROSIM, DORTMUND, KIM, ITLUP, LILT, MASTER, MEPLAN, OSAKA, POLIS, PSCOG, TRANSLOG, TOPAZ, HAMILTON and other), and we refer to a very substantial review for details (Southworth, Frank, 1995).

2.2. Modeling of passenger transport

The number of person/vehicle-trip originating in each zone (trip generation) is treated like a function of demographic and socio-economic variables: population, car ownership, income, etc. Estimation techniques are handled differently following trip purposes: business trips, journeys to work and social/leisure trips. This classification is not exhaustive and may be refined as needed. Methodology uses econometric tools to assess the number of trips per trip purpose. Input data are, amongst others, based on household surveys. In this frame, estimation is made on the basis of travel behaviour of groups, households or persons. The person-category approach, i.e. at the level of the individual, has several advantages as it has a better compatibility with other steps (modal choice, assignment) which are based more on individual behaviour of the travellers rather than on households.

2.3. Traffic distribution models

This second step estimates where the "produced" trip will go to and where the "attracted" trip comes from. For this purpose, trips leaving or entering a zone are spread into an origin/destination (O/D) matrix of transport flows (and traffic loads) for the model zone. Matrices O/D represent the number of trips between each centroid node. Each element of the matrix O/D represents the number of vehicles/passengers (or number of tonnes moved), per modelling time period, with origin i and destination j, for all ij coded on the model zone (where i, j represent nodes).

2.4. Urban Planning

Modelling the changes in destination of the trips is linked, to a big extent, with location of businesses and residential areas. This implies numerous urban planning issues, such as:

- *Early consideration of environmental implications in the urban planning process.* Environmental Impact Assessment can be a powerful tool for anticipating the likely consequences of projects of offices relocation. Among policy options the following could be of particular importance:
  - integrating land use and transport planning**.** It is widely accepted that urban form, that is the pattern and density of development within and between settlements, influences travel patterns. The spatial planning system is a key mechanism influencing urban form. Other enabling factors such as price mechanisms, and availability of public transport would obviously need to be in place.
  - increasing urban densities around points of high accessibility. The common feature shared by different solutions is the idea of increasing urban densities around points of high accessibility, and especially points of high accessibility to public transport: “right business in the right place”. The Hague can be a successful example where 2 office locations at *Centraal* and *Hollands Spoor* station were identified to improve mobility of 3000 employees. Project of sitting work places at accessibility points in Copenhagen is another case study in this approach;
  - encouraging mixed land use schemes. Over-rigid land use zoning has been criticised as one of the causes of new single use development areas within cities. Mixed use is an urban form, which offers the opportunity for reduction in movement overall, particularly if linked to traffic restraint systems. At the city scale it implies seeking a balance of houses, jobs and facilities in each broad sector of the city through whatever broad zoning or land allocation system is used in that particular country.
  - flexibility of design. The flexible design of buildings means that buildings are not restricted to a single function. The same basic structures can serve school, office and factory uses. Changes in technology and the imperatives of ecology will offer the opportunity to make buildings ever more flexible and responsive.
- *Parking policy* can restrict traffic access, for example by giving preference to residents over commuters, limitation of parking provision for offices and other employment sites, *and* priority parking for environmentally friendly vehicles as part of an overall traffic policy. Following the referendum on car traffic in 1992 (*Plan IRIS,* 1993). For instance, Amsterdam has chosen parking policy as the main instrument to reduce car journeys. The overall aim of reducing car traffic by 35% will be achieved by reducing commuter

parking, giving priority to residents, constructing underground car parks and eliminating on-street parking from many areas or charging at a much higher rate.

2.5. Linking mobility models with air pollutant emissions and non-renewable fuel consumption.

Econometric models estimate transport for a country or a region as a whole, on a yearly, quarterly or monthly basis. The only linking contribution that could be expected from econometric models is the possibility of considering forecast scenarios. Their ability to predict future changes of fuel consumption, vehicle mileage or vehicle fleet composition could be useful for the assessment of future air pollution reduction measures. The major disadvantage of existing models is the aggregate character of the data, which make it impossible to get measurements such as mean speed and to distinguish between the different categories of vehicles-travelling needed for emission model use. However, the latter parameters can be assessed from surveys and calculations (exogenous character). New econometric models can be built to distinguish vehicles travelling (or other measures of travel demand) under different modes and to split, for example, urban from non urban vehicles travelling, provided statistics are available. Further investigation would be requested to assess this possibility. The existing econometric models, which have been constructed for other goals than emission assessment, partly satisfy the requirements of emission models, provided no simplifying assumption is made. However, econometric models are able to predict fuel consumption, but without differentiating different fuel types. Once again, if data on total annual fuel consumption for each type of fuel could be found, models could be built on a time series basis, e.g. using as explanatory variables the relative price for each type of fuel. Econometric models can be linked with emission models, such as COPERT II (Ahlvik et al, 1997), which calculates the total annual fuel consumption as a calibration parameter for estimating uncertain parameters (e.g. average annual mileage driven on each road class and for each vehicle category).

Network flow models. For road networks, there is an asymmetry between individual and public transport. Individual transport is measured in the number of vehicles. On the contrary, public transport is usually measured in number of passengers. For linking purposes, only measurement in the number of vehicles can be used. In the case of models dealing with the number of passengers, the model must be able to convert this value into the number of vehicles. From our analysis, in general, mobility models cannot directly provide emission models with usable data. Adjustments and approximations are necessary. According to emission types, three cases are distinguished.

- *Hot emissions and fuel consumption.* Considering data requirements the main incomplete data for hot emission calculation are the following:

- number of vehicles per category,
- kilometres driven per vehicle category on different road section types,
- average speed per road type taken into account or allocation of typical traffic situations to the road network with respect to different road section types.

However mobility models provide:

- number of vehicles per mode on each O/D trip and the paths/route chosen for each trip,
- average speed of a representative vehicle in function of road link characteristics (bends, slopes) and in function of the flow on the link.

- From mobility models, it is thus possible to infer for each O/D trip: the number of vehicles travelling per mode and the average speed from the origin to the destination (knowing the average speed on each link type travelled). Trip distance, number of kilometres travelled per time period, number of starts can also be deduced from the input and output of the mobility models. Matching problems between hot emission or fuel consumption calculation and mobility models remain in the calculation of kilometres driven per vehicle category and of kilometres driven per road type.
- It is necessary to assess the degree of certitude needed for input data (average speed, trip distances, etc.) to get acceptable results. Also, the transportation network area studied with mobility models is still only partly covering the actual transport network.

• *Cold start emissions*. Considering cold start emissions and fuel consumption, apart from meteorological parameters and fuel properties, the data required that could possibly be supplied by mobility models concern:

- average trip length per vehicle trip;
- total annual kilometres of the vehicle for each category;
- distance travelled by the vehicle;
- number of starts per day and per vehicle;
- parking duration before the trip.

The travelled distance and the number of starts per day and per vehicle can be supplied by mobility models with the same remarks as for hot emissions while considering the vehicle category split.

• *Evaporative emission*: similar uncertainty with cold start emissions remains with regard to the parking duration between trips. The same remark as for cold start emission has to be made concerning parking location.

3. Development of the Integrated Mobility Model for the Brussels-Capital Region

3.1. Conceptual structure of the model and steps of implementation.

Based on the existing experience in modelling of different socio-economic issues of mobility, and its environmental impacts (see *Favrel and Hecq, 1998*), an Integrated System of models (Figure 3.1) is proposed to include several main components:

1) Urban development model, including forecasts of population and employment dynamics, in accordance to different economic and urban planning scenarios. Such forecasts should be based on indicators of economic development by main sectors of activities and respective demand for labor resources; trends in population dynamics and labor resources structure with respective spatial distribution in the region. Office stock dynamics and other urban factors are to be considered.
2) Mobility model, providing scenarios of road traffic in the region, according to different origin-destination matrices, generated on the basis of the different urban development scenarios. For transportation network analysis the recent version of TRIPS package (*TRIPS, 1999*) is used, which provides powerful tools for assignment and graphical presentation.
3) A model linking mobility and air pollution. The focus is mainly on global pollution (CO_2, CH_4), tropospheric ozone-forming pollutants (NO_x, VOC, CO), and local pollutants (PM, SO_2). Also consumption of non-renewable fuels is analysed. COPERT methodology (versions II and III) was used for calculation of the emission functions per kilometre driven, taking into consideration climate conditions, private cars fleet composition with specific speed profiles, as well as new European/Belgian regulations on vehicles, integrated in COPERT III. The emissions are calculated spatially on the transportation network as a function of the assigned traffic intensity, average speed on each link, and length of the trip.
4) In the final stage, as part of the «Sustainable mobility in the Brussels-Capital region» SSTC project CEESE-ULB is currently developing a methodology for the assessment of the physical effects and external costs caused by air pollution generated by road traffic in an urban area (see also *Favrel and Hecq, 1998, 2000* for further details).

The data necessary for identification of the proposed complex of models is basically available from different sources, but nevertheless, an in-depth study of the recent literature with a following update of the information base is required along with some additional surveying. Main sources of the data include National Statistical Institute, Administration of the Brussels-Capital region (e.g. Regional Mobility Plan "IRIS" reports), Brussels Office Survey (Jones Lang Wootton reports), Review of Office Property (by Brussels Capital region), and others.

The implementation of the integrated model is planned within several phases, and at the initial stage the mobility demand related information (socio-economic, office and dwellings dynamics forecasts) is mainly obtained from the results of previous studies (*Plan IRIS, 1989-1995*). This enables to analyse environmental impacts of mobility scenarios within existing urban policy options, along with some additional considerations like dynamics of vehicles park composition.

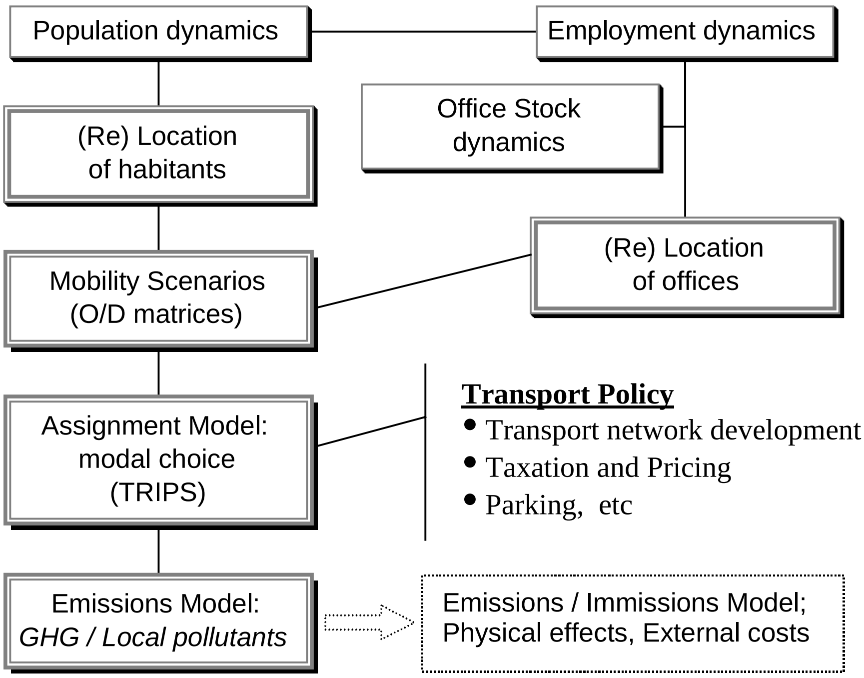


Figure 3.1. General structure of the system of models

As one of the first steps in development of the proposed integrated approach we have designed a model that allows the assessment of the contribution of mobility by private cars to emission of the air pollutants in the Brussels area. The software was developed to link the mobility model, road traffic assignment and emissions calculations.

The following sections describe the recent situation and main considerations for envisaged model design and scenario analysis (sections 3.2, 3.3), and already implemented developments within the proposed modelling approach (sections 3.4 - 3.6).

3.2. Urban development

Main urban development tendencies are discussed in this section, which are important for analysis of mobility in the region.

The ***population*** of the Brussels metropolitan area has been slowly but regularly decreasing and the evolution in the Brussels-Capital region has been much faster, with an important consequence: as the main part of the Region's financial resources comes from the taxes levied on its inhabitants income, these resources are quickly diminishing as a result of the decrease of the population and average household income. ***Households*** migrating to the close periphery are mainly middle and upper class families, with a high car ownership level. Evolution in these suburbs cannot be controlled by the Government of the Brussels region because it is located outside of its borders, nor by the Federal Government, because the land use planning jurisdiction has been fully decentralised.

For the last twenty years of the 20^{th} century the ***economy*** of the region has undergone a significant mutation. Initially an industrial centre, it progressively became an important administrative centre and has recently been designated as the European Union Capital. Many industrial activities and wholesale have also been, and are migrating towards the periphery, seeking both for better accessibility by road and cheaper land (Table 3.1).

Table 3.1. Share of Brussels in the National Economy

	1980	*1990*	*1997*
Share of Brussels in the Gross National Product	15.5%	13.4%	12.6%
Part of Brussels in the global amount of taxable revenue of individuals of the country	11.6%	9.8%	9.2%

Source: *Duchâteau (1998),* and own calculations, based on the data of *Banque Nationale, 1999*

Even despite absolute growth of the gross product of Brussels region (and respectively the traffic), its relative share in the national economy decreased, leading to additional mobility to the periphery.

It is difficult to identify the actual cause of such an evolution, but this process apparently was accelerated by the dramatic improvement of the accessibility to the city by road, which resulted from the building of a high standard motorway network during the 1970-s.

As important factors influencing the mobility, the structural changes in the economic activities, especially related to technical change, should be considered. A model of economic dynamics and labour resources in the region, to be implemented as a part of the discussed integrated approach, needs to operate with the information per sector of economic activity. The sectors of services and communication need to be considered in greater detail since these are of particular interest for this study as most Belgian offices in this sector are located in Brussels area.

There are several tendencies, which determine the ***office stock*** dynamics and its spatial distribution. Many companies leave city centres for locations, which are considered more accessible by their suppliers, clients and staff. At the same time, the comparative advantages of ***housing*** in cities are decreasing, which reinforces the tendency of better-off inhabitants to look for a place to live in the surrounding area of the city, whereas the poorest inhabitants tend to accept housing left in the centres. Because of the narrowness of the territory of the Brussels-Capital region, this phenomenon extends beyond the limits of the region, entailing a loss of its substance and a relative impoverishment (see also Table 2.1 above).

These global trends, as well as the results of the more precise analyses, show that the Brussels-Capital region is seriously endangered by an evolution similar to that of some North American cities whose centres have been completely deserted by a lot of companies as well as by the middle-class population or the most well-off.

3.3. Mobility

The number of vehicles on the road in Belgium is constantly increasing. In January 1991, the average number of private cars at the disposal of households per 100 inhabitants in the country amounted to 38. The trend of the evolution observed this last decade suggests that the growth of the motorization rate continues in the coming years, although possibly at a lower speed because of a progressive saturation effect in the demand for vehicles. The general assumption in Belgium is that this saturation point will be reached at 50 vehicles per 100 inhabitants (*Duchâteau, 1998*). It is relatively modest compared to the levels already reached in North America (nearly 60 vehicles per 100 inhabitants).

The chart below (Figure 3.2) depicts the aggregated dynamics of the mobility in the region per main categories of roads for private cars.

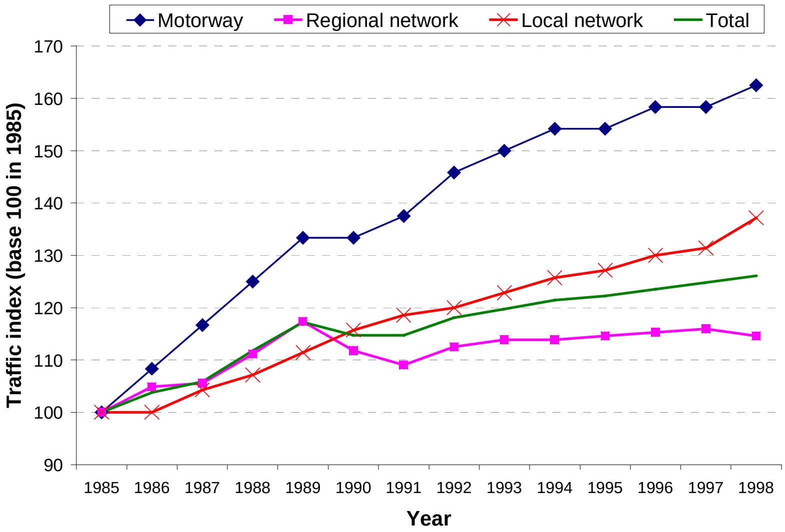


Figure 3.2. Traffic intensity (in vehicle-kilometres) in the Brussels-Capital region, 1985-1998

Calculation based on *Recenment de la Circulation, Ministere des Communications et del'infrastructure, 1998*.

Of course, households also took advantage of the new form of mobility that a private car offers in order to change the way they choose where they live. For many of them, the comparison of the advantages and the price of a location in the old urban centre with those of a location in the suburbs have led to the choice of the latter. The growth of population in the suburbs of Brussels is a consequence of this choice.

The increase of mobility by car has also had indirect consequences on the suppliers of goods and services by extending their market areas and by modifying the conditions of competition that they impose on each other and by forcing them to reconsider their location criteria. For some of them, especially traders, the location choice is a question of survival because accessibility to their sale points is a critical element of competition. The increase of jobs in the periphery of the city indicates that decisions against the city were of large scale in the 80's. This contributed to the decline of the city.

This mobility has led to an increase in commuting from home to work in Brussels from 276,000 units in 1980 to 322,000 units in 1990. If the demographic and economic trends are confirmed, this commuting could rise to 357,000 in 2000 and to more than 400,000 in 2005.

The combined effect of the deconcentration of housing and of employment and the increase in motorization of the population has led to a very important increase in automobile traffic both in and around the city. If this trend will continue, and all the other variables remain unchanged, especially as far as the offer of transport is concerned, the congestion of the road network will develop. The result of this is a doubling of automobile travel time during the morning peak period.

Such an evolution is, of course, not realistic because it would lead to an unbearable deterioration of the functioning conditions of the city:

- Urban economic players cannot accept such a situation because the worsening of their accessibility endangers their very survival; if nothing is done to change the situation, their reaction will be to leave the city for a more or less far peripheral location.
- The inhabitants will support neither the impediments to mobility due to congestion nor the increase in pollution that will result from it; their reaction will be similar to that of the economic players: those who can afford it will leave the city in huge numbers.

As far as the regional public authorities are concerned, they either cannot stay put without any reaction to the threat of seeing a rise in the exodus of inhabitants and employment.

3.4. Network model of private road transport

The Brussels-Capital region covers the total square of 161 km² with 951,580 inhabitants (1997) and takes the central geographical position in Belgium (Figure 3.3). Administratively, the region is divided into 19 municipalities (communes), but the total area under study (Figure 3.4) comprises a wider territory covering also nearby districts from/to which the traffic is most intensive, and it is divided into smaller 167 districts.

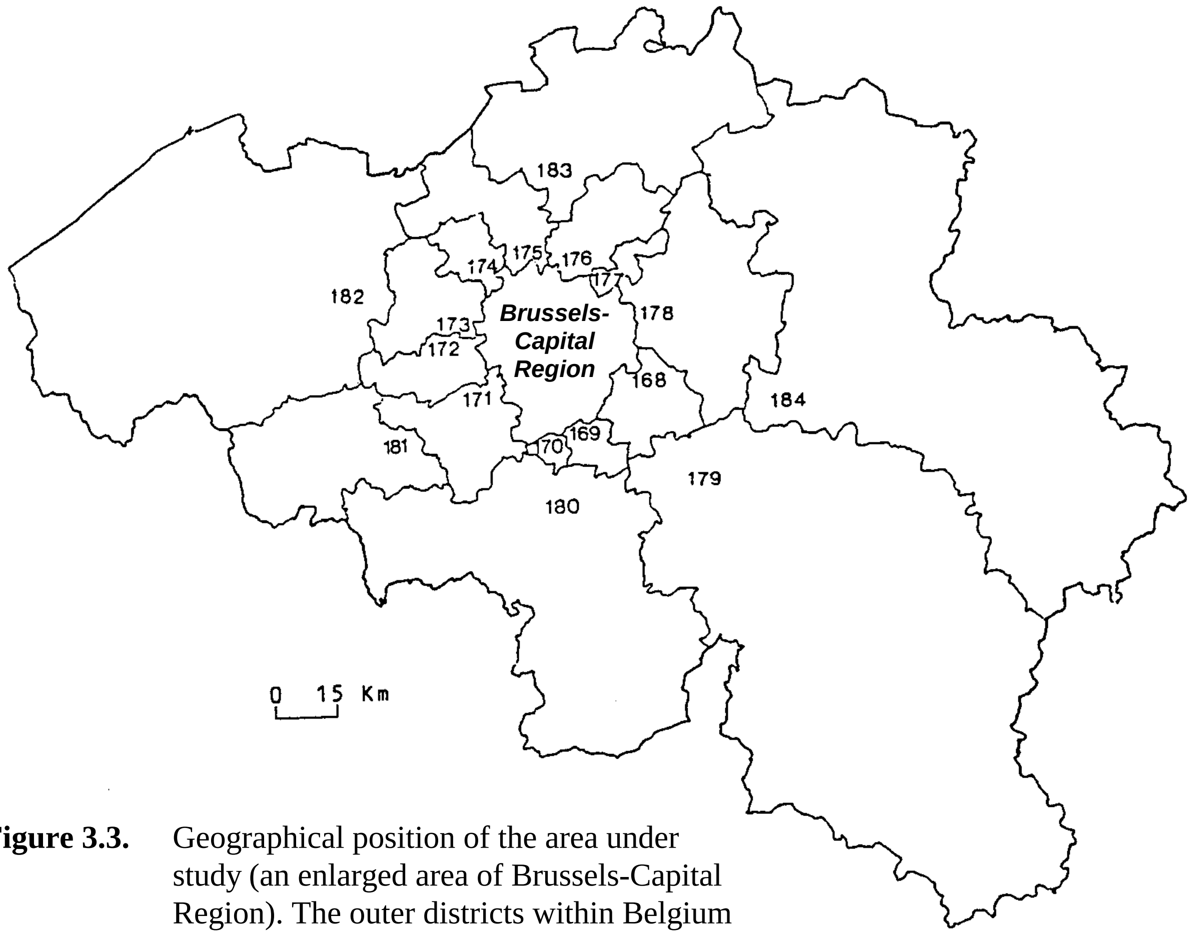
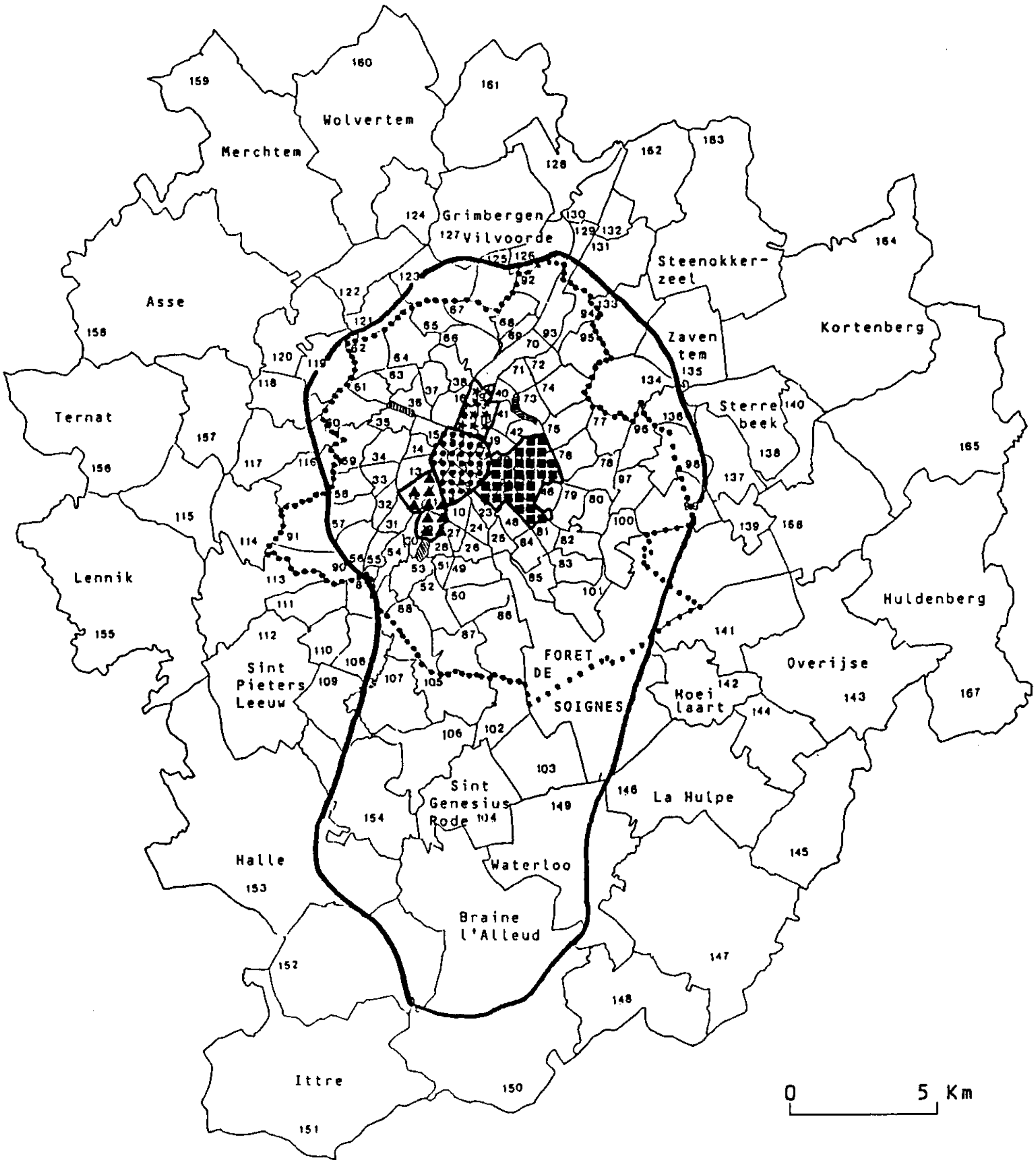


Figure 3.3. Geographical position of the area under study (an enlarged area of Brussels-Capital Region). The outer districts within Belgium (from/to which passengers' mobility is about 20% of the total of Brussels area traffic) are numbered from 168 till 184.



Legend:
- 150 Number of district (1987)
- ■ Brussels-Europe area: districts 20-22, 43-45, 47
- ▲ "Midi" (south central) area: districts 11, 12, 29
- ★ "Nord" (north central) area: districts 17, 18, 39
- ● "Pentagone" (central) area: districts 1-9
- ▬ Ring road
- ●●● Administrative border of the the Brussels-Capital Regtion

Figure 3.4. Area under study

The road network (see Figure 3.5) due to further disaggregation of the administrative districts in the central part of Brussels has in total 255 zones, from (to) which the trips are generated, with 2545 nodes and 8366 links.

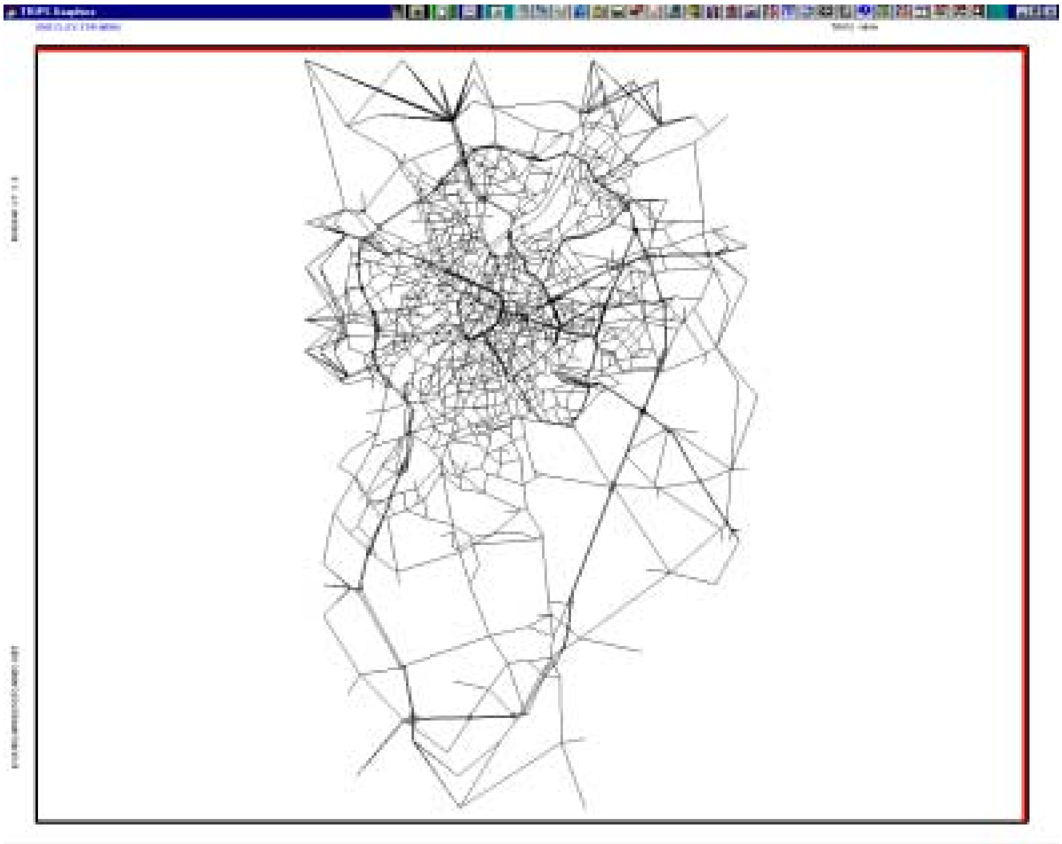


Figure 3.5. Brussels road network (printout from TRIPS/MVGRAF program)

3.5. Simulation tools for transport modeling

As a basic computer tool for spatial analysis of mobility the latest available version of the TRIPS package is used (*TRIPS, 1999*). It includes a set of inter-related modules:

- Highway Assessment
- Public Transport Assignment
- Demand Modelling
- Matrix Estimation
- TRIPS Graphics
- TRIPS Manager - Graphical Project Management Tool

The private car transportation has been modelled (*Plan IRIS, 1989-1995*) according to the origin-destination matrix (Fig. 3.6) for the morning peak hour (7.30-8.30) on an average day of 1991. The traffic intensity volumes (number of vehicles), average time and speed per each link are calculated as a result of traffic assignment with TRIPS Highway Assessment module. The model permits different algorithms of traffic assignment (minimal cost paths - so called "all or nothing" assignment or multiple paths for each origin and destination - *dial assignment* model or *Burrell* assignment). For this study the Burrell model was used, which provides sufficiently good results on the available data.

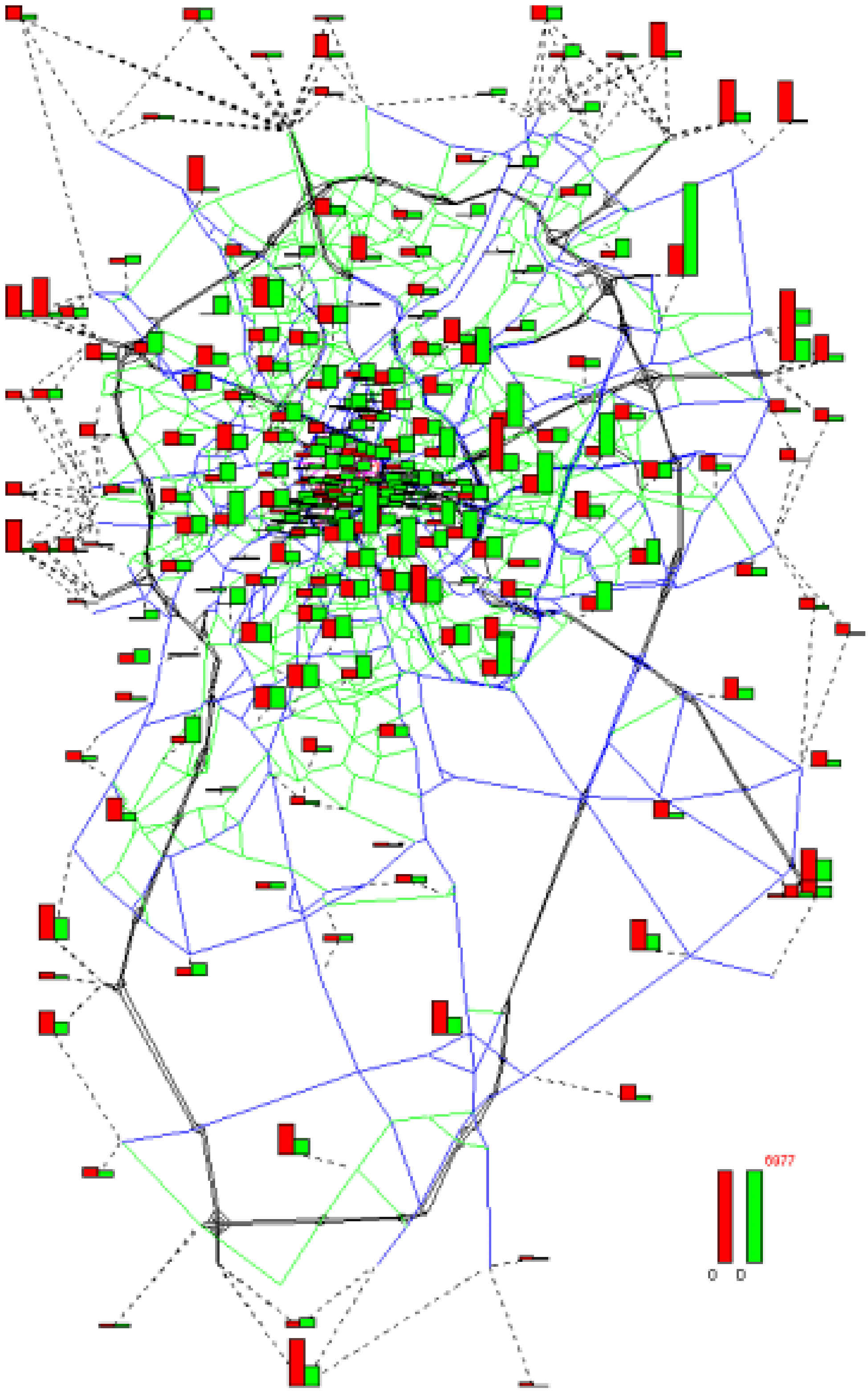


Figure 3.6. Origin-Destination Matrix (morning peak hour, 1991).
(Left histograms – origins, right – destinations)

Let us explain the main principles of how a mobility model works in TRIPS. The computer program developed in TRIPS, is displayed on the Figure 3.7.

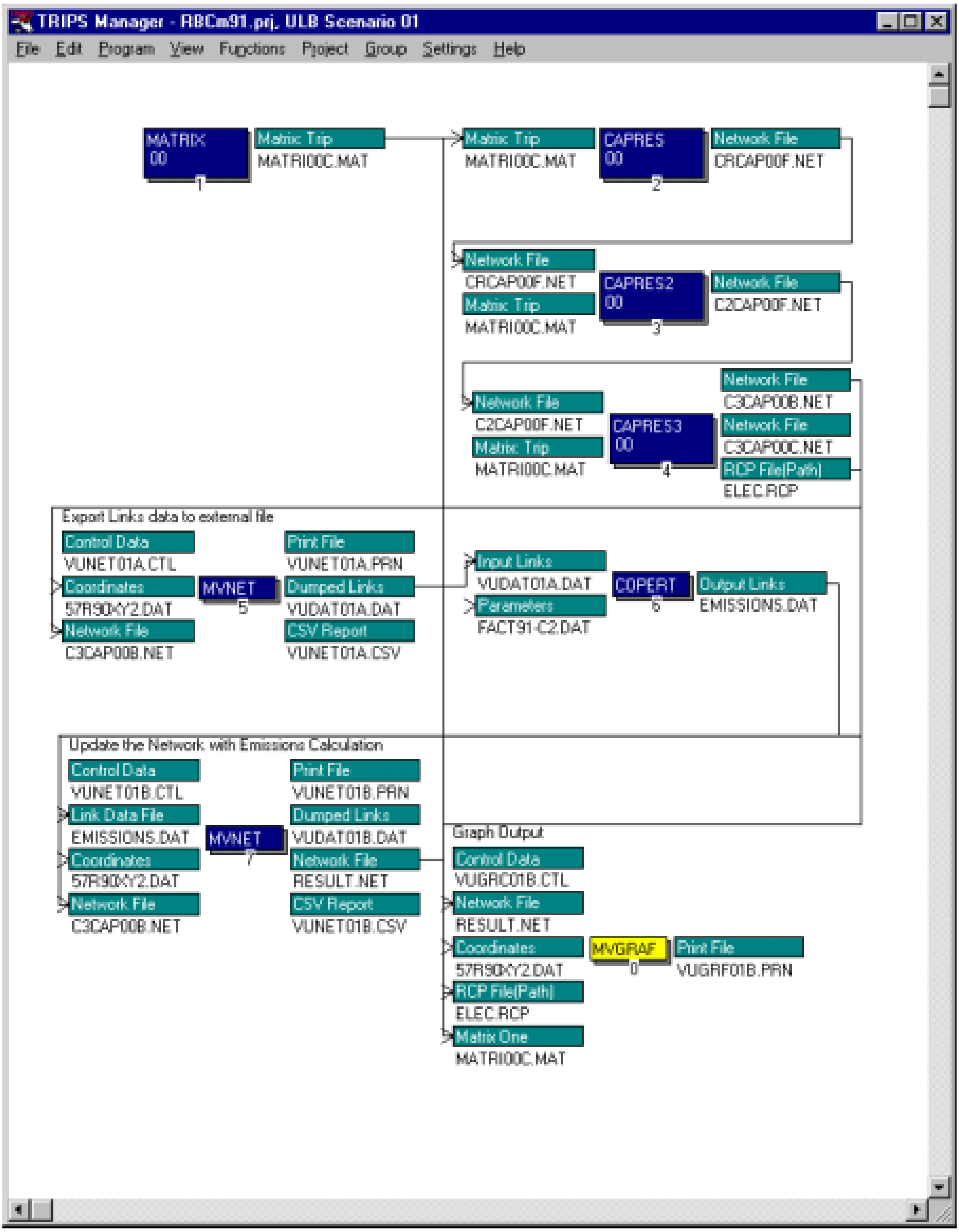


Figure 3.7. TRIPS program

It is a graphical representation of the model, linking different modules (such as matrix estimation, assignment and capacity restraints, network processing, etc) in a sequence of calculation steps.

Each step of calculation (execution order is indicated in the bottom of each module box) is linked with the other by external input and output files. In particular, the TRIPS program on Figure 3.7 represents the following steps:

- Origin-destination matrix generation (block **MATRIX**). The matrix (see Figure 3.6) calculated as the result of this step is written to the file MATRI00.MAT, which serves as input for further steps.
- Assignment and capacity restraints iterations (blocks **CAPRES**, **CAPRES2**, **CAPRES3**), consequently solve the assignment problem, using one of the available algorithms, and finally generating a network file (C3CAPOOB.NET), which is processed further on.
- Module **MVNET** imports the information about each link of the network (distance, average speed, capacity, number of cars assigned, etc) to an external text file VUDAT01A.DAT, which is possible to access from a user program.
- Module **COPERT** (a user-written program, described below in section 3.8.2) reads this links file VUDAT01A.DAT, and the file FACT91.DAT (containing emission factors, calculated, as described further on in sections 3.6), calculates the emissions and fuel consumption per each link, and writes the results in the EMISSIONS.DAT file.
- This file then in read by **MVNET**, which finally writes all the emissions and fuel consumption information in the RESULT.NET network file, ready for visualisation.
- Graphical module **MVGRAF** is now able to plot the results of assignment along with environmental and other information on the network (see the plots below on Fig. 3.10). The result of the assignment for the year of 1991 is presented using TRIPS Graphic Module (MVGRAF) on the Figure 3.10a for the central part of the Brussels area.

3.6. A model, linking the mobility and air-pollution in the region.

The last step in our modelling scheme is to analyse the impact of mobility on the indicators of environmental quality. Main air pollutants under consideration are:

- carbon dioxide (CO_2),
- methane (CH_4),
- nitrogen oxides (NO_x),
- volatile organic compounds (VOC),
- carbon monoxide (CO),
- particulate matter (PM)
- sulphur dioxide (SO_2),

Consumption of fuels is also assessed:

- Petrol
- Diesel-oil
- LPG (Liquid Petroleum Gas)

3.6.1. Basic approach to assessment of urban pollution

Some authors demonstrated that there are statistical correlation between concentrations of pollutants in the urban atmosphere, pollutant emission and some meteorological parameters like wind speed or temperature (Benarie, 1980). On the basis of this conclusion, Cross & Lacey (1981) developed a simple model to forecast sulphur dioxide and black smoke concentration levels in urban environments. This model produced good results in London even though it was less sophisticated than most of the forecast-oriented models usually mentioned in the literature. The idea behind this approach is that only some predominating variables, carefully selected on the basis of a statistical approach, determine pollutant concentrations in an urban atmosphere. This type of approach has also been used by other authors (Hallez *et al.*, 1989; Meurrens *et al.*, 1983; Hallez *et al*. 1982) to develop another type of model where the influence of different meteorological factors is taken into account in the form of multiplying functions.

On the basis of these findings, the CESSE/ULB has developed an econometric type model based on a non-linear multiple regression analysis. This model has been constructed after having studied the influence of various parameters related to pollutant concentrations in an urban atmosphere (Hecq *et al.*, 1992; Hecq and Taminiaux, 1993; Hecq *et al.*, 1994; Hecq *et al.*, 1995).

For the purposes of our analysis we will use the network model to calculate emissions of mail air pollutants[2]. The model considers the following air pollutants: carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOC), and particulate matter (PM), sulphur dioxide (SO_2),

The calculation of the emissions from road traffic is based on two types of data.

First, the volume of traffic has to be estimated, e.g. in the form of vehicle-kilometres driven by the different vehicle categories within the area considered (we use the results of the traffic assignment within TRIPS package and also regional statistics for model validation).

Second, suitable emission factors are required for the different vehicle categories circulating in the Brussels area. Average speed dependent emission factors, proposed in the COPERT II methodology (*Ahlvik et al., 1997*), have been used.

COPERT distinguishes for each vehicle category (e.g. passenger cars, light duty vehicles, heavy-duty vehicles) different sub-categories according to fuel type (petroleum, diesel, and liquid petroleum gases - LPG), cylinder capacity, catalyst type, and different legislation and regulations (see also *Sanger et al. 1997*), governing motor vehicle emissions, fuel specifications and consumption.

For the period considered, the Belgian vehicle fleet has been distributed according to these sub-categories on the basis of the available statistic. An aggregated structure used in the model is presented on the Table 3.3, from which the vehicle fleet of the Brussels-Capital region has been deduced.

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[2] In this report, we describe only the emission model. Further analysis of concentrations of air pollutants (emissions-immissions link) is described in *Favrel and Hecq, 1998.*

Table 3.3. Composition of the Belgian private vehicle fleet in the base year 1991
Calculation based on *FIGAZ (1996).*

Vehicles categories	Composition of the park 1991	(%)
Petrol Engines	**2,797,526**	**(71.57)**
< 1.4 l	***1,405,917***	***(35.97)***
PRE ECE [<1971]	31,229	(0.80)
ECE 15/00-01 [1972-1977]	36,847	(0.94)
ECE 15/02 [1978-1979]	53,988	(1.38)
ECE 15/03 [1980-1984]	344,979	(8.83)
ECE 15/04 [1985-1990]	788,857	(20.18)
91/441/EEC [1991-1996]	150,016	(3.84)
94/12/ECE [>1997]	0	(0.00)
1.4-2.0 l	***1,186,085***	***(30.34)***
PRE ECE [<1971]	26,346	(0.67)
ECE 15/00-01 [1972-1977]	31,086	(0.80)
ECE 15/02 [1978-1979]	45,547	(1.17)
ECE 15/03 [1980-1984]	291,037	(7.45)
ECE 15/04 [1985-1990]	665,510	(17.02)
91/441/EEC [1991-1996]	126,559	(3.24)
94/12/ECE [>1997]	0	(0.00)
>2.0 l	***205,524***	***(5.26)***
PRE ECE [<1971]	4,565	(0.12)
ECE 15/00-01 [1972-1977]	5,386	(0.14)
ECE 15/02 [1978-1979]	7,892	(0.20)
ECE 15/03 [1980-1984]	50,431	(1.29)
ECE 15/04 [1985-1989]	93,516	(2.39)
91/441/EEC [1990-1996]	43,733	(1.12)
94/12/ECE [>1997]	0	(0.00)
Diesel Engines	**1,089,055**	**(27.86)**
< 2 l	***795,512***	***(20.35)***
Conventional [<1990]	710,628	(18.18)
91/441/EEC [1991-1996]	84,884	(2.17)
94/12/ECE [>1997]	0	(0.00)
> 2 l	***293,543***	***(7.51)***
Conventional [<1989]	231,081	(5.91)
91/441/EEC [1990-1996]	62,462	(1.60)
94/12/ECE [>1997]	0	(0.00)
LPG Engines	**22,484**	**(0.58)**
Conventional [<1990]	20,085	(0.51)
91/441/EEC [1991-1996]	2,399	(0.06)
94/12/ECE [>1997]	0	(0.00)
Total fleet	**3,909,065**	**(100.00)**

Using the mileage (number of vehicles multiplied by link length) and the average speed of each vehicle category on each link of the network, the methodology developed provides the spatially distributed emissions, generated by road traffic in the Brussels-Capital region.

Hot and *cold start* emissions are distinguished. Cold start emissions represent the additional emissions resulting from vehicles while they are warming up or with a catalyst below its light-off temperature. The ratio of cold to hot emissions and the fraction of kilometres driven with cold engines are calculated using the yearly average temperature and an estimate of the average trip length following the COPERT methodology.

Since each link has its own length, average speed, traffic intensity and other characteristics, we made an assumption, that average emission factors per vehicle can be used based upon COPERT, as functions of the speed on the link. The temperature, the fleet composition (Table 3.3), and the share of cold start and hot emissions were taken as parameters. Given these parameters, the emission functions for an average vehicle can be calculated as functions of the speed only (see Figure 3.8).

Emission factor functions for methane (CH4) are calculated from the composition of VOC emissions in weight of exhaust: for conventional gasoline vehicles (until 1990) CH4 = 5% of VOC, for gasoline vehicles equipped with three-way catalyst (from 1991) - 12%; for diesel engine vehicles - 4 %; and for LPG vehicles - 3%.

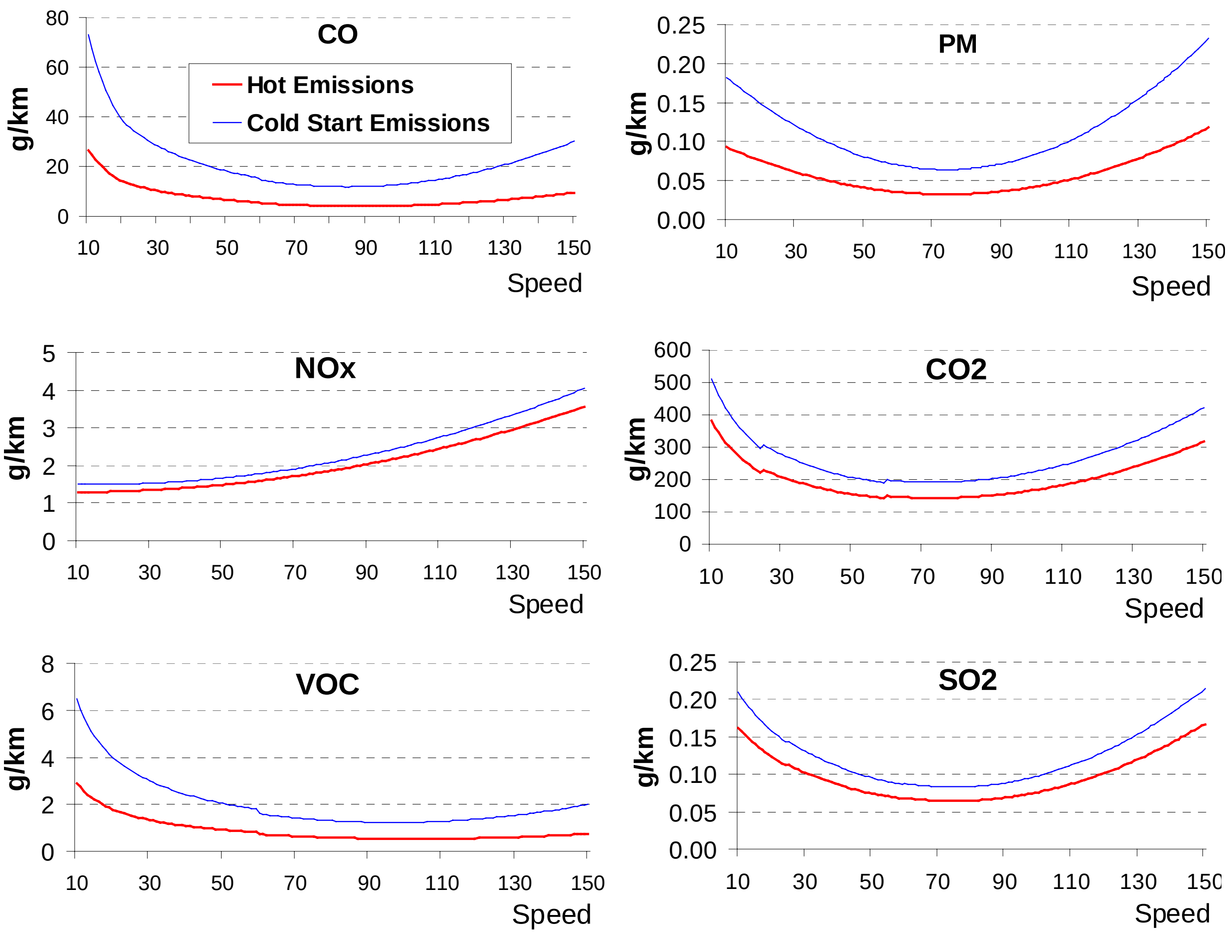

Figure 3.8. Emission functions for an average car in the Brussels-Capital region in 1991.

The overall calculation of emissions on the region's road network can be summarised as follows:

$$ET_i = ET_{i,hot} + ET_{i,cold} ,$$

$$ET_i = \sum_j \sum_k EF_{i,j,hot}(S_k) \cdot VM_{j,k,hot} + \sum_j \sum_k EF_{i,j,cold}(S_k) \cdot VM_{j,k,cold} ,$$

where:

i	pollutant index;
j	vehicle category index;
k	link index;
ET_i	emission of pollutant *i* due to road traffic;
$ET_{i,hot}$	emission of pollutant *i* due to road traffic with hot engines;
$ET_{i,cold}$	emission of pollutant *i* due to road traffic whit cold engines;
$EF_{i,j,hot}$	emission factor of pollutant *i* for vehicle category *j* driven with hot engines;
$EF_{i,j,cold}$	emission factor of pollutant *i* for vehicle category *j* driven with cold engines;
S_k	average speed on the link *k*;
$VM_{j,k,hot}$	vehicle mileage for vehicle category *j* driven on link *k* with hot engines;
$VM_{j,k,cold}$	vehicle mileage for vehicle category *j* driven on link *k* with cold engines.

3.6.2. Simulation tool for spatial emissions modelling

To calculate the distribution of the emission of the air pollution and the fuel consumption on the road network an external module **COPERT** was developed (in *Visual Basic*).

This program is linked to the TRIPS project (see Figure 3.7), so that it is possible to spatially visualise the emissions of each pollutant along with the assignment results on the road map of the Brussels-Capital region. The front-end of this module is presented on the Figure 3.9.

The results of the calculation of emissions and fuel consumption for the base reference year 1991 are presented using TRIPS Graphic Module (MVGRAF) on the Figure 3.10b-k for the central part of the Brussels area.

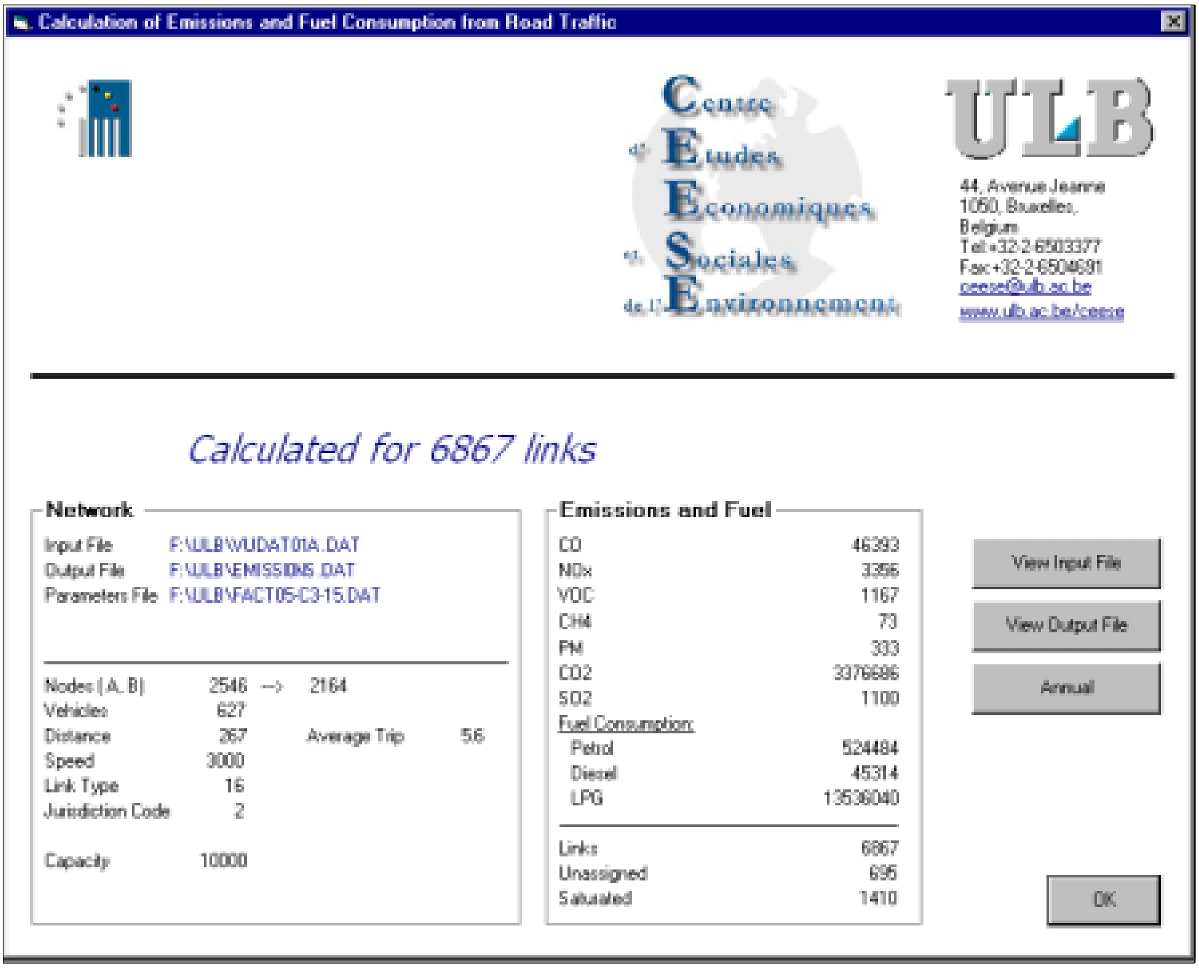

Figure 3.9. Module **COPERT** for spatial calculation of the emissions and fuel consumption per each link for the TRIPS road network.

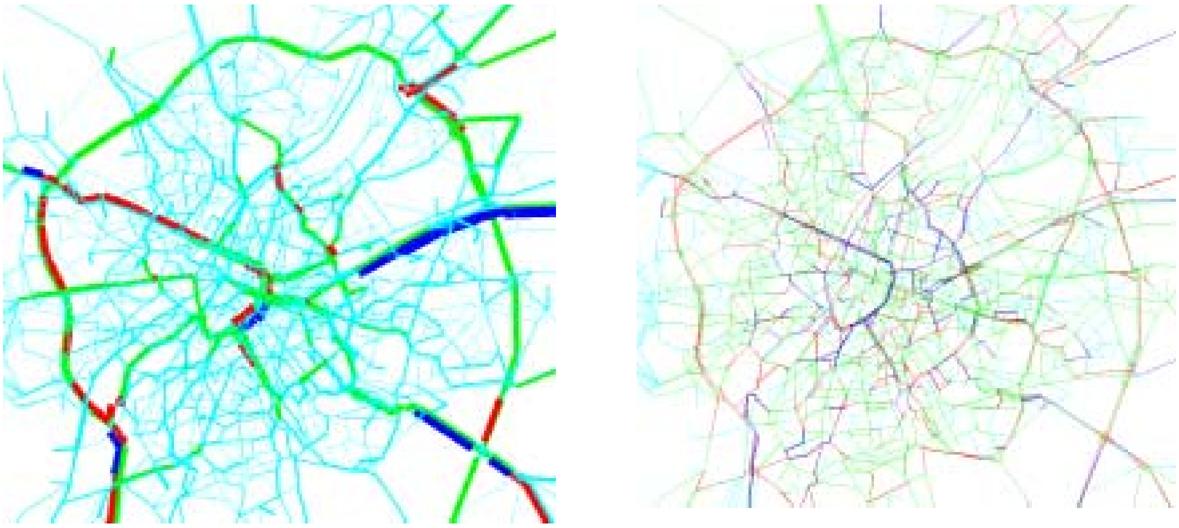

Figure 3.10.a. *Traffic Intensity* (number of cars per link and *Saturation Index* (1991)

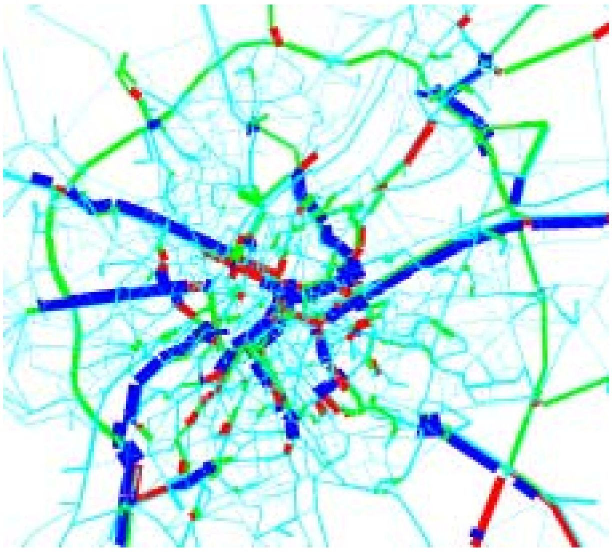

Figure 3.10b. CO2 Emissions (1991)

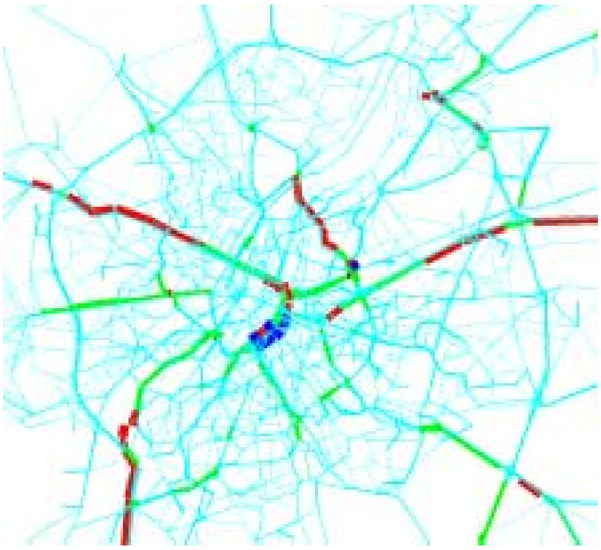

Figure 3.10c. CH4 Emissions (1991)

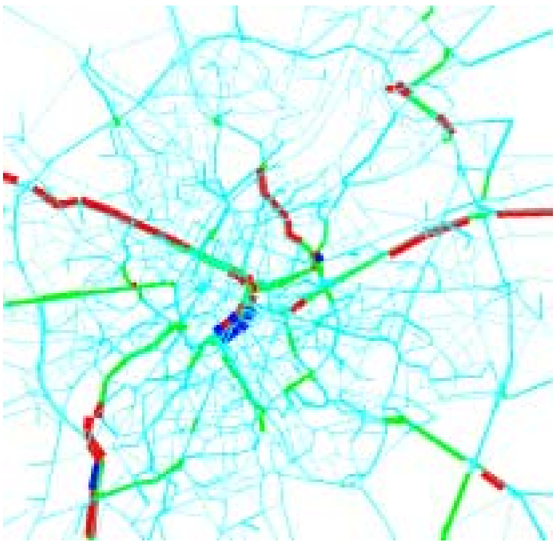

Figure 3.10d. VOC Emissions (1991)

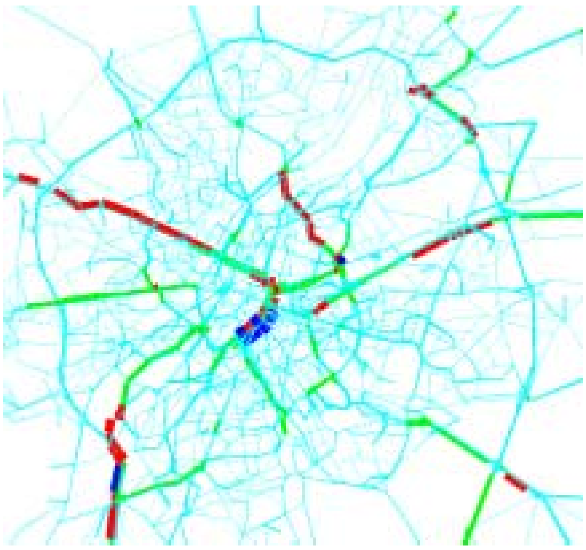

Figure 3.10e. PM Emissions (1991)

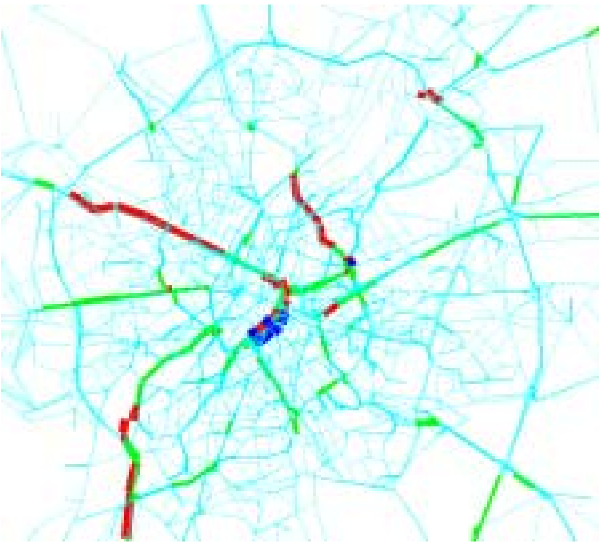

Figure 3.10f. CO Emissions (1991)

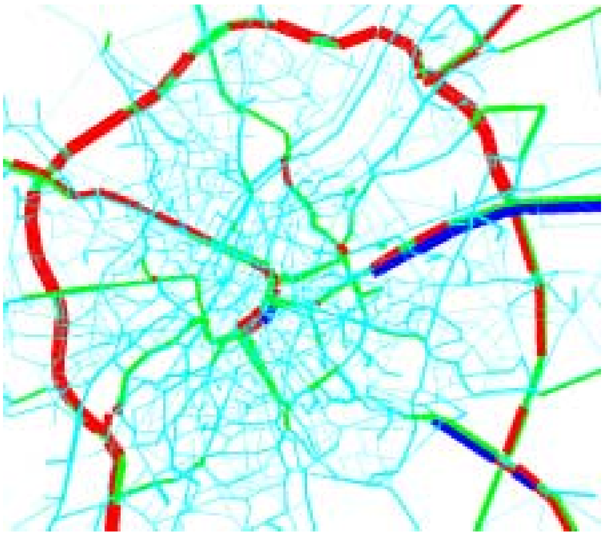

Figure 3.10g. NOx Emissions (1991)

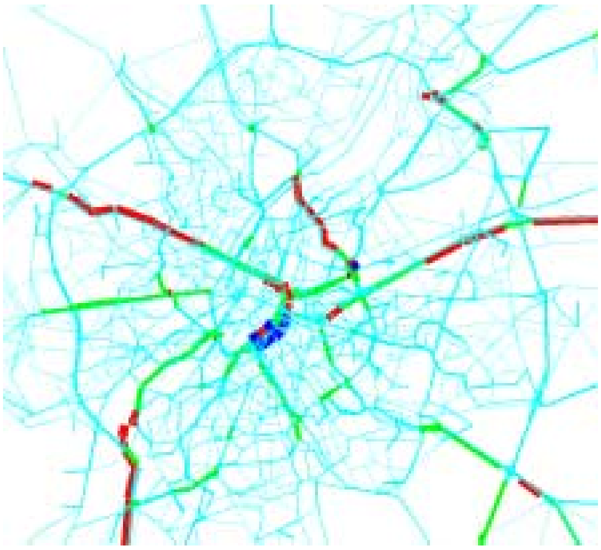

Figure 3.10h. SO2 Emissions (1991)

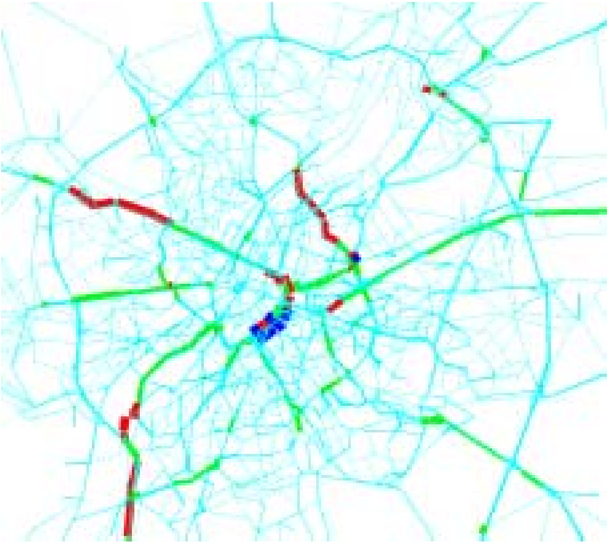

Figure 3.10i. Petrol Consumption (1991)

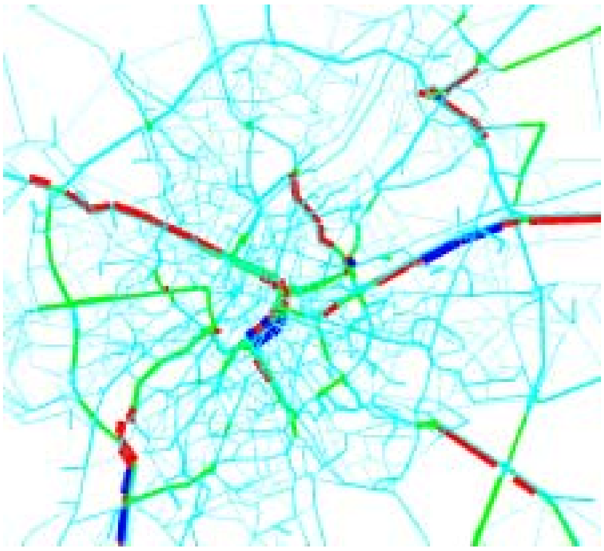

Figure 3.10j. Diesel Consumption (1991)

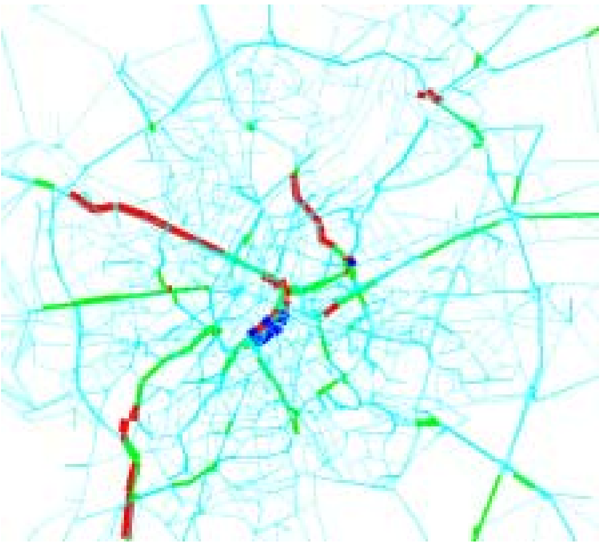

Figure 3.10k. LPG Consumption (1991)

4. *Plan IRIS:* Considerations for Scenarios

As a basis for our analysis, the existing urban policies for the Brussels-Capital Region perspective development are used in order to build the scenarios for modelling the environmental impact of possible policy options.

For this study it is of special interest to assess the impact of policies defined in the Regional Mobility Plan (IRIS Plan, 1997) on air pollution, and greenhouse gases, in particular.

The global strategy of the Plan IRIS includes five groups of actions, respectively aimed at: urban structure; public transport; car parking; automobile traffic; getting around on foot and by bicycle. These actions with their justification (Duchâteau H., 1998), are discussed below.

4.1. Actions on Urban Structure

An analysis of the mechanisms leading to an increase in automobile mobility shows that more and more city users are obliged to move around in their own cars because urban functions to which they must or want to have access (workplace, services, shops, hospitals, etc) are located in places where public transport does not go from their origin.

As far as Brussels is concerned, this conclusion was drawn from the observation of the modal distribution of trips during the morning peak period, as a function of whether the destination of these trips was in the Brussels-Capital region or more to the outside and whether the place of residence was located inside the Brussels-Capital Region, outside the Region at its periphery (outer suburbs comprising 33 townships) or in the rest of the country. Table 4.1[3] compares data collected on:

- the Central Business District from the large central roads up to the Cinquantenaire park, accessible by train through the Central station, the Congrès station, the Quartier Léopold station and the Schuman station and by the tube through the central sections of lines 1A, 1B, 2 and 3;
- the inner suburbs between the large middle ring roads and the outer limits of the region, accessible by some suburban railway stations and by the ends of the tube lines.

The very large differences in the modal distribution shown in table 4.1 are principally caused by the difference of accessibility between the Central Business District and the inner suburbs.

The Central Business District is easily accessible by public transport, from everywhere in the city thanks to the tube, and from the whole country to the railway; on the other hand, access by car is more difficult because of the congestion and the difficulty of finding a parking place. By contrast, the inner suburbs are relatively easily accessible by road, among others because of the presence of the ring road, and is less easily accessible by public transport (the ends of the tube lines).

[3] Source: STRATEC, Regional Mobility Plan, report (q), July 1992

Table 4.1 The effects of the locations of origin and destination on the modal distribution of mobility. Situation in 1991, average workday, 7 a.m. - 9 a.m.

Origin	Total amount	% in public transport	% in private vehicle
Travel to the central business district			
Region	56900	51	49
Periphery	14200	42	58
Rest of the country	31900	71	29
TOTAL	103000	56	44
Travel to the inner suburbs			
Region	57900	29	71
Periphery	31300	13	87
Rest of the country	24100	35	65
TOTAL	113300	26	74
Travel across the whole region			
Region	271200	39	61
Periphery	94200	21	79
Rest of the country	113900	51	49
TOTAL	479400	38	62

It is important to notice in this respect, that:

- a certain grouping of motorised trip destinations (workplace and higher education areas, among others) in the city centre would allow reducing the total number of trips by car to the Region; in this way, the transfer of 10,000 destinations of trips from the middle ring to the centre would allow reducing by 3,000 the number of trips by car to the city, as 74% of the trips to the inner suburbs are made by car against 44% for the trips to the Central Business District;
- in the same way, returning to live in the Region by a part of the population which today lives in the periphery, would have a positive influence as 79% of the trips from the periphery are made by car against 61% from the Region itself;
- on the other hand, it can be seen that commuting to Brussels from the rest of the country contributes to a lesser extent to the automobile traffic in the city than other trips.

These global observations, completed by ideas directed more specifically to the development of areas ideal for walking and cycling and with access to public transport, have led to the formulation of a series of recommendations which, through the Land Use Master Plan, can have determining effects on the needs of trips by car and on the problems these trips cause. These recommendations are listed as follows:

To improve the accessibility of workplaces:

- Concentrate the employment, which generates a high traffic of people per m2 in areas which are easily accessible by public transport.
- Favour the development of dense residential areas along zones where there is a good public transport service.
- Reserve dense housing areas within reach by foot of highly concentrated employment areas.
- Facilitate Park & Ride and Kiss & Ride for the access to and from less densely populated areas.

- Preserve the industrial railway lines in order to re-allocate them to passenger transport.

To facilitate movement during the working day:

- Accelerate processes of renewed use of the ground in the central areas in order to avoid an under-utilisation and to avoid “no man’s lands” whose presence increases the need for motorised transport.
- Organise a mix of mutually complementary activities that do not depend on car use, in the centre of the city.

To facilitate accessibility of shops and services:

- Promote small local shopping centres.
- Maintain and re-vitalise the big commercial centres in the Central Business District.

To facilitate accessibility to collective facilities:

- Locate the regional facilities in the centre.
- Promote the growth of local facilities.

To preserve the accessibility of education establishments:

- Maintain the network of neighbourhood education establishments.
- Discourage the establishment of comprehensive schools at the periphery of urban areas.

4.2. Actions on Public Transport

The analysis of the behaviour of users who have the possibility to use either their car or public transport to get around show that the choices they make are indeed strongly linked to the respective characteristics of the travel they make in one of these two modes. More precisely, the choice of public transport to effect a given trip is most probable if the gap between the duration of the trip by public transport and the duration of the trip with a private car is small. Improving the quality of the service offered by public transport is therefore not a useless proposition.

In the case of Brussels, urban public transport offers a relatively good service to the centre from points of origin located in the Region, and the railway is also very effective from any city in the country. By contrast, the service of public transport from the periphery (see table 4.2[4]) and generally from a distance of 35 km around Brussels is poor.

Table 4.2. Average duration of movement during the morning peak period (7 a.m.-9 a.m.) to the business centre of Brussels (in minutes)

Origin	Average duration of trips		
	By public transport (1)	By private car (2)	Difference (1)-(2)
Region	34.0	24.3	9.7
Periphery	62.5	44.1	18.4
Rest of the Country	68.9	64.5	4.4

[4] Source: STRATEC, Regional Mobility Plan, report (q), July 1992

This is why measures leading to the creation of a suburban railway service are first on the list of objectives of the Regional Mobility Plan of Brussels-Capital concerning public transport:

1. Improve the accessibility of the periphery by developing the suburban services of the National Railway Company (by creating an express suburban rail network - RER).
2. Improve the accessibility of the centre by railway through a more efficient use of the railway infrastructures originally aimed at transporting goods but which are at the moment unused (East and West orbital lines).
3. Create Park & Ride infrastructures in areas where the deconcentration of housing makes it impossible to offer good public transport services.
4. Take advantage of existing underground infrastructures (metro and "pre-metro") which account for nearly 50% of the present volume of users of the urban transportation company.
5. Improve the commercial speed of the surface urban network.

These measures should allow reducing the actual duration of trips by at least a 15 minutes.

The introduction of RER services was recommended in the IRIS plan and is now at the implementation stage, to start operating approximately in 2010. RER consist of new regional train services over distances from 10 to 40 km from the centre of Brussels on the existing star shaped rail network. Its characteristics are similar to the ones of the Brussels metro, which is appreciated by the population. RER services advantages are mainly linked on the RER speed (acceleration and deceleration, door opening, quicker boarding and alighting), RER frequency, higher stops number, higher capacity.

4.3. Actions on the Parking of Private Cars

When time to find a parking place increases because the number of spaces is limited or parking is not free, the probability that someone chooses public transport increases significantly. This confirms the importance to be attached to the control of public parking in order to control automobile mobility, especially if the actions on parking can be made selectively: by way of a parking policy, one can aim to reduce the use of private cars for long trips (eg. from home to work), without limiting this use for smaller trips (shopping, business, etc). Proposed actions concerning parking are listed below:

- Reduce parking possibilities on streets in the city centre by severely limiting long-term parking and by re-allocating the public space thereby gained to short-term parking, to pedestrians and to lanes reserved for public transportation and to green areas or planting areas.
- Strengthen control on the duration of parking in alternating “even-day / odd-day” places.
- Implement an effective system of restricting parking along roads to residents living in housing areas without garages.
- Review the rules and regulations relating to the building of off-road parking spaces and vary their maximum number according to the number of jobs, the kind of activity and the level of service offered by public transportation networks in the local area.

4.4. Actions on Automobile Traffic

All actions proposed above will lead to a global reduction of the pressure of the automobile in the city. This decrease must immediately be made to lead to a better control of the rest of the traffic and to a suppression of all inter-area transit traffic in residential areas and in shopping and leisure areas where the traffic is most often perceived as an aggression (noise, risks of accidents for the children, pollution, etc.).

Actions of this type are listed below, showing strategic actions on automobile traffic.

- Extending to the whole region the concept of dividing the territory into zones inaccessible to motor transit
- Strengthen the hierarchy of the roads (transit ways, local access roads) and at the same time strengthen the general need for accessibility, respect the areas' characteristics and protect those areas from transit traffic.
- Implement in these areas methods of one way traffic and of speed limitations (30 km areas).
- No increase and even sometimes decrease the capacity of roads giving access to the city in order to contain the morning congestion out of its limits.
- Regulate the capacity of roads leaving the city in order to limit the risks of congestion of its internal network during the evening peak hour.

However, collective problems caused by automobile traffic congestion will not necessarily disappear, at least not until the implementation of a system of charging fees for the use of road infrastructures equal to the marginal cost of congestion. Until the time such a user fee system is implemented, congestion must be brought under control, that is, limited to places where it causes the least problems.

4.5. Actions in Favor of Walking and Cycling

At present, in Brussels about 40% of the people who leave their home during the day only move about on foot. The regional Mobility policy must be more attentive to these two categories of users than it used to be. On the other hand, very few people, about 1%, use a (motor)bike although they are much more numerous in cities such as Brussels where promotion campaigns in favour of their use were conducted. These two subjects constitute the last part of the action proposals for the Regional Mobility Plan, listed below.

Actions in the Field of Pedestrian and two-wheel traffic:

- Improve the comfort and safety of pavements and pedestrian crossings on roads by measures concerning parking.
- Develop cycle lanes across "non-transit" areas.
- Promote combined "bicycle-public transport" travel.

5. Scenario Simulations and Discussion of the Results

According with the data collected, the calibration of the model developed was performed to adjust parameters of travelling cost functions, emission coefficients and other important controls of the models system.

The reference calculations with the model have been performed for the morning peak-hour on a representative day for the year 1991 and 1996 according the actual statistical information from the Plan IRIS reports.

Possible scenarios for sustainable mobility in the region are discussed in this section. The environmental impacts of urban mobility have been estimated using the emissions model described above.

The urban policies for the Brussels-Capital region defined in the Regional Mobility (*Plan IRIS, 1989-1995*) have been used to build the scenarios of prognostic simulations for the year 2005. Global strategy of IRIS Plan includes six groups of actions (discussed in detail in *Duchâteau, 1998*) aimed at: urban structure; public transport; car parking; automobile traffic; getting around on foot and by bicycle; and actions on urban road pricing.

In particular, the comparison of two scenarios (S1 and S2) for the year 2005 are demonstrated below, based on these considerations for possible future actions in order to increase accessibility in the city and reduce the pollution.

Scenario S1

Scenario S1 is the "business-as-usual" scenario, where the trends are extrapolated from the year 1991 and 1996, from which the latest information is available.

The origin-destination matrix (Fig. 5.1) for the year 2005 was built upon the forecasts within the Plan IRIS (1989-1995). The network saturation rate in 2005 increases in comparison to the 1991 situation due to almost 70% growth of total vehicle-kilometres driven on the network in total. The over-congested links are marked in blue (dark thick lines)[5] on Figure 5.2 (saturation rate > 1). Such network over-saturation results in a significant decrease of average speed, especially on the ring road and other highways, and brings severe congestion in the centre of the city at the peak-hours.

It is assumed that the fleet of vehicles develops, proportionally substituting the old cars by the new (Table 5.1), with a growing share (until 1%) of LPG-driven vehicles in the total private car fleet. For this new fleet composition and the climatic conditions (the average temperature is assumed to increase in 2005 approximately to 1.5°C to the level of 1991), the new emission factors were calculated.

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[5] On the map charts here and below the bandwidth and colour reflect the volume of the respective indicator, growing from light blue, through green, red, to dark blue as the highest. (In black and white version - the darker and wider the line - the higher is the volume)

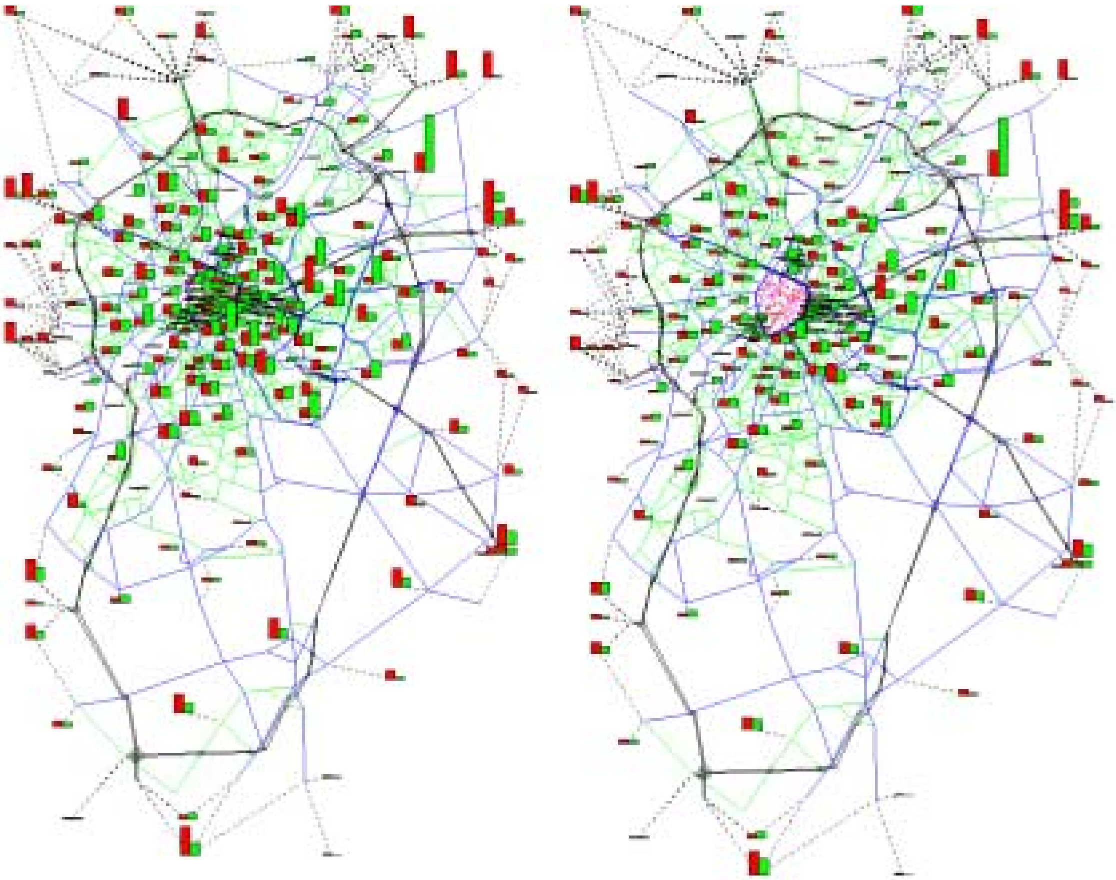

Figure 5.1 Origin-Destination matrix for private transport (morning peak hour, 2005): Scenarios **S1** (left) and **S2** (right).

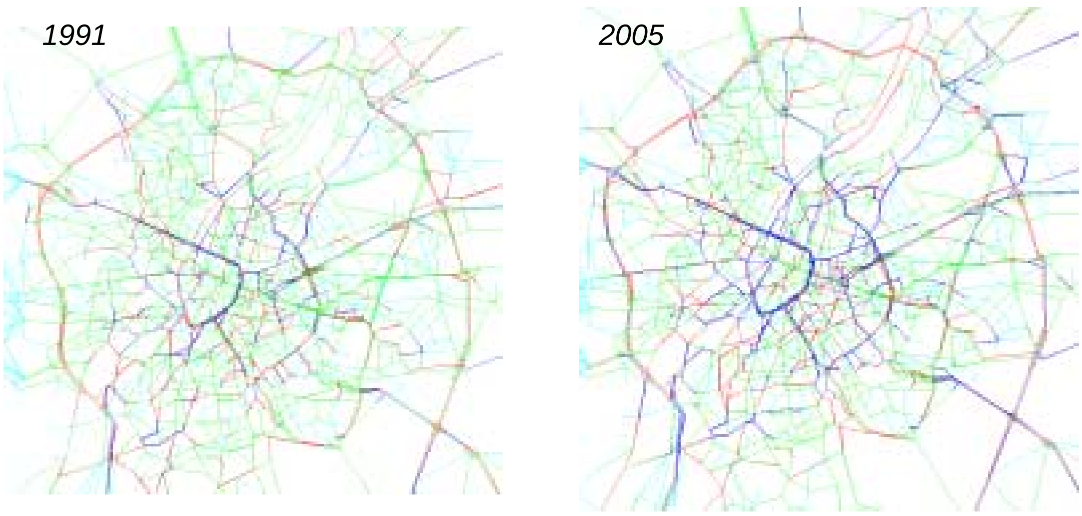

Figure 5.2. Network saturation rate (link intensity vs. link capacity), morning peak-hour

Table 5.1. Forecasted Composition of the Belgian private vehicle fleet in 2005 according to technologies and legislation used in COPERT III Methodology.

Vehicles Categories	**Share (%)**
Petrol Engines	**(60.00)**
< 1.4 l	***(25.00)***
ECE 15/04 [1985-1990]	(0.50)
Euro I - 91/441/EEC [1991-1996]	(1.50)
Euro II - 94/12/ECE [1997-2000]	(11.00)
Euro III – 98/69/EC Stage 2000 [2001-2005]	(12.00)
1.4-2.0 l	***(29.00)***
ECE 15/04 [1985-1990]	(0.50)
Euro I - 91/441/EEC [1991-1996]	(1.50)
Euro II - 94/12/ECE [1997-2000]	(12.00)
Euro III - 98/69/EC Stage 2000 [2001-2005]	(15.00)
>2.0 l	***(6.00)***
Euro I - 91/441/EEC [1990-1996]	(1.00)
Euro II - 94/12/ECE [1997-2000] and <1997	(2.00)
Euro III - 98/69/EC Stage 2000 [2001-2005]	(3.00)
Diesel Engines	**(37.00)**
< 2 l	***(30.00)***
Conventional [<1990]	(0.50)
Euro I - 91/441/EEC [1991-1996]	(4.50)
Euro II - 94/12/ECE [1997-2000]	(15.00)
Euro III - 98/69/EC Stage 2000 [2001-2005]	(10.00)
> 2 l	***(7.00)***
Conventional [<1989]	(0.10)
Euro I - 91/441/EEC [1990-1996]	(0.40)
Euro II - 94/12/ECE [1997-2000]	(3.50)
Euro III - 98/69/EC Stage 2000 [2001-2005]	(3.00)
LPG Engines	**(3.00)**
Euro I - 91/441/EEC [1991-1996]	(0.10)
Euro II - 94/12/ECE [1997-2000]	(1.00)
Euro III - 98/69/EC Stage 2000 [2001-2005]	(1.90)
Total fleet	**(100.00)**

Due to further growth of traffic and respectively of fuel consumption in 2005, the emissions of carbon dioxide (CO_2) increase significantly, as well as emissions of particulate matters (PM) also grow (see Table 5.2). Emissions of NO_X (which are lower at a slow car speed - Fig 3.8), and also of VOC and CO decrease, basically as a result of improvement of vehicles characteristics, such as use of advanced catalytic converters. However this effect on reduction of PM (which has been observed during the period of 1991 till 1996), is not enough to compensate the growth in traffic forecasted within business-as-usual scenario S1. Due to the introduction of fuels with low sulphur content (starting from the end of 1996) the emissions of SO_2 also decrease.

Scenario S2

Scenario is based on so-called "*voluntarist*" group of scenarios of *Plan IRIS (1989-1995),* where several prospective measures and urban policies were introduced:

- development of the mixed land-use schemes, favouring the localisation of offices and residential areas close to the accessibility points;
- improvement of the links in public transports between the city centre and the suburbs (suburban metro/suburban express rail system - RER);
- introduction of the parking control, which would favour the switch from roads to public transport.
- decrease of automobile traffic in residential areas and limitation of the congestion in the city centre by means of traffic-flow control measures;
- improvement of the travel conditions of pedestrians and cyclists.

Basically, above measures are aimed at reduction of the need in mobility in general, and in particular, stimulate a modal shift from private cars in favour of public transport, mainly through introduction of RER - suburban express rail system. In terms of transport model, the above changes were introduced mainly in the origin-destination matrix (reduced demand for private car use - compare scenarios S1 and S2 on Figure 5.1), as well as in the road network itself (e.g., penalties on particular segments of the roads, link capacities and times). This information has been provided by the Equipment and Transport Administration (AED) of the Brussels-Capital region, based on the *Plan IRIS (1989-1995)* assumptions and calculations.

Comparison of aggregated indicators for the above-discussed scenarios is given in Table 5.2. Significant reduction of traffic intensity, coupled with other urban policy measures in scenario S2, result in dramatic abatement of environmental pressure.

Table 5.2. Comparative analysis of scenarios: totals relative dynamics (*1991* = 100%)

Year	*Traffic Intensity*	*Air Pollutants Emission*							*Fuel Consumption*		
	Veh*km	***CO2***	***CH4***	***NOx***	***VOC***	***CO***	***PM***	***SO2***	***Petrol***	***Diesel***	***LPG***
1991	100	100	100	100	100	100	100	100	100	100	100
1996	120	116	87	86	85	86	99	109	103	160	57
2005 (S1)	163	179	91	80	68	75	129	94	154	255	470
2005 (S2)	124	117	60	60	40	41	87	69	98	180	346

Figures 5.3-5.6 depict spatial distribution of several emissions in 2005 for scenarios S1 and S2. Substantial decrease of emissions in scenario S2 is observed, especially for the carbon dioxide (CO_2), as well as pollution of nitrogen oxides (NO_X). As already mentioned above, since NO_X emission is proportional to speed, the higher volumes of this pollution are concentrated on the highways, such as the ring road. Other pollutants concentrate on most busy and congested roads. Projected within scenario S2 better accessibility by public transport of some important locations in the city, such as Zaventem International Airport (around which many offices are located) also helps to avoid outrageous levels of pollution in their neighbourhood (Fig 5.6).

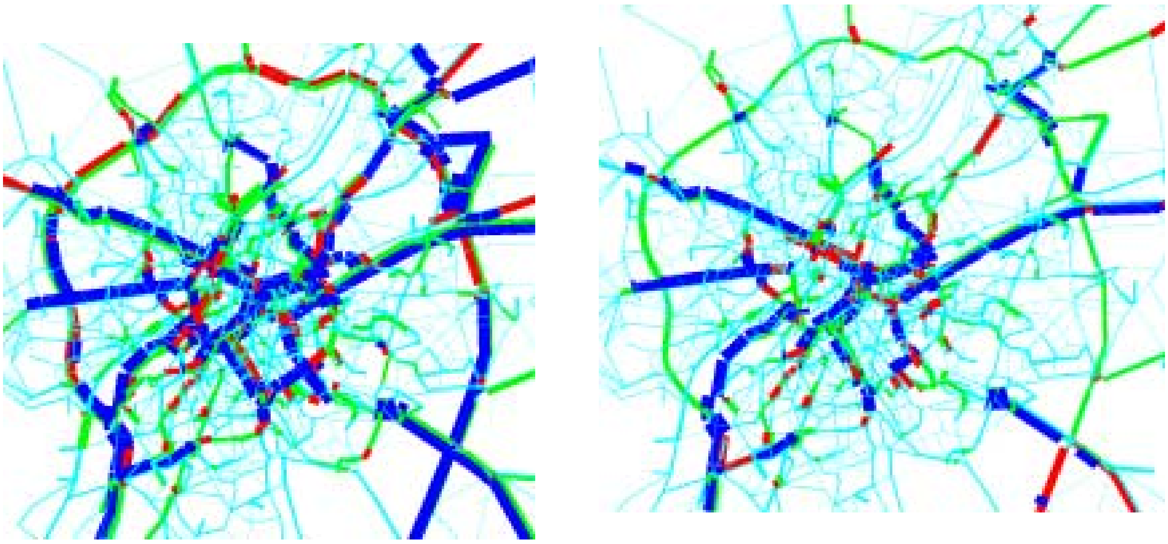

Figure 5.3. CO_2 Emissions (2005), Scenarios: S1 and S2

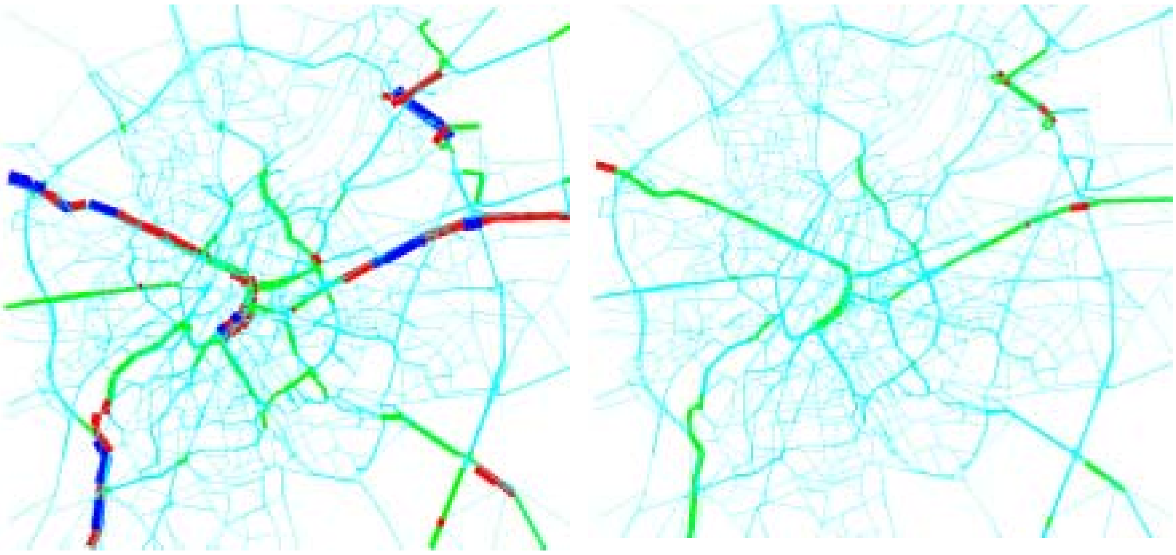

Figure 5.4. CH_4 Emissions (2005), Scenarios: S1 and S2

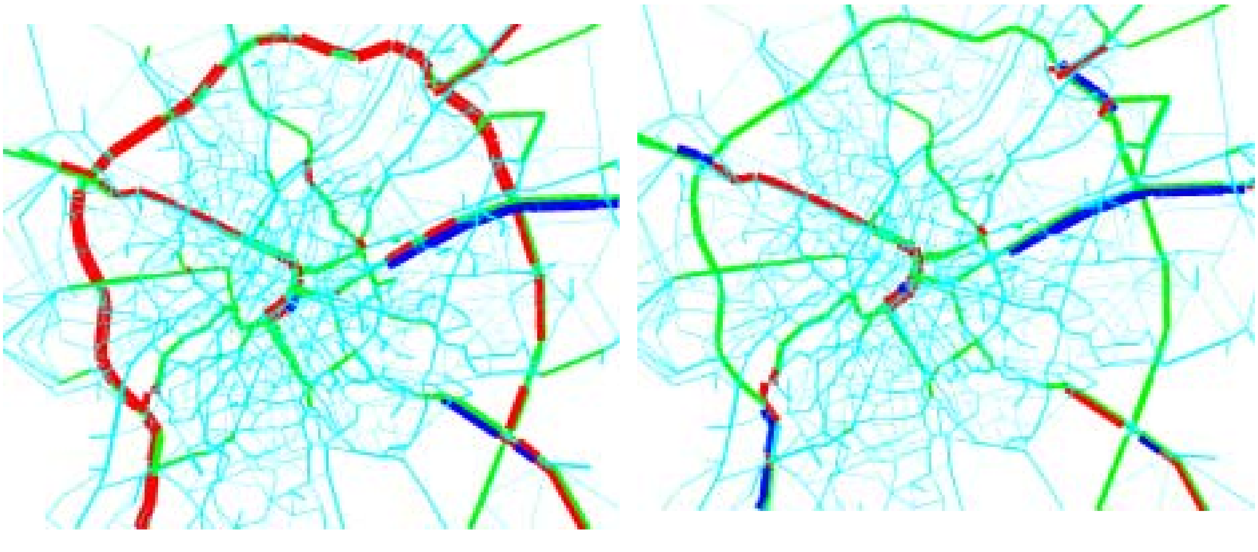

Figure 5.5. NO_X Emissions (2005), Scenarios: S1 and S2

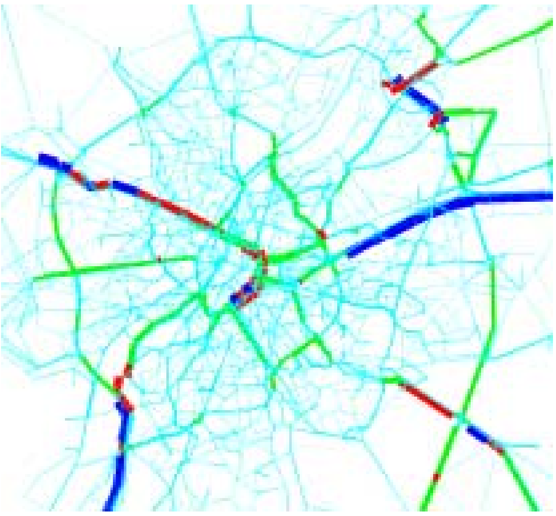

Figure 5.6. SO_2 Emissions (2005), Scenarios S1 and S2

The evaluation of the mobility impact on air pollution is a multi-criteria task. Indeed, speaking of a "sustainable mobility" a compromise should made between simultaneous achievement of several goals. These goals include: providing sufficient transport services and accessibility to match the mobility demand in the urban area, reasonable travel time from origin to destination, travelling comfort and safety for both - those in a vehicle, and those on the road, and last but not least, acceptable emissions level from the road transport. The last two issues (safety and emissions) are linked directly when we speak about damage to human health, which is the case of local emissions causing immediate impact on people in urban areas. More implicit impact is caused by global (greenhouse) emissions.

Thus, reduction of emissions itself employs necessity to differentiate the types of pollution addressed and possible measures of their abatement. Since the emission factor for each pollutant is a function of speed, these concerns bring us to discussion of an "optimal" speed on the roads, which could meet the above multi-criteria tasks. From Figure 3.8 such an "optimal" average speed on the road (in terms of minimum emissions per each category of pollutant per kilometre driven by an average car) can be calculated (Table 5.3), using the fact that the emission factor functions are convex over speed:

Table 5.3. The average speed at which minimum level of (hot) emissions is achieved
Calculated for the Brussels-Capital region using COPERT methodology

Year	CO2	NOx	VOC	CO	PM	SO2
1991	59	7	103	88	74	75
1996	76	34	99	80	71	75
2005 (S1)	74	36	93	72	70	79
2005 (S2)	78	67	86	70	66	76

This table shows that according to development of the vehicles fleet composition the "optimal" speed on the road slightly decreases with time, except for the NOx and CO2 emissions, and tend to be in the range of 60-80 km/h for most of pollutants. Theoretically this could be considered as a positive effect, would the traffic flow with such speed on every link. But since the network becomes more congested with time, in reality some links of the network provide very low, when other much higher than this favourable average speed, resulting in excessive emissions.

6. Conclusions

Restoring mobility by only decreasing the road traffic congestion, that is, trying to suppress the traffic bottlenecks, increasing the capacity of the main road networks, creating new parking lots or implementing sophisticated techniques of traffic management, is no longer a realistic strategy in the long term. These are the answers that have been applied for years with only one objective: increase the flow and fluidity of automobile traffic. They are responsible for their own inefficiency because any possibility of an increase in mobility is used by residential and economic players to increase even further their demand of automobile travel.

Experience has shown that in any city where measures were taken to increase the fluidity of traffic, the initial problems reappear some years later in an even more acute form. Indeed, in cities where road networks are very congested this approach only results in a slight shift of the thresholds and a slight postponement of the critical point. It enables a management of the situation in the short term, but does not modify the fundamental causes of the problem. In any case, it does not contribute to creating the new conditions required for a sustainable development of cities. In the case of Brussels, it would be particularly harmful as it would favour the centrifugal powers that would empty it of its substance because of the Region’s small area (*Duchâteau, 1998*).

As a possible way to find solutions to this problem, an integrated approach to modelling urban development, mobility and its environmental impacts is proposed and discussed within recent paper. As a first step in its implementation, we have designed a mobility model that allows spatial assessment of the road traffic contribution to air pollutant emissions on a network flow model.

On the basis of the model, the contribution of road traffic to the pollutant emissions in the Brussels-Capital region has been determined. In particular, the comparison of two scenarios for the year 2005 have been demonstrated, based on statistical trends, and major considerations from Regional Mobility Plan (Plan IRIS, 1993-1997) for possible actions in the future in order to increase accessibility in the city, reduce demand for mobility and favour modal shift from private cars to public transport.

The general modelling results approve that these policies also lead to abatement of air pollution. Nevertheless, thought the reduction of carbon dioxide emissions in scenario S2 is significant in comparison to S1, it is still not a sufficient contribution to general abatement of greenhouse gases so that to match the targets defined by Kyoto Protocol for Belgium. This conclusion, however, corresponds with many studies that indicate that these targets are far too optimistic, and they are likely not to be hit at the levels they are set now. Belgium would have to either reconsider these obligations, or to search for more radical policies, perhaps mainly in energy and industry sectors, but also in transport. However, it is important to realise, that implementation of majority of measures defined in "voluntarist" scenario (S2) of Plan IRIS would require, above all, serious behavioural changes in mobility patterns and modal choice.

Stimulation of the use of LPG-driven vehicles is also seen by author as a possible way to reduction of emissions of some pollutants.

Results of modelling and recommendations drawn for regional and urban planning stress importance of consideration of both local urban pollution and global greenhouse gases as one complex problem, rather than tackling them somehow separately. Practically this means that the urban policies should be sought in systemic solutions, which would favour mixed land-use schemes radically reducing demand for mobility and the way people will travel.

Further development of the described system of models and of methods used for environmental impact assessment is recently underway within ongoing continuation of this study at the CEESE-ULB in co-operation with the Brussels-Capital region administration.

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