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Environmental Impacts of Mobility and Urban Development: A Case Study of the Brussels-Capital Region

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Abstract

Aggravation of traffic intensity and air pollution in urban areas is urging the studies on strategic environmental assessment (SEA) of transportation networks and the integration of land-use planning with transport-environment concerns.

The aim of this study is to analyse the environmental impacts of mobility induced by major regional development tendencies and policies in the Brussels-Capital region. An integrated modelling approach is proposed, including analysis of socio-economic factors of mobility, road network assignment model, and estimation of air pollution from traffic.

The first version of the model, linking urban mobility and emissions from private vehicles is developed using TRIPS package for network analysis. For possible scenarios of mobility according the policies defined in the Brussels Regional Mobility Plan (*Plan "IRIS", 1989-1995*) emissions of different air pollutants and fuel consumption were evaluated for the year 2005 as a result of road traffic modelling.

1. Introduction

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 (*Plan IRIS, 1989-1995*) predict the complete saturation of the road network before the year 2005 in the European 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 the possible effects of measures towards a more sustainable transport system as an important element of the regional sustainable development.

Today it is generally accepted that transport policies alone will not lead to 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. However, as *Lobe, and Duchâteau (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.

This paper presents a study recently being undertaken in the Centre for Economic and Social Studies on the Environment (CEESE) of Université Libre de Bruxelles (ULB) within a project to analyse the ecological aspects of mobility induced by major regional policy for the case study of Brussels-Capital region (*Safonov, 2000*). 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 emissions (CO_2, CO, NO_x, SO_2, VOC, particular matter, as well as others) and the consumption of non-renewable fuel.

While considering the impacts of air pollution (e.g. in terms of building deterioration, health effects, climate change), the general approach associates to traffic a sequence based on the five following steps: human activities, emissions, immissions (pollution concentrations), 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.

The new model is being synthesised for analysis of influence of recent urban and transport policies on the mobility of people in an urban area. The environmental impacts of such mobility are analysed on the basis of the information available for the Brussels-Capital region.

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

2.1. 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, and 2000,* and *Safonov, 2000* for literature survey), an Integrated System of models (Figure 2.1) is proposed to include several main components:

1) Urban development model. This will include forecasts of population and employment dynamics, in accordance to different economic and urban development 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 local pollution of CO, NO_x, VOC, and PM. Also consumption of non-renewable fuels with respective CO_2 and SO_2 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, 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» 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).

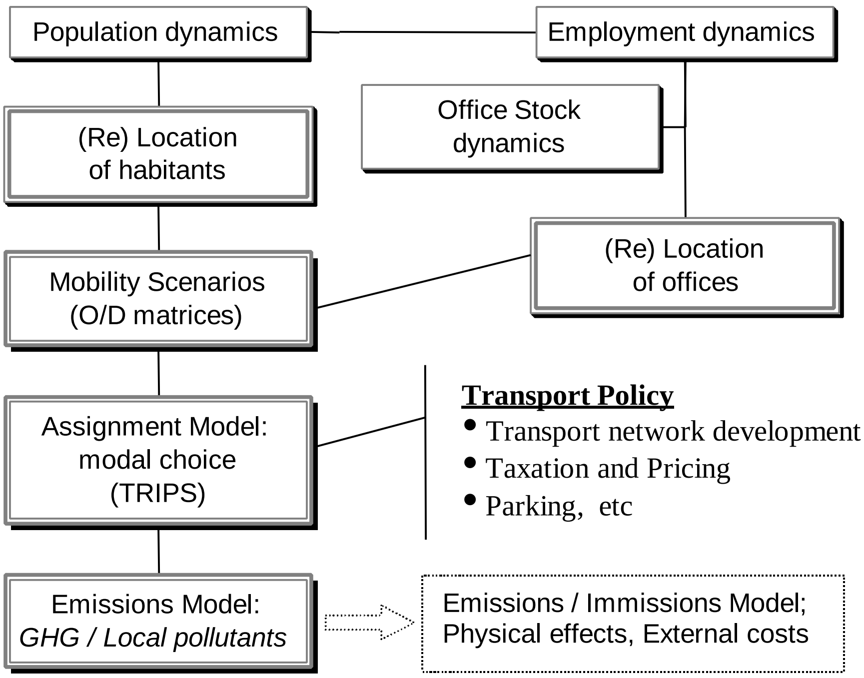


Figure 2.1. General structure of the system of models

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.

As one of the first steps in development of the proposed integrated approach we have designed a model that allows the assessment of the private car mobility contribution to the air pollutant emissions in the Brussels area. The software was developed to link the mobility model, road traffic assignment and emissions calculations (*Safonov, 2000*).

The following sections describe the recent situation and main considerations for envisaged model design and scenario analysis (sections *2.2, 2.3*), and already implemented developments within the proposed modelling approach (sections *2.4, 2.5*).

2.2. 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 2.1).

Table 2.1. 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*

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.

2.3. 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 2.2) depicts the aggregated dynamics of the mobility in the region per main categories of roads for private cars.

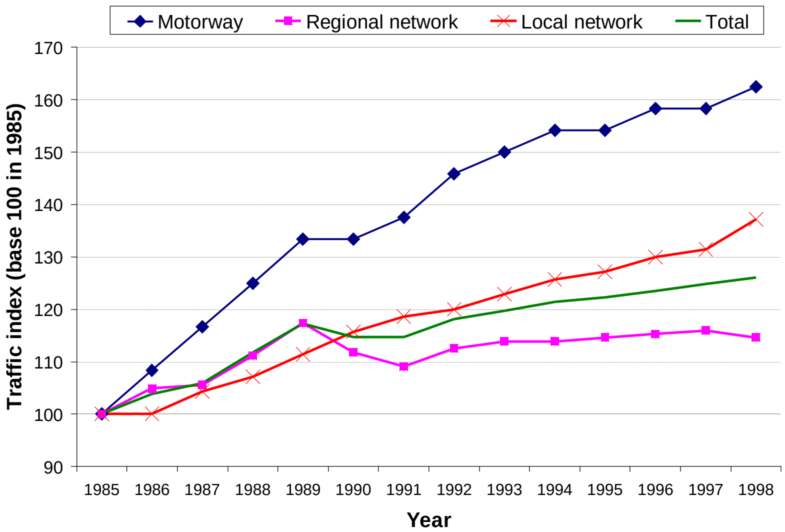


Figure 2.2. Traffic intensity (in vehicle-kilometres) in the Brussels-Capital region, 1985-1998
Calculation based on *Recenment de la Circulation, Ministere des Communications et del'infrastructure, 1998*.

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.

2.4. Network model of private road transport

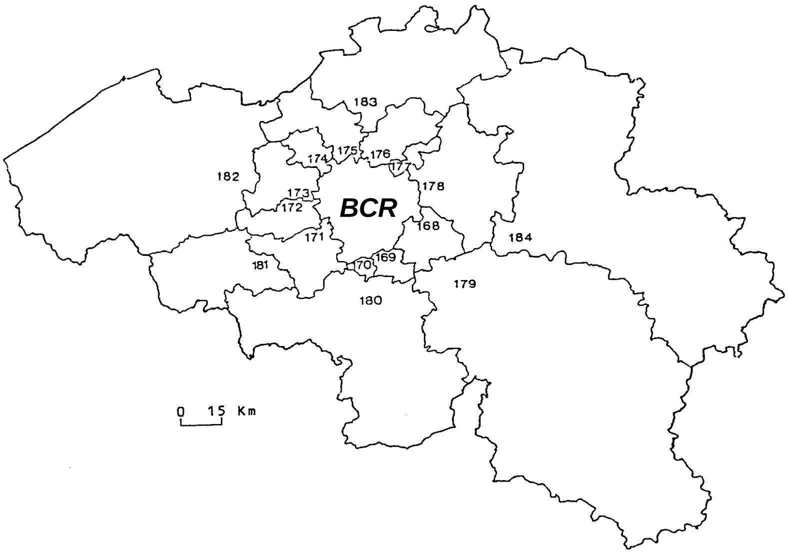
The Brussels-Capital region covers the total square of 161 km² with 951,580 inhabitants (1997) and takes the central geographical position in Belgium (Figure 2.3). Administratively, the region is divided into 19 municipalities (communes), but the total area under study (Figure 2.4) comprises a wider territory covering also nearby districts from/to which the traffic is most intensive, and it is divided into smaller 167 districts.

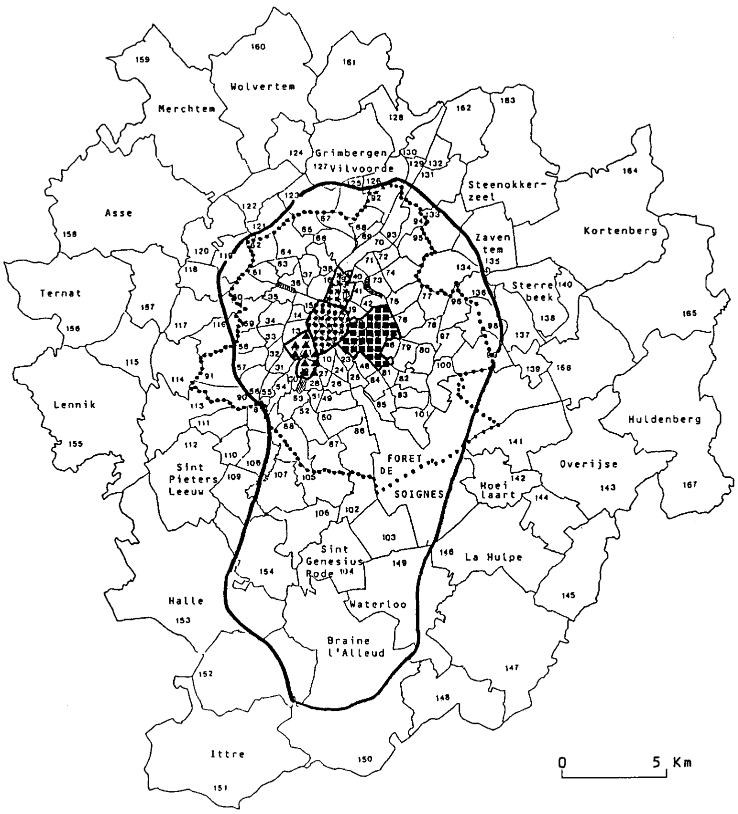
The road network (see Figure 2.5) due to further disaggregation of the administrative districts in the central part of Brussels has in total 255 zones, from (to) which the trips are generated, with 2545 nodes and 8366 links.

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. 2.5) 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 2.3. 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.





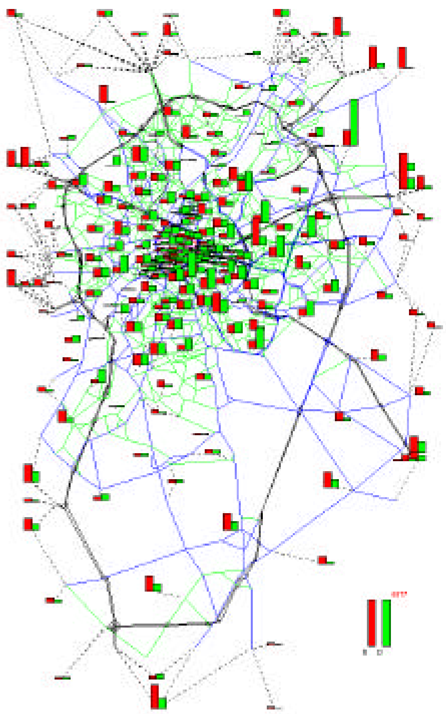


Figure 2.4. Area under study.

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 Brussels-Capital region

Figure 2.5. Road network and Origin-Destination matrix for private transport (morning peak hour, 1991).

Left histograms - origins, right - destinations.

2.5. Air pollution

The last step in our modelling scheme is to analyse the impact of mobility on the indicators of air quality[1]. The model considers the following air pollutants: carbon dioxide (CO_2), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOC), and particulate matter (PM).

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 2.2, from which the vehicle fleet of the Brussels-Capital region has been deduced.

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.

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;

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

$EF_{i,j,hot}$ 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.

Table 2.2. Composition of the Belgian private vehicle fleet in 1991
Calculation based on *FIGAZ (1996).*

Vehicles categories	Number of cars, 1991	Share (%)
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)**

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 2.2), 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 2.6).

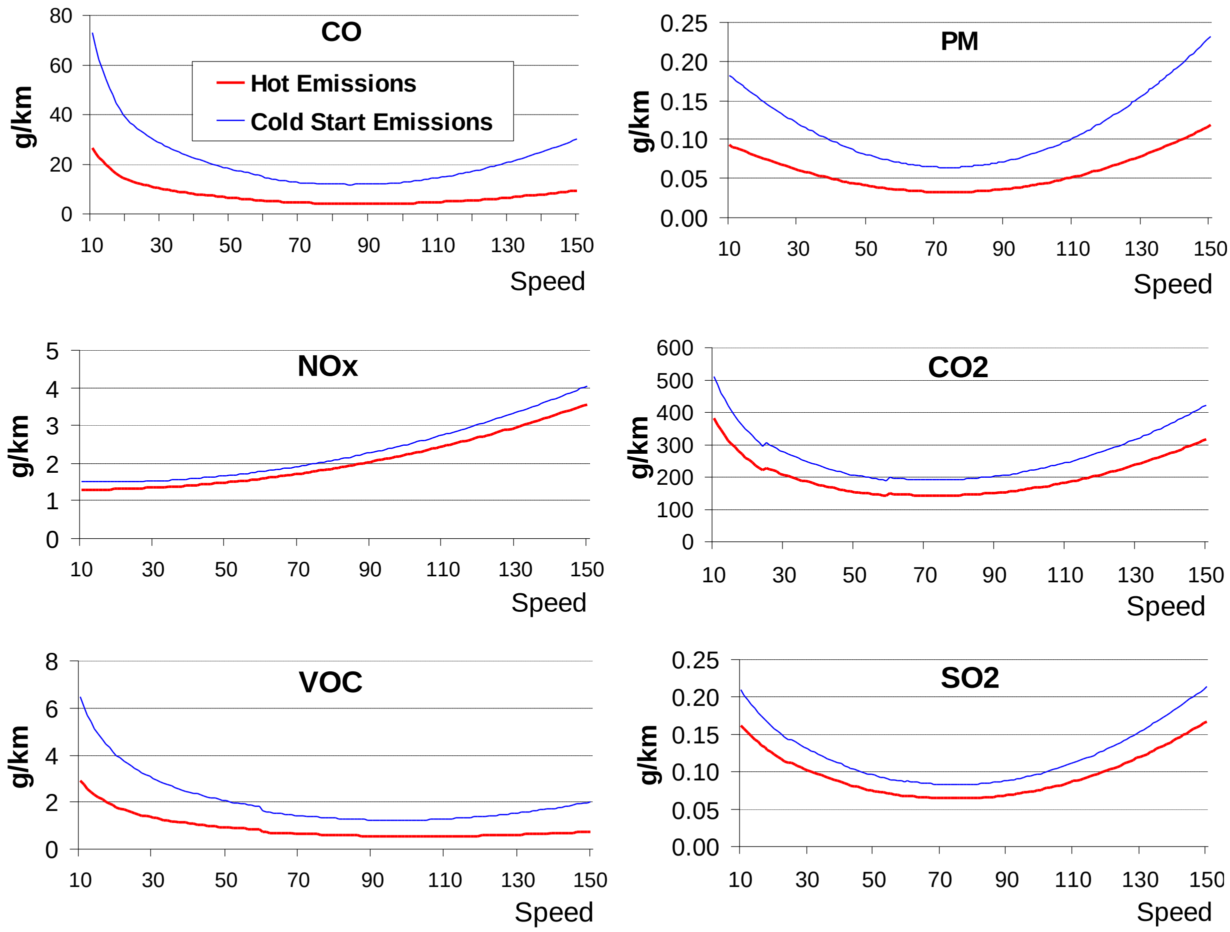


Figure 2.6. Emission functions for an average car in the Brussels-Capital region in 1991.

To calculate the distribution of the emission of the air pollution and the fuel consumption on the road network an external module was developed (in *Visual Basic*). This program is linked to the TRIPS project, so that is it possible to spatially visualise the emissions of each pollutant along with the assignment results on the road map of the Brussels-Capital region. For details of the software organisation see, *Safonov, 2000.*

3. Scenario Simulations

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 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 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)[2] on Figure 3.1 (saturation rate > 1). This 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.

Figure 3.1. Network saturation rate (link intensity vs. link capacity), morning peak-hour

[2] 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)

It is assumed that the fleet of vehicles develops, proportionally substituting the old cars by the new (Table 3.1), 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.

Table 3.1. 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 CO_2 increase significantly, as well as emissions of particulate matters (PM) also grow (see Table 3.2). Emissions of NO_X (which are lower at a slow car speed - Fig 2.6), and also of CO and VOC decrease, basically as a result of improvement of vehicles characteristics, such as use of advanced autocatalytic 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 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), 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 3.2. Significant reduction of traffic intensity, coupled with other urban policy measures in scenario S2, result in dramatic abatement of environmental pressure.

Table 3.2. Comparative analysis of scenarios: totals relative dynamics (*1991* = 100%)

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

Figures 3.2-3.4 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) and sulphur dioxide (SO_2). 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 3.3).

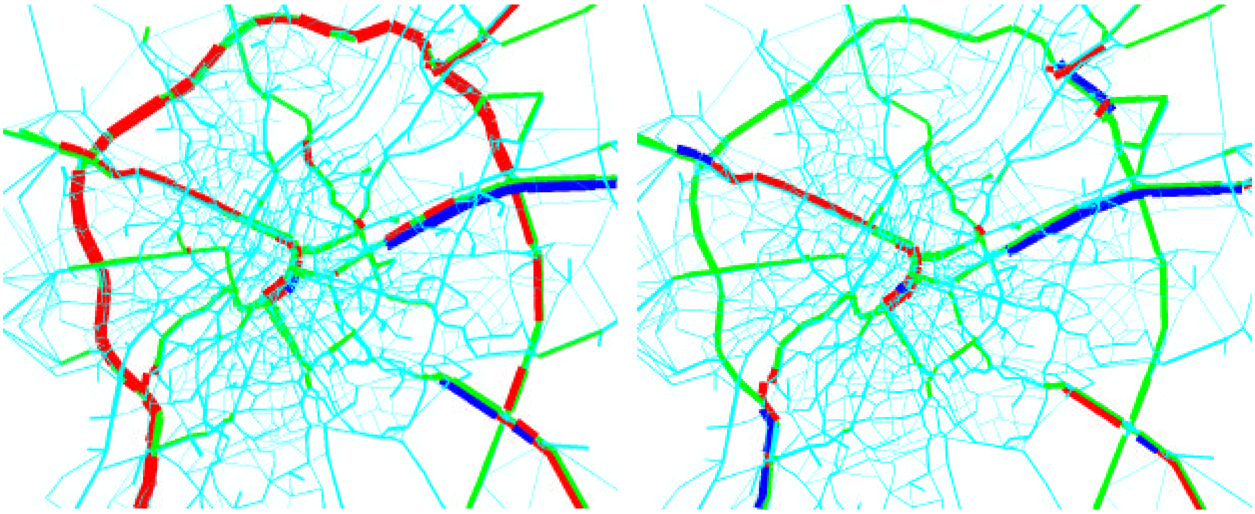


Figure 3.2. NO_X Emissions (2005), Scenarios: S1 and S2

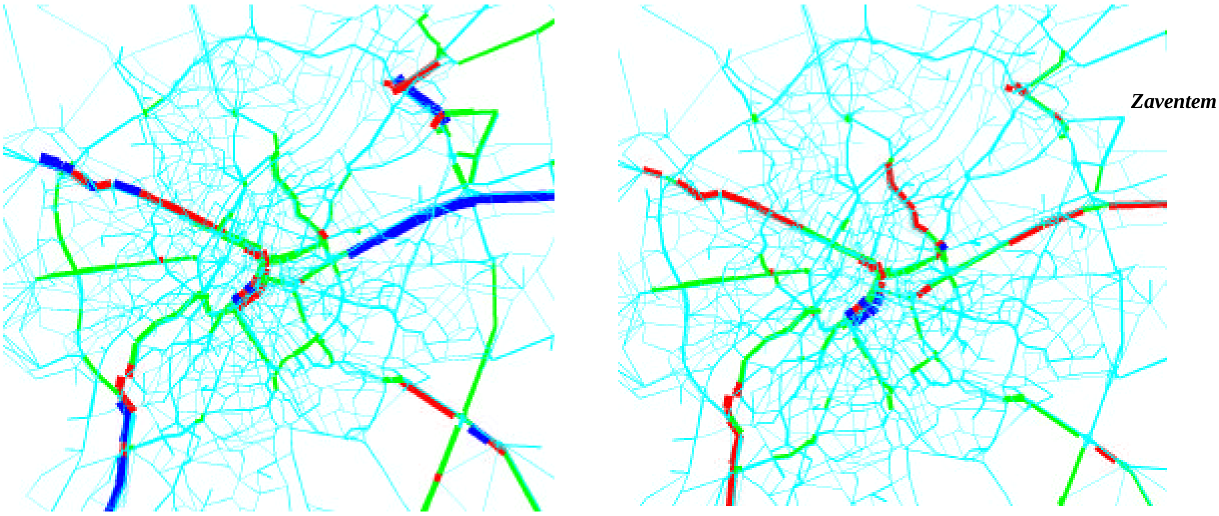


Figure 3.3. SO_2 Emissions (2005), Scenarios S1 and S2

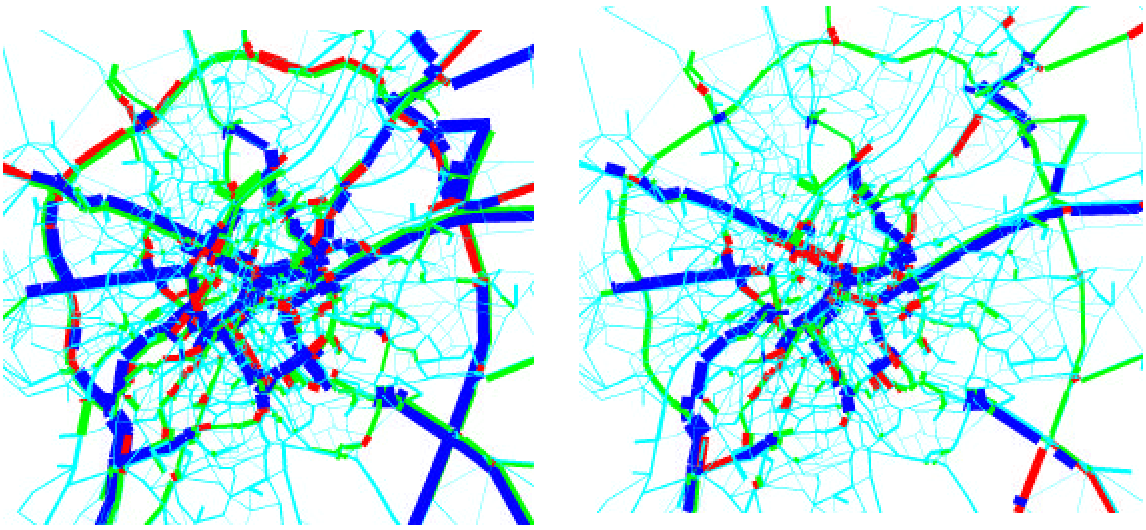


Figure 3.4. CO_2 Emissions (2005), Scenarios S1 and S2

4. Conclusions

The evaluation of the impact of mobility on air pollution is a multi-criteria task. Indeed, speaking of a "*sustainable mobility*", a compromise should be 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 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.

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.

In particular, the comparison of two scenarios for the year 2005 have been demonstrated, based on statistical trends, and major considerations 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. However, it is important to realise, that implementation of such scenarios 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 authors as a possible way to reduction of emissions.

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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