THE SCATTER PROJECT – SPRAWLING CITIES AND TRANSPORT : FROM EVALUATION TO RECOMMENDATIONS

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1. GENERAL OBJECTIVES OF SCATTER

SCATTER is a project under the European Commission DG Research, "Energy, Environment and Sustainable Development Programme" (Key Action 4 – City of Tomorrow and Cultural Heritage), which started on January 1st 2002 and will last until June 2004.

The partners involved are STRATEC sa (Belgium), the Centre for Advanced Spatial Analysis CASA – University College London (United-Kingdom), Steinbeis Transfer Centre Applied System Analysis - STASA GmbH (Germany), LT Consultants Ltd (Finland), Trasporti e Territorio - TRT Srl (Italy), the *Centre d'Etudes sur les Réseaux, les Transports, l'Urbanisme et les Constructions publiques* - CERTU (France), the *Centre d'Etudes Techniques de l'Equipement de l'Ouest* - CETE de l'Ouest (France), and STRAFICA Ltd (Finland).

SCATTER tackles the issue of urban sprawl, in particular in the context of cities implementing new suburban public transport services. Urban sprawl is widespread in Europe. In a growing number of cities, population and employment in central areas is declining while increasing rapidly in suburban and peripheral areas. This induces a high level of car use and, usually, congestion on roads with access to city centres. To limit the damage caused by urban sprawl in terms of congestion, air pollution and energy consumption, many European cities are implementing (or planning to implement) suburban public transport services, such as heavy or light rail. But by improving accessibility, they create an incentive for a new wave of urban sprawl. Therefore, in parallel with these new public transport services, accompanying measures have to be elaborated and implemented, in order to prevent, mitigate and control the sprawl phenomenon.

The project comprises six case cities : Brussels, Stuttgart, Bristol, Helsinki, Rennes and Milan and has the final objective to provide recommendations and guidelines to European cities, and design an “urban sprawl monitoring tool”.

SCATTER started in January 2002 and it is now at the two thirds of its project life. This paper gives account of preliminary results of the project and is particularly focused on the outcomes of three activities : the state of the art review, the statistical analysis on the 6 case cities, and preliminary results of policy simulations in the case city of Brussels.

Updated information about the project can be found in www.casa.ucl.ac.uk/scatter/.

2. OVERALL METHODOLOGY

The study contains three major stages.

The first stage of the work aims to ***improve the understanding of the mechanisms of urban sprawl and its effects***. This first stage includes a state-of the-art review of urban sprawl impacts (work package 1), a systemic analysis of urban sprawl on basis of interviews of experts and authorities in the 6 case cities (WP2), and a statistical analysis of urban sprawl effects in the 6 cities (WP3).

The second stage of the project aims to ***assess the impacts of policy measures aiming to tackle urban sprawl, and their overall efficiency***. At first, a review of policy measures was made, including the measures experienced in the USA (WP4). American cities have been subject to urban sprawl for a longer time than those in Europe and an extensive work already exists there. This review also contains an analysis of institutional barriers and of ways of cooperation between different institutional players.

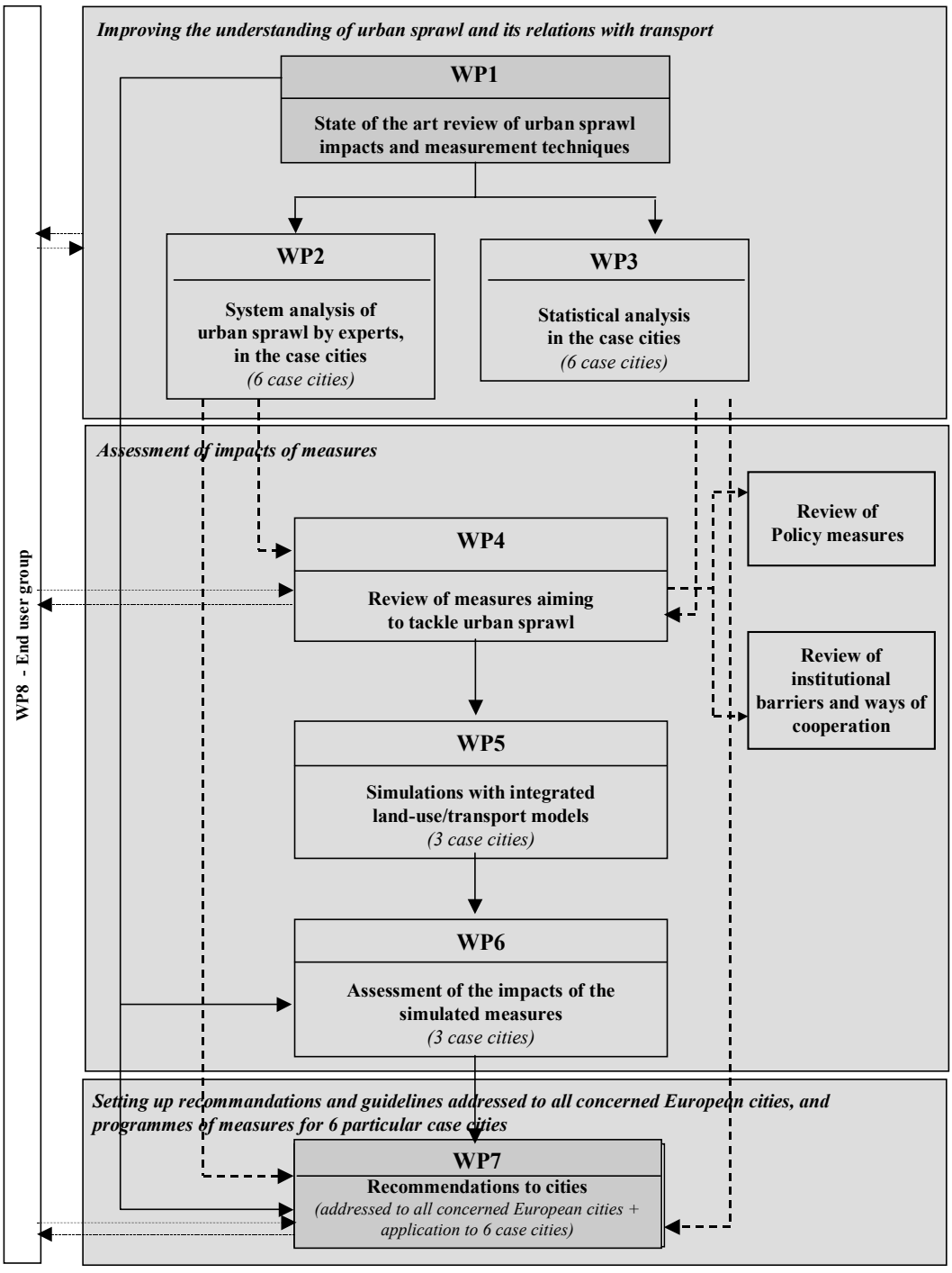
Still in this second stage, simulations of measures aiming to reduce urban sprawl will be carried out on a sub-set of 3 case cities (Brussels, Stuttgart, Helsinki) (WP5), using integrated land-use/transport models. A quantitative assessment of the impacts of the measures will be produced, on the basis of indicators built on the outcomes of the simulations.

The third stage of the project (WP7) will be the ***set up of concrete recommendations*** to European regional/local authorities, on policies to control urban sprawl, especially when a suburban public transport is implemented. A general “urban sprawl monitoring tool” will be designed and a practical programme of measures for each of the 6 case cities will be designed.

In parallel with these technical work packages, 2 workshops will be organised, which namely will gather together local authorities from the 6 case cities.

The project flow chart (Figure 1) provides an overview of the project. As already said above, this paper focuses on the outcomes of WP1 (state of the art review), WP3 (statistical analysis) and preliminary results of WP5 (simulations) on the case city of Brussels.

Figure 1. SCATTER project flow chart



3. HOW TO DEFINE URBAN SPRAWL ? A MULTI-DIMENSIONAL DEFINITION

Clearly, urban sprawl is a multi-dimensional phenomenon, and hence, requests a multi-dimensional definition. It is also difficult to make a clear distinction between the causes, conditions, and consequences of urban sprawl. The literature reveals a world of contradictory causal and temporal relationships between several events, sprawl being often just one of them. Furthermore, beyond defining urban sprawl, a key issue is how to make a distinction between urban growth and sprawl. Some of the main dimensions constituting “urban sprawl” are discussed below.

3.1 Uncoordinated growth and low density

Urban sprawl is usually assumed to refer to the uncoordinated growth of cities, particularly around their edges or peripheries.

The role of population density in urban areas is clearly central in the definition of sprawl. There may be pockets of high density in a sprawling landscape but the key issue is that uncoordinated growth leads to piecemeal development which in general is low density development. Therefore, sustainable planning which aims to reduce the problems of sprawl is essentially dependent upon the control of densities.

In the United States and in United-Kingdom at least[1], the argument about sprawl has been significant for at least 100 years if not longer. In the early and mid 20th century, sprawl was often confused with suburban development and there was considerable disquiet with the way lower density urban living was becoming the dominant way in which peoples’ aspirations about living in cities were moving. But in one sense this was a reaction to something new and the early suburbs now appear to be considerably more coordinated than the kinds of developments which have taken place in the last 25 years, particularly in North America.

Finally, many definitions of urban sprawl use the concept of low density to identify sprawl, however, what is considered low–density is relative and varies with each country cultural expectations. For instance, in the U.S. low density is development of two to four houses per acre while in the U.K. low density would not consist of less than eight to twelve houses per acre.

3.2 The spatial scales relevant for research and action

One key issue relates to the scale at which urban growth and sprawl is identified. There is a strong disjuncture between thinking of cities as socio-economic nodes in a network and thinking of them as physical entities. This is reflected too in the literature on sprawl which spans the scales from low level physical concerns at the level of site development to much more abstract pictures of how cities are growing in terms of population and employment.

A typical example is the case of polycentric systems, which are often, described both as intra-urban patterns of clustering of population and economic activities (London, Paris, Milan) and inter-urban patterns such as the Dutch Randstad, the Flemish Diamond and the area of Padua, Treviso and Venice in Northern Italy.

This is not a trivial argument because the spatial scale at which urban sprawl is observed can heavily influence the identification of relevant issues and the selection and design of suitable indicators. It also crucial to select the proper territorial scale in policy design and implementation, to have a chance to reach the goals. Finally, this twofold issue of "various analysis scales/proper scale for policy" is also related to the question of institutional barriers and modes of cooperation between different institutional players : one of the first questions facing local/regional authorities who wish to set up a platform of cooperation is "how to define the proper area for tackling urban sprawl".

3.3 Different urban forms

A variety of urban forms have been covered by the term "urban sprawl" ranging from contiguous suburban growth, linear patterns of strip development, leapfrog and scattered development. In terms of urban form, sprawl is positioned against the ideal of the compact city, with high density, centralized development and a spatial mixture of functions, but what is considered to be sprawl ranges along a continuum of more compact to completely dispersed development.

At the more compact end of the scale, suburban growth (i.e. a contiguous expansion of existing development from a central core) was identified as sprawl in the early literature of the 1950's and 1960's, but this more compact form is no more classified as sprawl now.

"Scattered" or "leapfrog" development lies at the other end of the scale. This form exhibits discontinuous development away from an older central core, with the areas of development interspersed with vacant land.

Compact growth around a number of smaller centres which are located at a distance from the main urban core is also classified as sprawl. This is superficially similar to the poly-nucleated city (which is not referred to as sprawl) where the downtown is served by several more distant centres. The distinction between the two depends on the level of services offered by the centres and the level of interaction of the city centres with the surrounding suburbs. Linear urban forms, such as strip development along major transport routes have also been considered sprawl.

One problem with these definitions is that the resulting impacts of these different forms may be vastly different. As some other authors do, we would therefore suggest to acknowledge that there are different levels of sprawl which require different policy measures.

3.4 Land uses

Land use patterns are another element which can contribute to define sprawl.

Sprawl is commonly associated with land uses which are spatially segregated.

In the common view of sprawl which applies in the United States, for example, the characteristics of sprawl are among others homogenous single family residential development, with scattered units ; non residential uses of shopping centres, strip retail, freestanding industry, office buildings, schools and other community uses ; and land uses which are spatially segregated. This pattern of segregated land uses in turn induces a high reliance on private car for transport.

However “less dense” patterns don’t occur always and everywhere in the same way. As regards the distribution and organisation of land-use activities and urban functions, different patterns have been identified/may exist : mixed or single land-use patterns, patterns of different rural-urban relationships, concentrated, clustered or dispersed patterns.

3.5 Temporal dimension and urbanisation process

There is also a temporal dimension in the issue of urban sprawl. It is likely that the different forms and the different functional organisations mentioned above correspond to various “ages” of the phenomenon of sprawl. For example :

- first age: very scattered – only residential
- second age: progressive densification – addition of retail and public services (schools, etc), i.e. employment directly induced by the population
- third age: still densification – addition of jobs - evolution towards autonomous centres also providing jobs to their residents.

Urban sprawl can therefore also be considered as a (more or less long) stage in the evolution process of an urban region.

Urban population is still growing and the growth of cities is a significant phenomenon. As an example of what was suggested above, but at a broader temporal scale, there was some discussion at the United Nations (1998) of urban growth following a pattern of “urban transition” and urban sprawl corresponding to a phase of this growth. The first phase is of fastest growth in the core of the city, termed urbanization in the United Nations report ; the second phase is suburbanization with fastest growth just outside the city core; the third phase is counter urbanization, with population in the core and suburbs moving out to more rural areas, and the fourth phase is re-urbanization with an increase in population in the core of the city. According to this model, the phenomenon of urban sprawl would fall into the third phase of growth.

4. CONTEXTS AND CAUSES

According most authors, the main causes of sprawl are as follows :

- the increase of income and the social demand for low density settlements
- the decrease in travel times and travel costs, from the periphery to the urban core
- the differences in housing market and the different tax rates, between the urban centre and the periphery
- the competition between administrative units (e.g. communes) to attract households or companies
- in some countries, national policies which favour low density settlements.

4.1 The consumer demand for single family low density housing

Some authors see the sprawl as a result of the consumer demand for low-density single family housing on large lots. According to this view, demand is driven by individual preferences : a strong desire for owning a single family home, having an adequate environment for raising a family, for privacy and for a rural ambiance.

Some authors also emphasize that, beyond the consumer preferences, this demand has been in some cases manipulated by public subsidies. In the United States for example, these took the form of federal assistance on mortgages.

In Europe, between the 70s and 80s, two simultaneous events opened the door to the first important wave of uncontrolled sprawl : the end of the welfare state, which dramatically reduced the level of national government subsidies to, among others, the housing sector; and the misinterpretation of demographic trends which, while showing a total decline of population (the end of the baby boom) were instead hiding an increase in the demand for new housing due to an unforeseen reduction in the size and lifestyles of households. The demographic explosion and immigration cycle of the post war period which had accelerated the concentration of population in towns and cities was now pushing towards the suburbs that part of the middle-class population which, helped by the economic expansion, the increased levels of income, the change in life-styles, and the affirmation of an anti-urban ideal chose to relocate in the outer suburban areas.

4.2 The influence of the transportation system

A drastic change in the transport systems, by drastically decreasing travel times and travel costs, is perhaps the single most important enabling factor leading to urban sprawl. In many countries, the development of the private automobile and the corresponding growth of the highway system played that role. But, it should be noted that in United Kingdom for example, the development of urban sprawl and suburban housing was more related to the

growth in the public transportation network than to the increase in car use. In London, for example, the growth of the suburbs began with the extension of the rail network to the suburbs in the 1860's, producing a radial pattern of growth along the lines of transportation. The latter development of a more widely spread, circular pattern of growth was also a result of the development of public transportation, in this case by motor bus. The private automobile played little part in the development of urban sprawl.

4.3 A lack of coordination between policies

An indirect cause of sprawl, or at least a cause of the incapacity of the authorities to control sprawl in its early stages, is the fragmentation of the political decision-levels, due to multiple institutional levels involved (local/regional/national or federal), multiple administrative territories covered, and multiple fields of competences (land planning, housing, transport, …) involved.

The fragmented planning systems and the parallel institutional fragmentation are considered by many authors the main barriers to an effective regulation of urban growth and therefore also urban sprawl. Countries with little or no spatial planning activity at the intermediate or regional level lack of the correct perspective to capture actual growth dynamics. Moreover, due to uncoordinated and fragmented planning, policies to prevent sprawl have usually little effect, as they are uncoordinated and not implemented over a wide enough area. The negative effects of this spatial fragmentation are clear, for example, in the case of fiscal policies.

In some countries, not only co-operation between administrative units is poorly practised, but also they compete with one another in the quest for collecting more population (i.e. housing) and jobs (i.e. business and industrial enterprises) as this will lead to higher public revenues (by means of local taxes). In such countries where each unit autonomously sets its own rates of taxes, less-urbanised communes in the peripheral areas will be likely to set low rates to attract economic activities and new residents.

5. EFFECTS AND COSTS

The effects of urban sprawl are one of the most hotly debated issues in the literature, with most usually focus on the negative effects.

5.1 The relation between urban form and sustainability

It is also now generally accepted that urban form has an effect on sustainability. However, at the level of the researchers, the current debate on the sustainability of different urban forms, roughly grouped into compact models and diffused models, is still open, among others due to the complexity embedded in a concept such as "sustainability"[2].

As regards the ecological dimension of the sustainability concept, both the United Nations and the European Union have moved in favour of a the

compact town model embracing the position, supported by research, that more dense cities consume the least amount of energy for transport.

At the macro-economic level, issues of economic efficiency and economic performance of cities emerge.

The European Union has pronounced itself in favour of the compact city model (European Commission, 1990) and of the polycentric regional systems (European Commission, 1997). In this sense the EU has embraced a successful approach adopted in some European countries where policies of urban containment have been balanced by strategies of “concentrated de-concentration”.

5.2 Negative and positive effects

The effects of sprawl can be divided into five groups, namely : public and private capital and operating costs, transportation and travel costs, land/natural habitat preservation, quality of life and social issues.

Another approach is to divide the effects into 3 groups according to the three dimensions of the sustainability concept : ecological effects, economical effects, social effects.
Anyway, the usually admitted negative effects are listed below :

- consumption of land, loss of high quality agricultural land and open space
- destruction of biotopes and fragmentation of eco-systems
- higher costs of new neighbourhood infrastructures
- higher costs of public services and especially transport services
- land use patterns which are unfavourable to the development of collective and other sustainable transport modes ; hence, increase of the level of use of private car
- increased trip lengths
- congestion on the radial roads giving access to the urban centres
- increase in fuel consumption
- increase in air pollution
- contribution to the decay of downtown areas
- social segregation (concentric model of population distribution on the base of age, family size, social and professional class) and reduction of social interaction, but authors are not quite unanimous on this point ; anyway, note that the housing market plays a major role in nurturing the social segregation
- poor access to services for those with limited mobility such as the young and elderly.

The pattern of spatially segregated land uses also raises the issue of possible spatial mismatches within intra-urban poly-centricity : mismatch between population and jobs location ; spatial mismatch of professional skills, where jobs and unemployment lie side by side ; and finally, the hypothesis that job

decentralisation harms low-income residents of central cities because of barriers that limit their access to suburban labour markets.

Another effect, without “positive” or “negative” label, concerns the origin-destination distribution of transport : the part of “tangential traffic” (suburb-to-suburb) seems to increase constantly. Note that, in the last decades, investments in public transport were focussed on connecting inner and outer suburbs and peripheries to the central business district, thus supporting a centripetal transport model and a monocentric urban system. Little attention was given to the problems of transit within the emerging intra-urban polycentric systems, especially with regards to the so called “tangential” mobility.

On the other hand, the positive effects are mostly situated at the individual level :

- access to cheaper private residential developments : middle-class households have the possibility to become owners of single family housing, with enhanced personal and public open space;
- access to cheaper private non-residential developments : young SME and companies have more pleasant work environment than what they could have afforded in the urban centre.

5.3 Central planning versus market driven approach

The debate on sprawl can also be considered as a set of arguments, between those advocating a planning approach and those advocating the efficiency of the market. Those from the “planning” family usually support compact development and advocate greater regulation and planning to solve the “problems” of sprawl. They justify intervention on the grounds that the market is not efficient due to externalities, or unintended effects of actions, the costs of which are not borne by the producer, the existence of public goods which are freely available and therefore not provided by the market, and lack of equity in that the goods and services are not distributed evenly among areas.

The other group is those who take an economic perspective – in this group there are both supporters of compact development and of sprawl, however, in both cases the view is that the economic market will ensure efficient development. Those advocating the free market approach assume competitive and efficient markets and point out that actions should be taken to place the cost of externalities on the producer rather than using regulation.

6. A STATISTICAL ANALYSIS TO IDENTIFY AND QUANTIFY URBAN SPRAWL

The objective of this activity was to design a statistical analysis framework aiming to identify and quantify urban sprawl, and to apply it to the six case cities.

The developed statistical framework consists of :

- a specially designed generalized shift-share analysis ;
- a new measure of concentration, called *H*- indicator ;
- the application of local spatial autocorrelation statistics ;
- as well as the calculation of more traditional indicators like densities, shown on maps.

This seems to provide sufficient and necessary conditions for the identification of different urban pattern, including urban sprawl.

6.1 The data base

The variables investigated were :

- total population and total employment, for all the cities
- income per capita, number of commuters, commuter trip length, house prices, number of dwellings, residential buildings, and number of jobs directly induced by the population, in some cities.

The analysis was applied on time-series data, covering a 20-years period or more, for most of the cities (10 years period for one city).

6.2 Definitions of the indicators

The indicators which were calculated are defined in detail in Deliverable 3 of SCATTER. We provide here only a succinct, summary definition which is sufficient to understand the interpretations and conclusions.

Generalised shift-share analysis applied on growth rates

The generalised shift-share framework consists of :

- calculating an average annual growth rate (λ), for the whole study area, at each year, for each considered variable ;
- calculating the annual deviation (γ) from this average annual growth rate, for three macro-zones defined as the urban centre, the outer urban ring, and the hinterland of the city, at each year, for the same considered variable ;
- and doing all this using a smoothing procedure, in order to smooth noisy patterns which would be due e.g. to possible data uncertainties.

New measure of concentration H

The new concentration-measure called H was inspired by physics and is defined as :

$$H = \int \rho(\vec{r})\, \vec{r}^{\,2}\, dA(\vec{r})$$

where the density (e.g. population density) $\rho(\vec{r})$ at distance $\vec{r}$ from city centre is weighted with the square of distance from the city centre. The integration $dA(\vec{r})$ has to be performed over the whole case study area (*A* being the urban area). This formulation translated in discrete terms leads to :

$$H = \sum_i X_i r_i^2$$

with :

i = 1,2, … n being the zones of the study area
X_i being the value of the stock variable X in i (e.g. population, employment)
r_i being the distance between the centre of gravity of each zone i and the centre of gravity of the whole study area.

The indicator H_{rel} is then defined on the same way than H, but considering relative values $X_i/X_{average}$ instead of X_i .

Indicators of spatial autocorrelation

The indicators of local and global spatial autocorrelation allow to estimate whether, as regards the value of a particular variable (e.g. population density), a zone i is surrounded rather by zones exhibiting close, similar values, or on the contrary, very dissimilar values, or is surrounded by a heterogeneous, patchy pattern of similar and dissimilar values.
As an example, when local spatial autocorrelation statistics is applied to population density, it may highlight a pattern as follows : the urban center (high autocorrelation - similar high densities), the rural hinterland (high autocorrelation - similar low densities), possibly including urban poles (low autocorrelation – urban poles surrounded by rural zones, with much lower densities), and finally a zone in-between characterized by very low spatial autocorrelation, because it corresponds to the suburban area, which is a mix of more or less recently urbanized communes and other still rural communes.

6.3 Main results

As a first conclusion, the application of the statistical analysis method showed that the development of the urban centres of all six case studies Milan, Brussels, Stuttgart, Bristol, Helsinki and Rennes are behind the average growth path of the whole conurbation areas over the last decades, while the deviations of the outer urban ring and often also of the hinterland are above the average growth path.

The shift-share analysis indicated that in all case studies the main growth poles of population and employment are situated in the outer urban ring or the hinterland or in both. This leads to an increase of the investigated stock variables (population, employment, commuters, dwellings and residential buildings) mainly in the outer urban ring accompanied by an increase of the investigated density variables (income per capita, commuter trip length and house prices) in some but not all zones belonging to the outer urban ring and

the hinterland. Milan is in so far an exceptional case, since total population and commuters are decreasing (stagnating). However, this could be related to the fact that the study area adopted for Milan could be too small.

Urban sprawl can be identified per definition, if the growth of the investigated indicators are more or less scattered over the whole region, with the urban centre of the region as source. The detailed statistical analysis indicates urban sprawl in the case studies of Milan and Bristol. Here, the necessary condition for urban sprawl, namely a strong de-concentration effect must be stated as well as scattered growth rates, distributed over the whole study areas.

In the case studies of Stuttgart and Brussels only a moderate to stagnating de-concentration is observed. The scattered growth rates of all indicators of Stuttgart and the spatial autocorrelation pattern exhibits that urban sprawl in the Stuttgart Region exists but is rather moderate. The spatial re-orientation of Brussels follows more a diffusion pattern (associated to the urban growth) with some implemented scattered structures. Several poles exist in Brussels periphery. A moderate sprawl phenomenon of jobs and population can be identified.

Helsinki and Rennes still tend to concentrate its activities close to their city centres. In so far both case studies do not exhibit all conditions of urban spawl. Nevertheless, Rennes and Helsinki show some typical aspects of urban sprawl, e.g. scattered spatial development of population and of workplaces. However, the spatial autocorrelation analysis and the shift-share analysis shows that for both variables only around the rather small urban centre a high spatial correlation can be found, despite the unbalanced and widely spread growth of population and workplaces in the outer urban ring of Rennes and Helsinki.

The global spatial autocorrelation indicators (global Moran's *I*) for the different case study areas provided a ranking of spatial autocorrelation: The communes belonging to the Brussels study area are much more similar in population density and workplace density than communes of Rennes and Bristol. Milan, Helsinki and Stuttgart are in-between.

The pattern of local spatial autocorrelation indicators (local Moran's *I*) indicated that the urban centres of Brussels and Helsinki and some neighbouring communities show strong spatial autocorrelation in population density and density of workplaces.

To summarise, one of the main results of the analysis was that the six cities all exhibit de-concentration behaviours, but with different modalities. They can be clustered into three groups :

- Milan, Bristol : *continuing and rather strong spatial de-concentration of activities* (activities include population and employment), with local specificities such as:
    - Milan: population and employment are out-migrating to areas which are more and more distant from the centre;
    - Bristol: it exhibits a more polycentric pattern, with 2 other urban poles included in the hinterland;
- Stuttgart, Brussels : *moderate spatial de-concentration of activities, tending towards a stagnation of the pattern*; in the case of
    - Brussels: it seems that the sprawl, as regards population, has slowed down these last years, and even stopped very recently;
    - Stuttgart: sprawl can be stated for population on a low level but in case of employment sprawling seems to stagnate;
- Rennes, Helsinki : *continuing spatial concentration of activities*: these two metropolitan areas do not exhibit all conditions of urban sprawl, but the growth of the population and of the employment is nevertheless scattered to a certain extent. In both areas, there is in the same time an out-migration of the rural population towards the urban centre and especially the outer urban ring, and a scattered growth pattern, but at a lower level than in the 4 other cities.

Finally, the work done so far in designing a statistical analysis framework will also contribute in the design of the “urban sprawl monitoring tool” to be set up at the end of the project (in work package 7). This tool is intended for all concerned cities and will be designed in order to be used without sophisticated models.

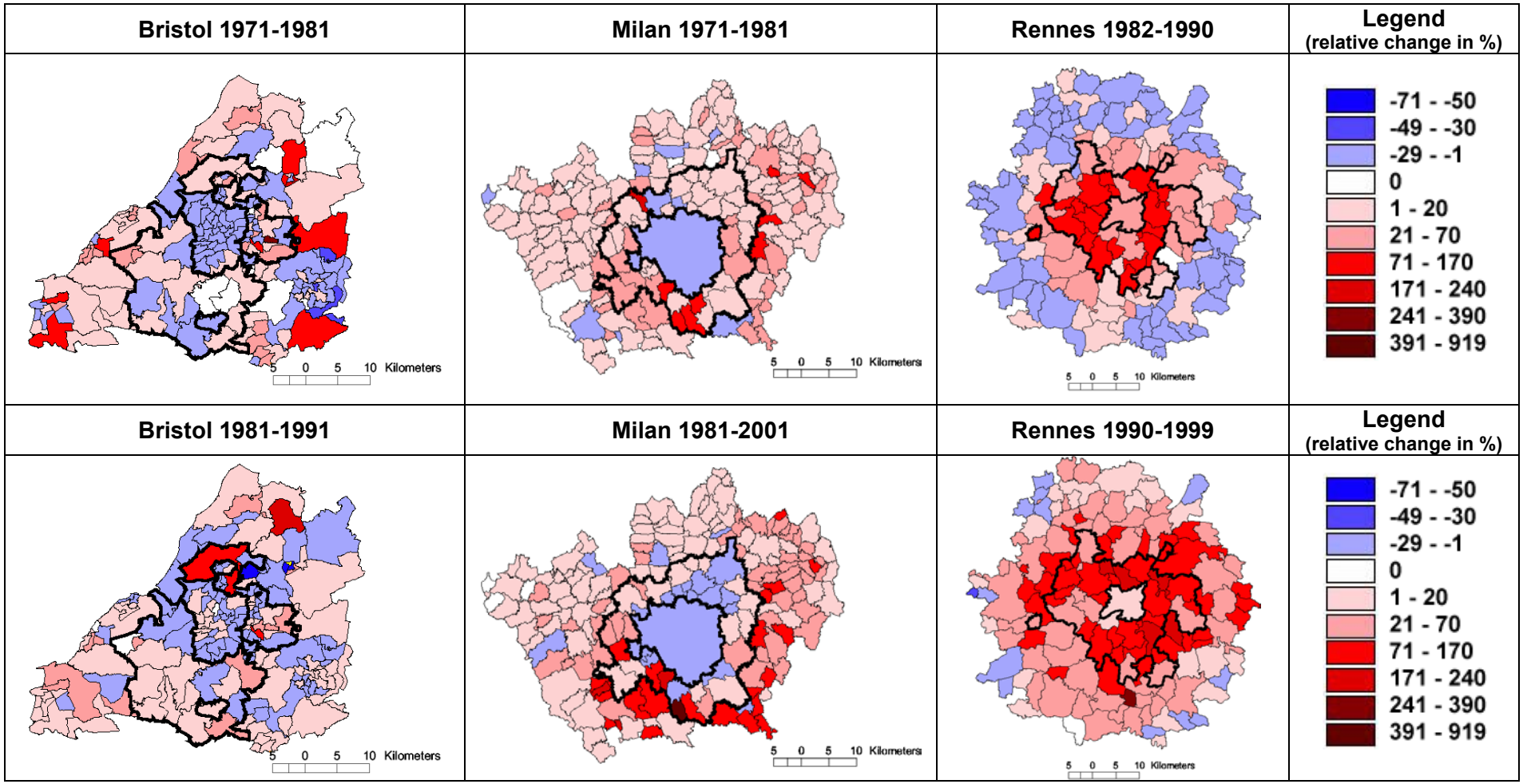


Figure 2a. Change in density of population by zone

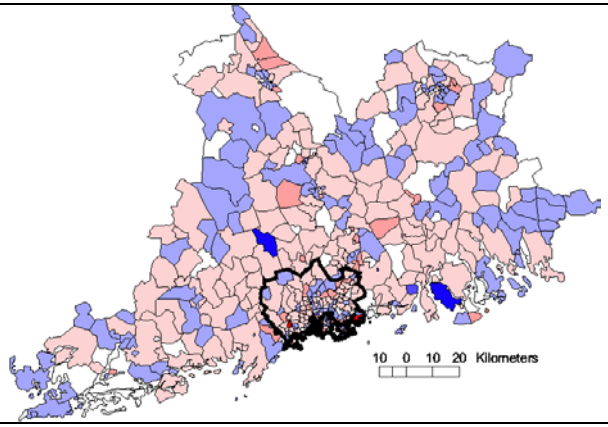
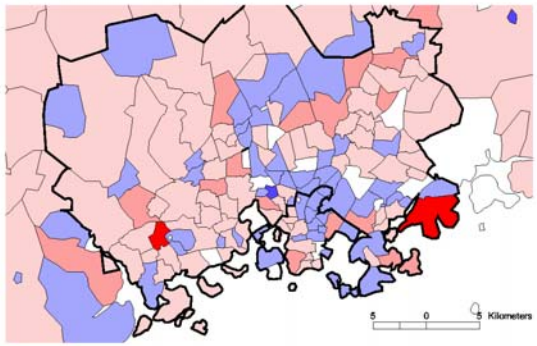
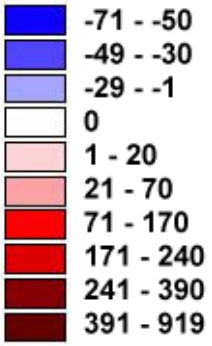
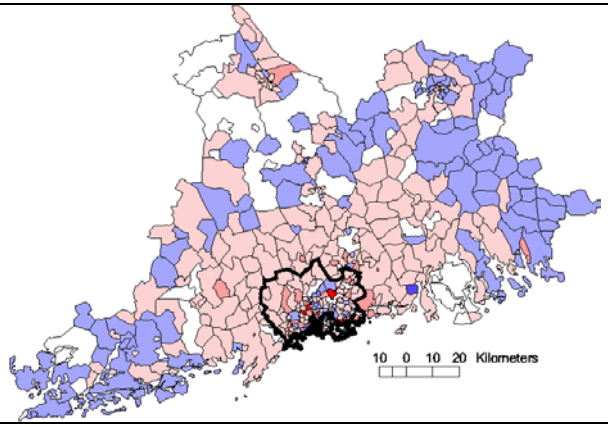
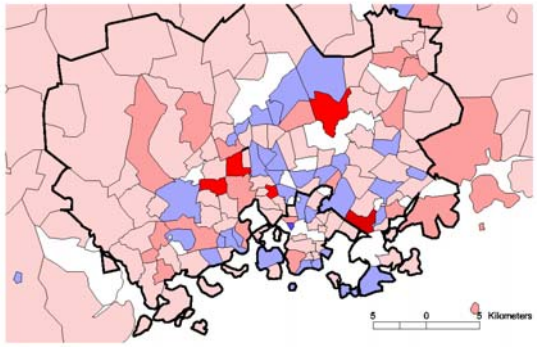
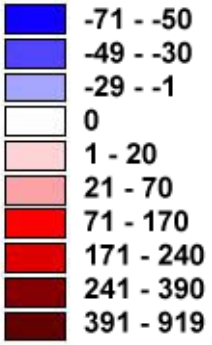
Helsinki 1990-1994	Inner Helsinki 1990-1994	Legend (relative change in %)
		
Helsinki 1994-1999	**Inner Helsinki 1994-1999**	**Legend (relative change in %)**
		

Figure 2b. Change in density of population by zone

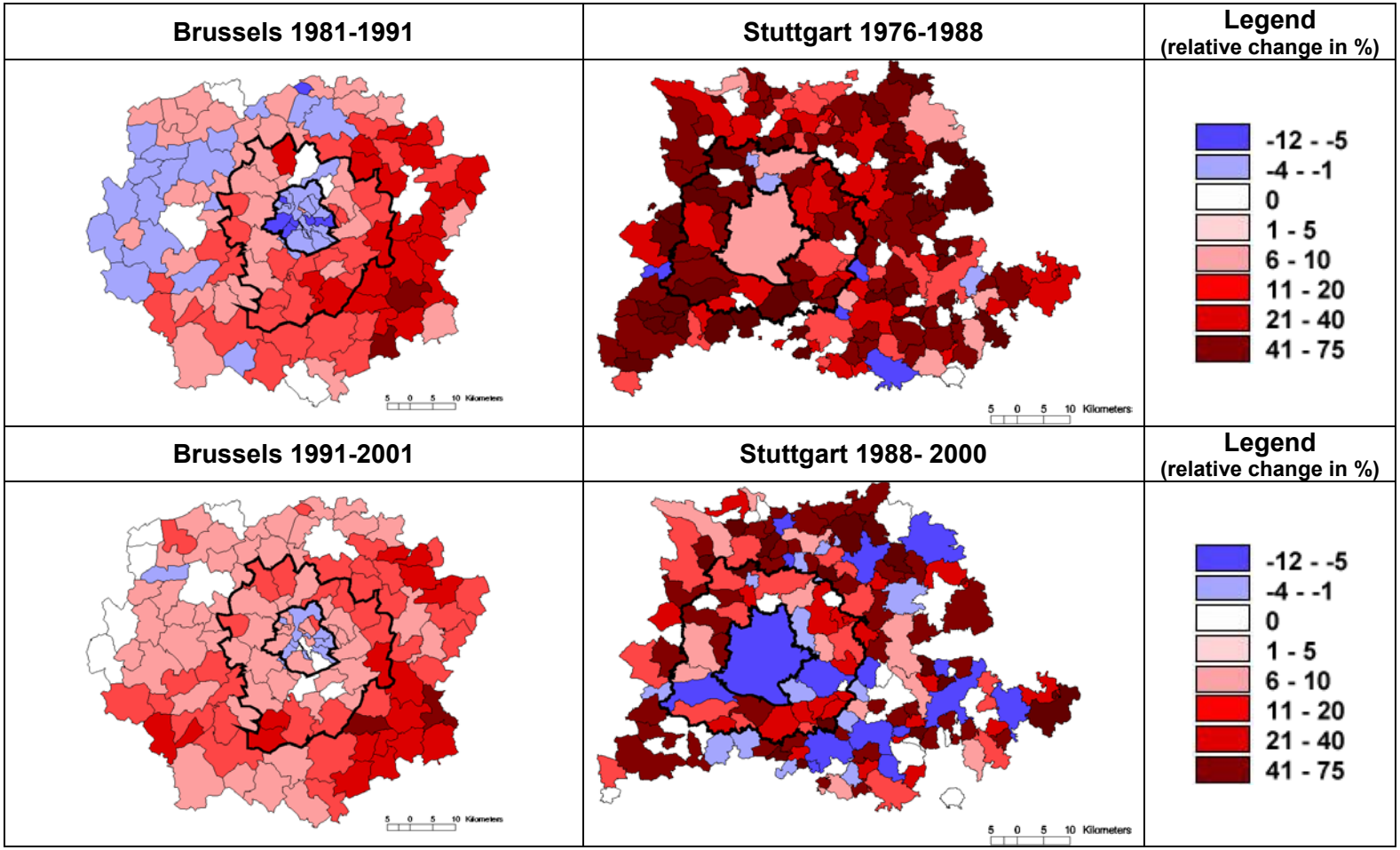


Figure 2c. Change in density of population by zone

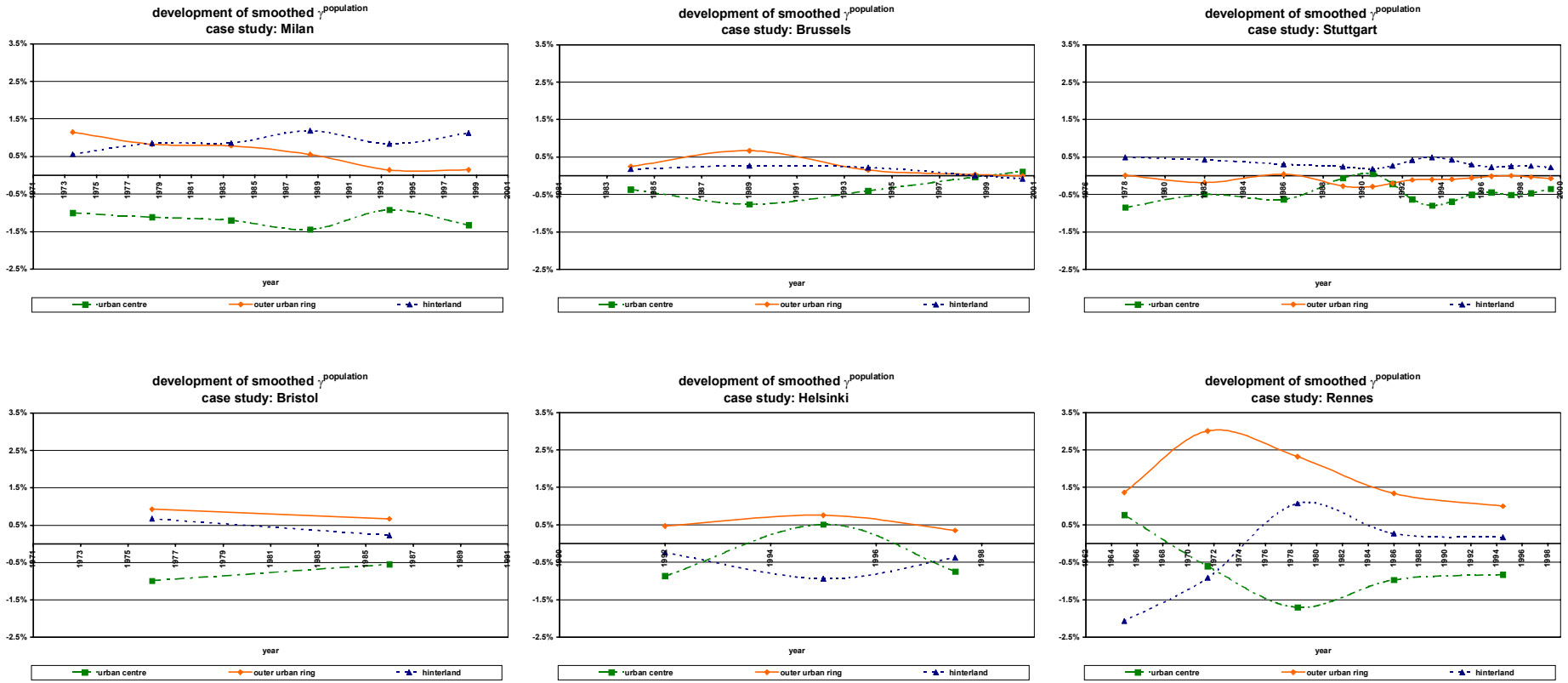


Figure 3. Deviation of the average growth path of $\tilde{\gamma}^{\text{population}}$

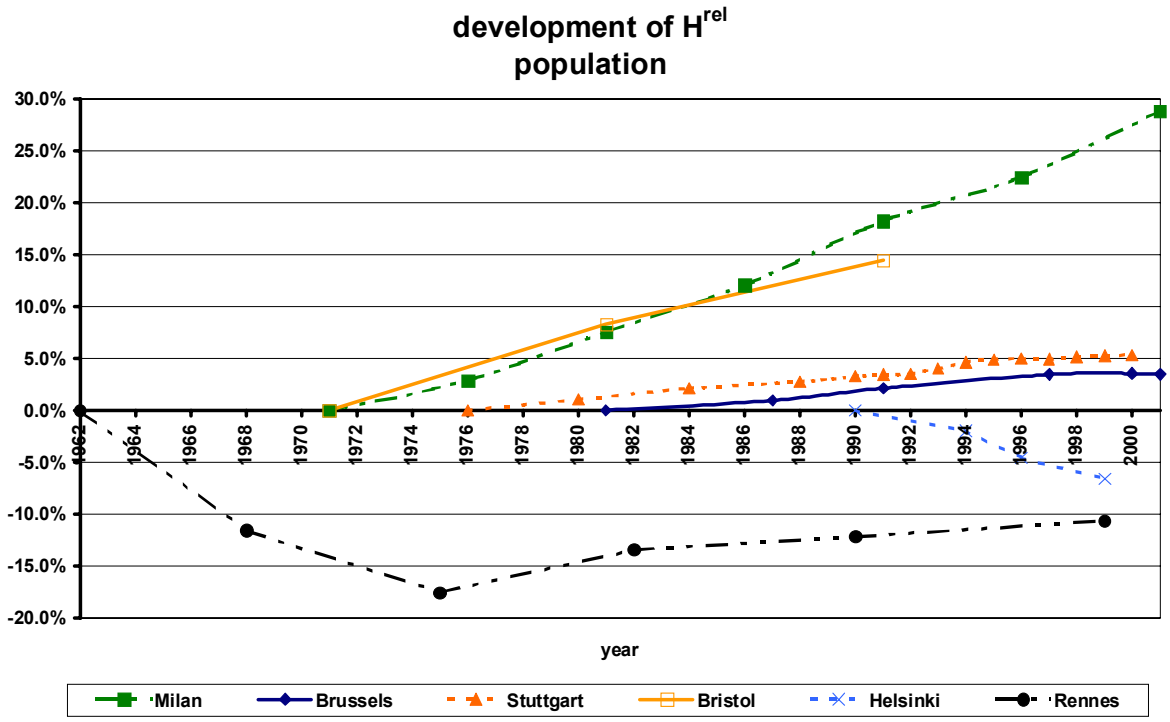


Figure 4. Concentration measure H^{rel} for population for all case studies

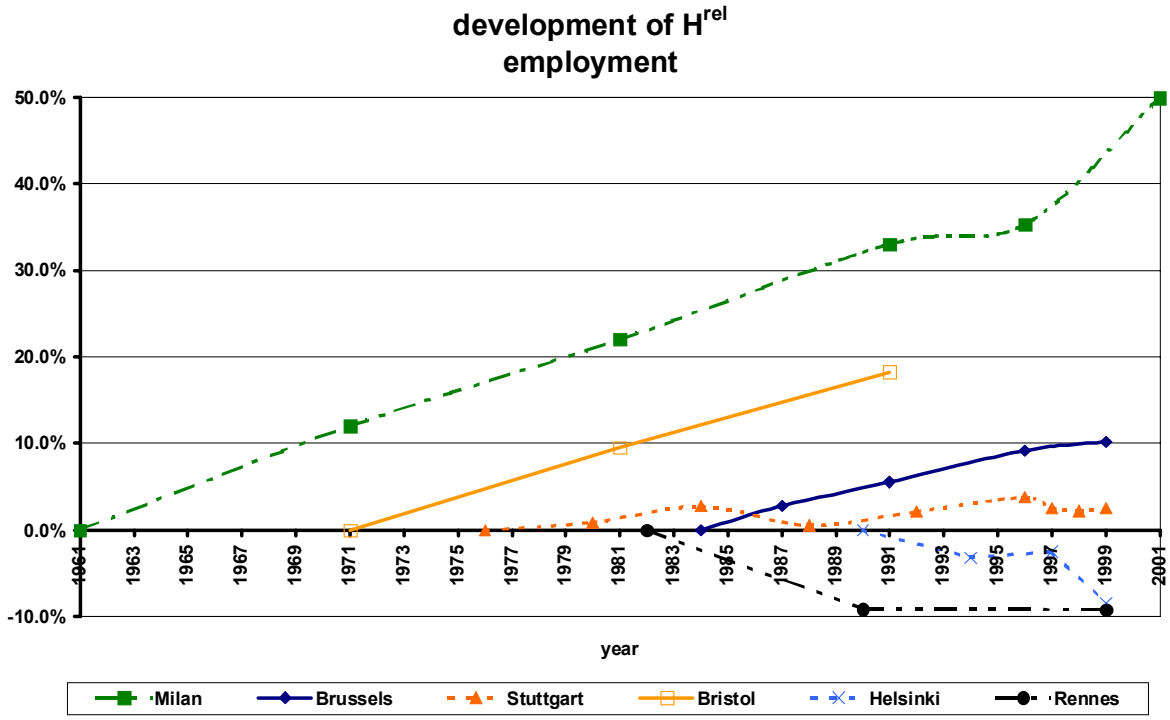


Figure 5. Concentration measure H^{rel} for employment for all case studies

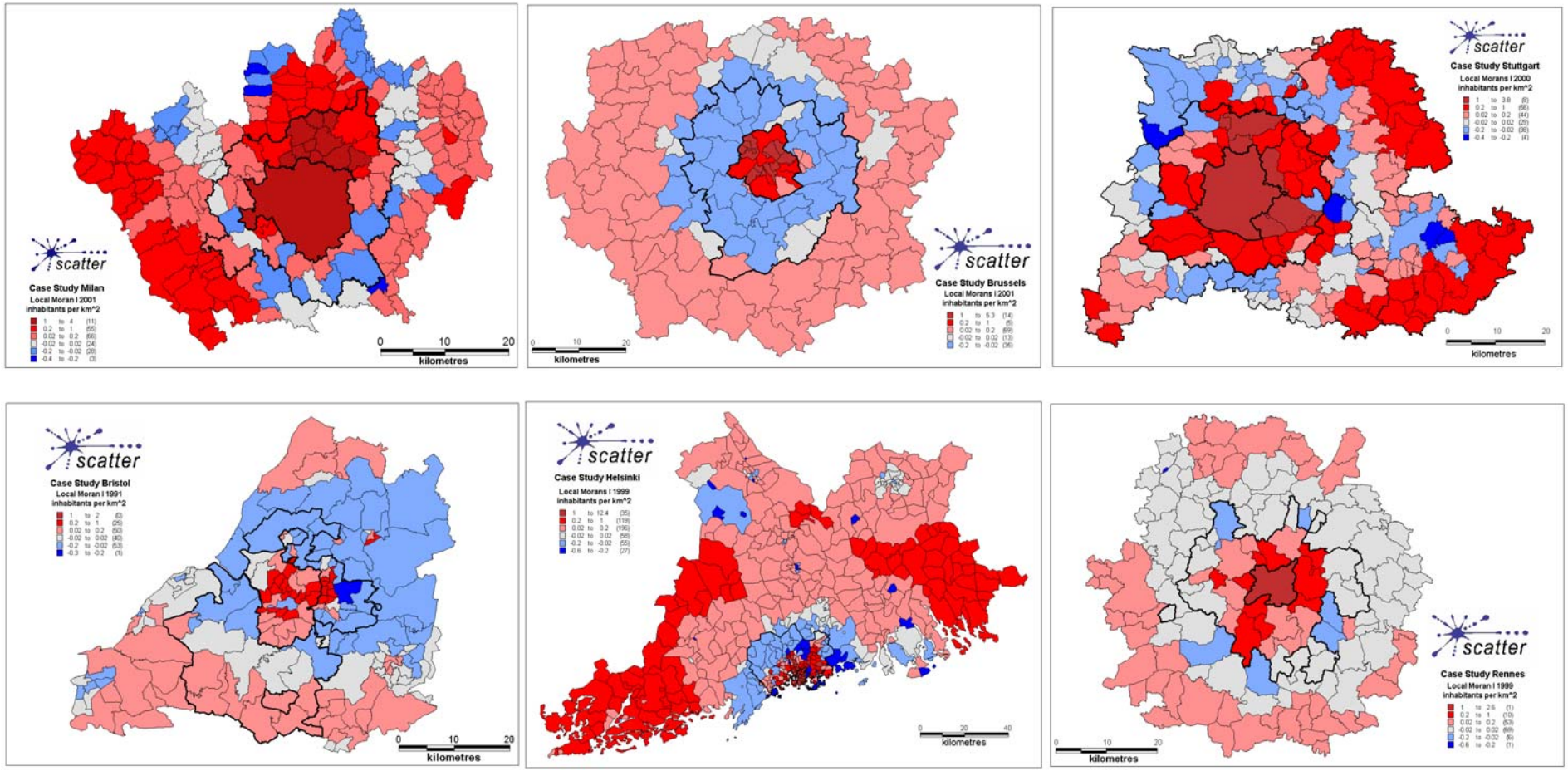


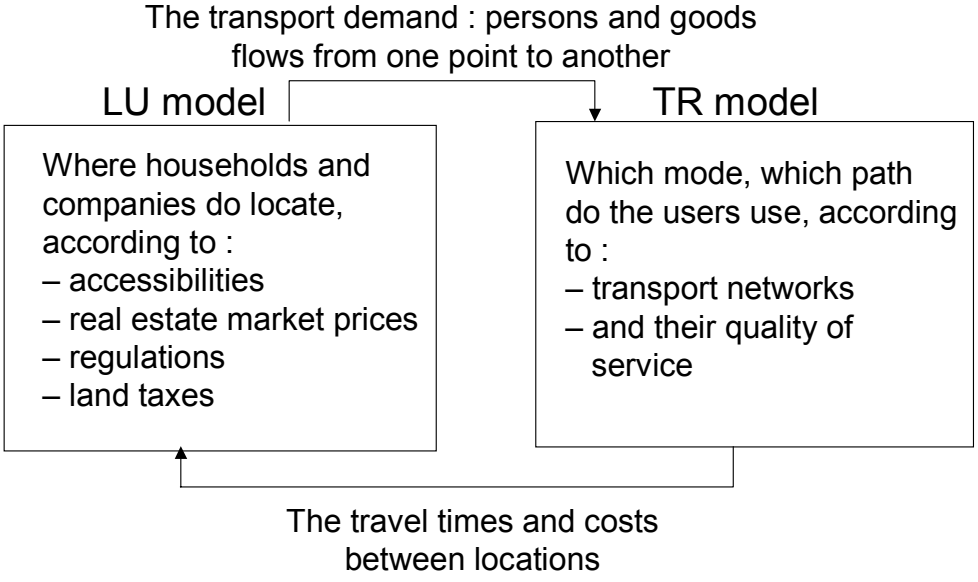
Figure 6. Spatial distribution of Local Moran *I* for inhabitants per km^2

7. QUANTITATIVE ASSESSMENT OF POLICIES BY SIMULATIONS WITH LAND-USE/TRANSPORT MODELS

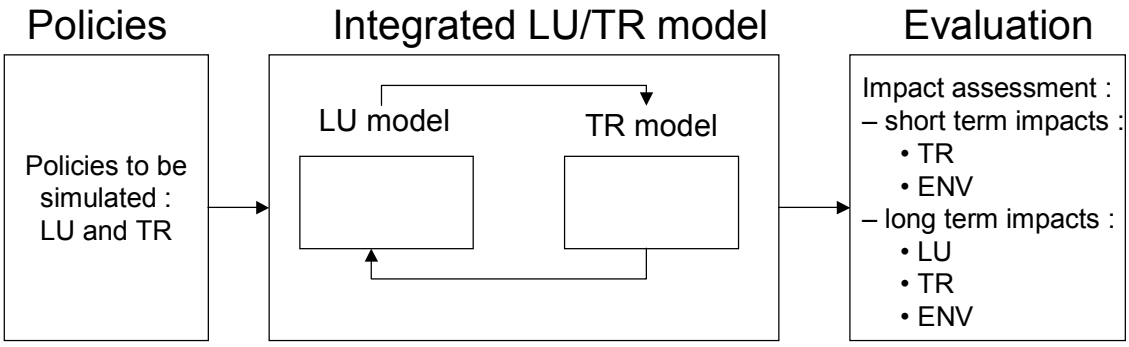
Integrated land-use/transport models are the most appropriate tool to properly analyse and assess the impacts of policies dealing with urban sprawl : indeed, they simulate the interactions between land-use and transport, in both directions, i.e. :

- the influence of land use on transport (modal shares, congestion, travel times and transport generalised costs) ;
- the influence of transport costs on location decisions by both households and companies; as the decrease of transport costs is one of the main causes of the sprawl of population and employment, this feature of the models is essential.

Urban/regional integrated LU/TR models (1/2)



Urban/regional integrated LU/TR models (2/2)



In all 3 case cities, the question of urban sprawl and accompanying measures for suburban public transport is quite topical. In Brussels, the authorities have decided to implement a new suburban express railway service ("*Réseau Express Régional*" or "R.E.R."), on the existing railway tracks, linking the suburbs to the central part of the metropolitan area. The main positive effect of this new efficient transport system will be a strong increase of the use of public transport in the entire area. But the expected negative effect is the acceleration of the out-migration of middle class and upper class families to the suburban area. In Stuttgart, the increasing suburban rail and light rail network had and will have socio-economic impacts as well as impacts on population redistribution, urban sprawl, commuting and modal shift. In Helsinki, due to sprawl, 1% growth in population of the metropolitan area causes 2% growth in car mileage; on the other hand, extension of the metro is planned and new rail investments were implemented recently.

Currently, only preliminary results from the Brussels case city are available. This section presents these results.

This part of the SCATTER project was co-funded by the European Commission, DG Research, the Administration of Equipment and Mobility (*Administration de l'Equipement et des Déplacements*) of the Brussels-Capital Region and the Belgian federal administration of Mobility and Transport (*Service Public Fédéral Mobilité et Transport*).

7.1 The Brussels case city : the RER project and the risk of a re-launch of the urban sprawl

Brussels is a metropolitan area of about 2.7 million inhabitants. Its central part, the so-called "Brussels-Capital Region", is an important administrative capital, grouping a little less than 1 million inhabitants. The Region has lost population for 30 years (about 120 000 inhabitants), while economic activities – with a rather stable total number of jobs (about 650 000) - were undergoing an important mutation : strong decline of industrial and heavy tertiary activities and strong growth of administrative functions. The result of this evolution is an increase in the number of daily commuters and traffic congestion.

The Regional Express Rail Network (RER) project aims to improve the global accessibility of Brussels by improving the rail services supply between the periphery and the city. Two basic principles are the guidelines of the project :

- firstly, the new suburban railway scheme will propose high capacity, rapid and frequent train services (9 new lines) to the commuters within a radius of about 30 km around the centre of Brussels;
- secondly, within the Brussels Region, the new lines will serve directly most of the high-density trip generating developments and redevelopments.

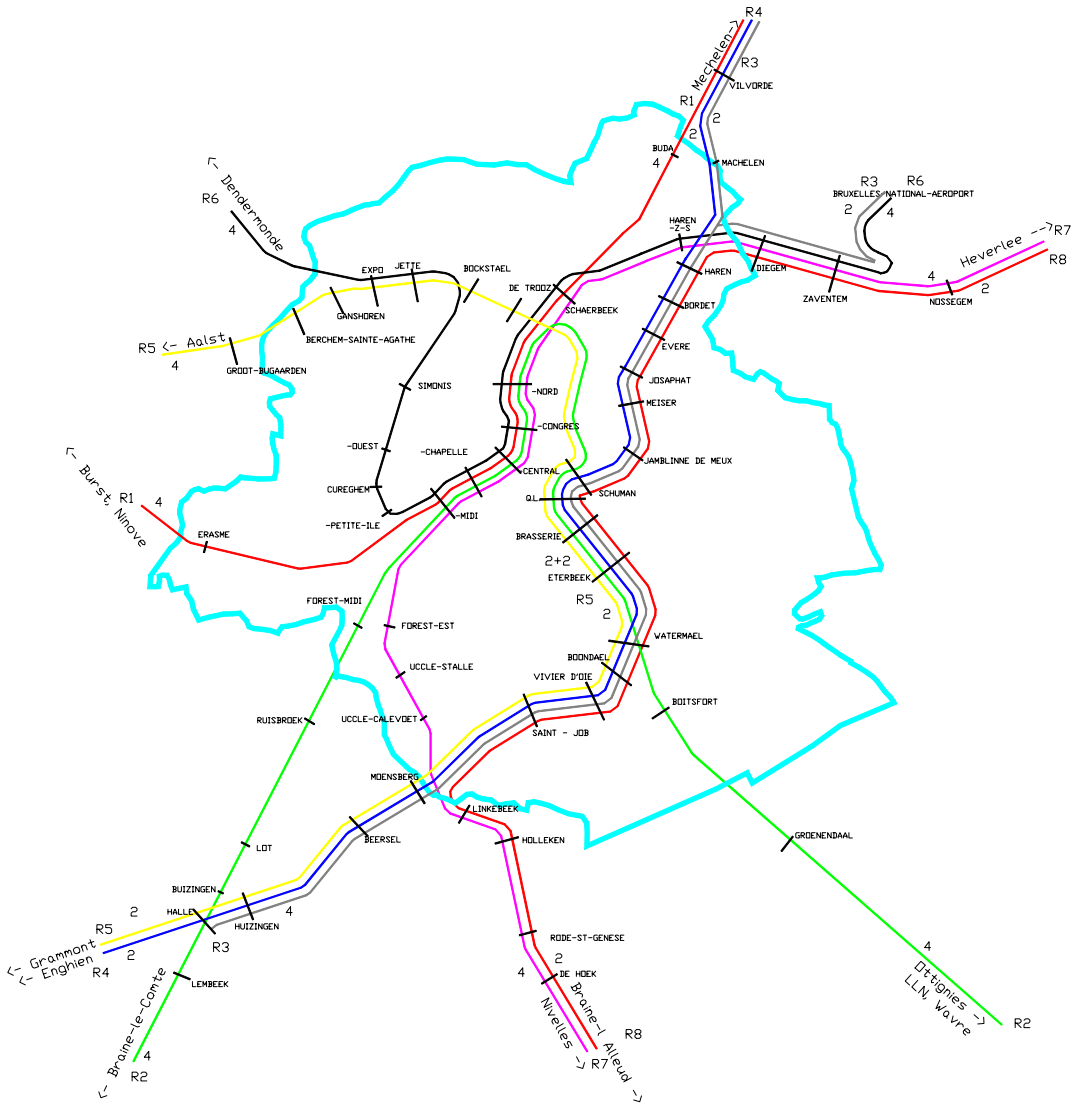


Figure 7 : The 9 lines of the RER of Brussels

The implementation of the RER goes with ambitious objectives as regards the modal shift from private car and the total number of RER passengers[3]. However, within the context of studies conducted about the RER, many experts and local authorities were afraid that long term indirect impacts of the RER project could re-launch urban sprawl and, consequently, induce a new reduction of the population of the Region and contribute to its impoverishment. This risk was partly confirmed by the ESTEEM study[4], which was co-funded by the European Commission, the Federal Government of Belgium and the Regional Government of Brussels. That study was realised through an integrated land use/transport model developed with the TRANUS software.

Therefore, the authorities decided, in 2000, to launch a new study, making use of the land use/transport modelling tool, and aiming to test and to fine tune a set of accompanying measures.

These accompanying measures have three objectives :

- ensure the quality of the whole public transport system through an integrated vision of the service to be delivered to the commuters from door to door ;
- remedy the external costs of congestion ;
- counterbalance the accelerating effect of the RER on the urban sprawl and reverse the process of central-city decay.

7.2 The integrated land-use/transport model of Brussels

The integrated land-use/transport model of the Brussels Metropolitan Area is built with the TRANUS software[5]. The initial version of the model has been developed in 1996 as part of the ESTEEM project, and has been used in several studies for federal, regional and local transport authorities, for the purpose of policy testing. For the PROPOLIS project[6], the Brussels model has been improved and updated, the study area has been slightly extended, and several additional households categories and socio-economic sectors have been added to the model to allow new policies to be tested. The model used in SCATTER is the version which was calibrated in PROPOLIS.

The basic principles underlying TRANUS are the economic theory of basic employment (Lowry), an input-output matrix (Leontieff), the random utility theory and the logit choice model specification (for mode choice, path choice as well as location choice), the generalised transport cost formulation, elastic consumption of land and/or floor space, and the general hypothesis of equilibrium.

The study area contains 135 municipalities (communes), centred on the Brussels-Capital Region and covering the whole territory that will be served by the future Regional Express Railway - thus including some middle-size neighbour cities : Leuven, Ottignies, Nivelles, Braine-le-Comte, Enghien, Aalst, Dendermonde, Mechelen. It spreads on about 4 400 km2, while the territory of the Brussels-Capital Region covers 161 km2.

The Brussels model comprises :

- 7 socio-economic segments of households, among which 5 are endogeneous[7]
- 13 economic activity sectors, among which 3 are endogeneous
- 3 land use types.

A first model was calibrated on the 2001 situation. Then a business-as-usual 2021 reference scenario was built exogeneously (outside the model), and a second model was calibrated against this exogeneous 2021 reference scenario, using all the behavioural coefficients which were calibrated in the 2001 model.

7.3 Accompanying measures which were tested and main preliminary results

The scenarios which have already been simulated are as follows :

- 2021 business-as-usual reference scenario (without the Regional Express Railway)
- 2021 RER scenario : RER only, without any accompanying measure
- 2021 measure scenarios : RER + accompanying measure(s) : numbered from 2.1 to 14.2

The accompanying measures are listed and defined in the tables below.

As outcomes of the simulations, some key indicators are given further below, in diagrams :

- number of induced (i.e. endogeneous) households in the Brussels-Capital Region
- number of induced households in the urban zones (whatever the Region)
- number of induced jobs in the Brussels-Capital Region
- number of induced jobs in the urban zones (whatever the Region)
- average travel time towards the Brussels-Capital Region for home-work trips, for active people from medium and high income households (all modes)
- average travel time towards the Brussels-Capital Region for home-work trips, for active people from low income households (all modes)
- total number of vehicle-km by car travelled in the morning peak-period (7h-9h), in the whole study area
- modal share of the public transport in the morning peak period, in the study area.

It is worth noting that the effects as regards travel times mainly result from the combination of two effects :

- the changes in the average trip distances
- and the modal shifts between on average faster modes (e.g. car) and on average slower modes (e.g. PT).

In all the diagrams below, the results are expressed as follows :

- the first bar expresses the effect of the scenario “2021 RER alone” compared to the scenario “2021 business-as-usual reference scenario (without RER)”
- the following bars express the effect of each scenario compared to the scenario “2021 RER alone”

These results are preliminary results, which will be refined in several ways :

- in the case of Brussels, further simulations will be carried out, either simulations with better adjusted values of parameters, or simulations combining several individual measures. The objective of these further simulations will be to optimise a package of measures, and offer decision-supporting results to the local/regional authorities ;

- similar simulations will be carried out with the Helsinki model and the Stuttgart model, which will allow a comparative analysis ;

- more sophisticated indicators will be calculated :

    - indicators which were set up in the statistical part of SCATTER (see section 6 above) : these express the extent of sprawl itself (H-measure, etc)
    - indicators from the evaluation framework which was set up in the PROPOLIS project : these express rather the environmental, social and economical effects of sprawl.

However, some comments can be made already.

As regards the measures specifically targeted to reduce urban sprawl (i.e. to increase the part of population located in urban zones), generally speaking, the territorial fiscal measures and the regulatory measures (scenarios 13 and 14) appear to be more efficient than the increase of car use cost (scenarios 10).

Increase of car use cost

Within the scenarios 10 (increase of car use cost), it is worth comparing the results of 10.2 (increase of the car use cost by 50 % on the whole study area) with those of 10.3 (cordon pricing) : both policies have a strong effect on the location of households (stronger effect for 10.3, but the supplement of cost applied is higher), but they have opposite effects as regards employment : the employment tends to re-centralise when the car use cost increases everywhere, because in that case, the central agglomeration, better served by PT and more generally by radial-form transport networks, remains the most efficient place where to be, but the employment tends to move outside the cordon when a cordon pricing is implemented. Anyway, in both scenarios, the average home-work trip distance decreases.

As regards the use of private car, the scenario 10.2 (increase by 50 % of the car use cost) leads to a decrease of about 1 200 000 vehicle-km : it is among the most efficient measures, together with the parking restriction policies (see scenarios 2.2 and 2.3).

Regulation of land use by fiscal or regulatory measures

The measures simulated in the scenarios 13 (development impact fee applied to households in suburban/rural areas and fiscal incentive applied to households in the urban areas) directly affect the cost of location for the households and hence, have a significant effect on the part of population located in urban zones. In particular they significantly increase the number of households in the Brussels-Capital Region (BCR), which in turn attracts employment induced by the households. The average ratio is about 0.25 induced job attracted in the BCR/induced household locating in the BCR.

The scenario 14.1.1 has a very low effect, while the scenario14.1.2 has an extremely high, unrealistic effect : this is due to the definition of the scenarios themselves (too few jobs affected by the measure in 14.1.1, too many affected in 14.1.2). These definitions will be adjusted in later simulations. The scenario 14.2, on the contrary, leads to sensible results : the measure directly affects the cost of location for the jobs in the sector “business services”. As a consequence, the number of induced jobs significantly increases in the Brussels-Capital Region, which in turns attracts households. Here, the average ratio is about 0.6 induced household attracted in the BCR/induced job locating in the BCR.

These ratios of course depend of the values of the policy variables and of the general context (i.e. the other parameters) and cannot be generalised, but it can be nevertheless already noted, at this stage, that in the case of Brussels, the “indirect” effects (on households) of measures directly attracting employment appear to be higher than the “indirect” effects (on employment) of measures directly attracting households.

Both series of scenarios 13 and 14 have minor effects on transport, and in particular on the number of vehicle-km travelled by car.

Improvement of the residential urban environment through traffic calming

This measure especially targeted to families is expressed through the scenarios 11.1 and 12.1 (see the table for the precise definition of the scenarios). Globally, the sum of the 2 scenarios lead well to a slight increase of households in the Brussels-Capital Region, but the effects on the number of households and on employment are lower than the scenarios 13 and 14.

Transport measures decreasing the generalised transport cost

Generally speaking, all the measures decreasing the generalised transport cost lead to an increase of the urban sprawl, i.e. a decrease of the part of population locating in the urban zones : as mentioned in the section 1 of this paper, the decrease of the generalised transport cost is indeed one of the main causes of sprawl. This concerns in particular the scenarios 7 (improving intermodality at railway stations), 8 (optimising the transport networks driving users towards the RER) and the scenarios 9 (changes in the fares of PT). On the contrary, the scenario 5.1 in which PT speed is improved only on the

territory of the Brussels-Capital-Region leads to an increase of both households and employment in the Capital Region. In the scenarios 4 (HOV lanes, implementation of express buses + decrease of road capacity on the main radial roads), the combination of the improvement of PT (including in the central agglomeration) and of the lower road capacity leads to a slight increase of households in the Brussels-Capital Region.

Parking policies

Generally speaking, the simulation results confirm that strong parking restriction measures can put to flight tertiary employment.

The results of the scenarios 2.1 to 2.3 highlight the fact that the effects of the measures are quite different, as regards the attractiveness of the central agglomeration, according to whether the restriction measures are applied essentially to the Brussels-Capital Region or as well to the urban centres in the periphery. In the former case (see scenario 2.1), the measure leads to a decrease of employment in the Brussels-Capital Region, and a loss of economic vitality. In the latter case (see scenario 2.3), the central position of the agglomeration makes it more attractive than the other urban centres, and the Brussels-Capital Region is winner in this competition.

Table 1 - Scenarios tested in the case city of Brussels : accompanying measures to the RER (scenarios tested so far)

Transport measures contributing to reduce urban sprawl

	INCREASE OF CAR USE COST
10.1	Measure applied to drivers using a company car Increase by 100 % of the cost per km
10.2	Measure applied to all drivers Increase by 50 % of the cost per km
10.3	Measure applied to all drivers Cordon pricing (the cordon is located just inside the Ring road which surrounds the Brussels-Capital Region and some adjacent communes) ; tariff : 7.5 €/day

Land-use measures aiming to reduce or control urban sprawl

	TERRITORIAL FISCALITY MEASURES APPLIED TO HOUSEHOLDS
13.1	Fiscal incentive (annual tax reduction) for households locating in the inner city within the Brussels-Capital Region (5 communes in all) + Annual tax applied on households locating in all the other zones (similar to a development impact fee). The fiscal incentive is1985 €/household/year. The tax was calculated so that the net cost of the measure for the government is zero, i.e. the tax is about 215 €/household/year. The measure is applied to all the households.
13.2	Same than 13.1 but the definition of urban zones (where households benefit a fiscal reduction) is extended to 7 urban centres in the periphery of Brussels The fiscal incentive is still 1985 €/household/year. The tax is higher (345 €/household/year), since more revenue is needed to be redistributed to the urban households and the tax is applied to less households. (Note that a further estimation of the external costs of suburbanisation led in the case of Brussels to an average value of 670 €/household/year. A development impact fee with such a level has been simulated in a later stage.)
	TERRITORIAL FISCALITY MEASURES AND REGULATORY MEASURES APPLIED TO COMPANIES, INSPIRED FROM THE ABC THEORY
14.1.1	ABC-type policy applied to a part of the tertiary sector

	Regulatory measure applied to the sector “business services” : obligation to locate in A-type zone, i.e. a zone served by high quality public transport at regional scale. In this case, A-zones are defined as zones having an InterCity-InterRegion railway station. There are A-zones in the Brussels-Capital Region as well as in the periphery. The measure is applied to all offices which changed their location after the RER was implemented.
14.1.2	Same than 14.1.1, but the measure is applied to all offices
14.2	ABC-type policy applied to a part of the tertiary sector Fiscal measure applied to the sector “business services” : annual tax applied to companies locating in a non-A zone. The tax is 1985 €/job/year (i.e. about the cost of an annual PT season ticket)
	IMPROVEMENT OF THE URBAN RESIDENTIAL ENVIRONMENT + SPECIALISATION OF THE URBAN ROAD NETWORK
12.1	Improvement of the quality of life in the residential neighbourhoods in the inner city within the Brussels-Capital Region (5 communes), through diversion of the transit traffic, traffic calming, greening, improving the safety for children
11.1	Implementation of a hierarchy in the road network of the Brussels-Capital Region, together with a reduction of the network capacity (measure recommended by the Regional Mobility Master Plan) This measure is a necessary corollary of the previous measure 12.1 : 11.1 and 12.1 must be implemented together.

Other transport measures aiming to reduce the use of car

Roughly these measures are designed to maximise the modal shift from car to the Regional Express railway and, hence, to reduce some of the negative effects of the previous wave of sprawl (congestion, pollution). However, some of them could re-launch the suburbanisation process.

	PARKING POLICIES

2.1	Strong capacity restriction in the inner city ; no increase in the parking tariff
	
	The whole study area is divided in 2 area types :
	
	- type 1 : inner city (8 communes) :
	  - parking capacity restriction : 1 place for 8 jobs
	  - parking tariff : base price (2001 price)
	- type 2 : rest of the study area :

	- parking capacity restriction : 1 place for 2 jobs - parking tariff : base price (2001 price)

2.2	Strong capacity restriction in the inner city + increase in the parking tariff
	
	The whole study area is divided in 2 area types :
	
	- type 1 : inner city (8 communes) :
	  - parking capacity restriction : 1 place for 8 jobs
	  - parking tariff : long term (home-work trips) : 12.5 €/day ; short term : 6.25 €/day
	- type 2 : rest of the study area :
	  - parking capacity restriction : 1 place for 2 jobs
	  - parking tariff : long term (home-work trips) : 6.25 €/day ; short term : charge free

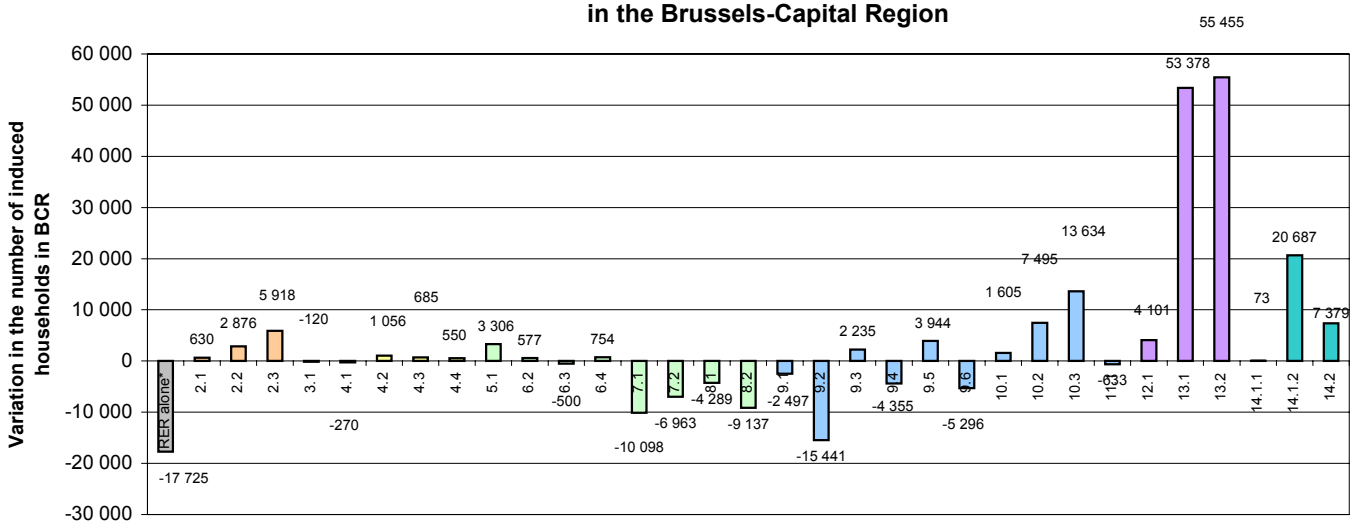
2.3	Strong capacity restriction + increase in the parking tariff, both in the inner city and in the urban centres of the periphery
	
	The whole study area is divided in 2 area types :
	
	- type 1 : inner city (8 communes) + urban centres of the periphery (15 communes) :
	  - parking capacity restriction : 1 place for 8 jobs
	  - parking tariff : long term (home-work trips) : 12.5 €/day ; short term : 6.25 €/day
	- type 2 : rest of the study area :
	  - parking capacity restriction : 1 place for 2 jobs
	  - parking tariff : long term (home-work trips) : 6.25 €/day ; short term : charge free

3.1	New regulation regarding parking facilities in the new office buildings The whole study area is divided in 2 area types : - type 1 : inner city (8 communes) + urban centres of the periphery (15 communes) : suppression of the capacity corresponding to the off-street parking facilities (only the on-street capacity remains available) - type 2 : rest of the study area : no change compared to the 2021 reference situation
	REDUCTION OF THE CAPACITY OF THE MAIN RADIAL ROADS, FOR THE BENEFIT OF HIGH OCCUPANCY VEHICLES (CAR POOLING) AND PUBLIC TRANSPORT
4.1	Lanes dedicated to High Occupancy Vehicles (HOV) Implementation of lanes dedicated to HOV (with 2 or more passengers) on 5 radial motorways leading to Brussels (E40 Eastern

	branch, E40 Western branch, E411, E19 Northern Branch, E19 Southern branch) + consequently : reduction of the motorway capacity for the private cars with single occupant
4.2	RER-bus (*Réseau Express Régional bus*) Implementation of lanes dedicated to regional express buses on radial highways leading to Brussels (average bus commercial speed : 24 km/h inside agglomerations, 30 km/h outside agglomerations, frequency : 4 buses/hour in one direction) + consequently : reduction of the highway capacity for the private cars In all, the new regional express bus lines amount to 19 lines.
4.3	Same scenario than 4.2 but the bus speed in areas outside agglomerations is 45 km/h (instead of 30 km/h)
4.4	Lanes dedicated to HOV + lanes dedicated to the regional express buses = Scenario 4.1 + scenario 4.3
	INCREASING THE SPEED OF SURFACE PUBLIC TRANSPORT
5.1	Increase of the speed of surface PT (bus and tramways) in the Brussels-Capital Region to 18 km/h (increase of the speed by 38 %) (the speed improvement could be e.g. obtained through rules giving priority to PT at the crossroads with traffic lights)
	IMPLEMENTATION OF PARK & RIDE FACILITIES
6.2	Parking facilities located at the RER stations At the stations located at the ends of the branches : no capacity restriction ; at the other stations : capacity restricted to the use in the 2021 reference scenario In all cases : charge free parking
6.3	Combination of scenario 6.2 and scenario 4.4 Parking facilities located at RER stations, at the express bus stations and at the end of the HOV lanes (same rules than in 6.2)
6.4	Parking facilities located at the RER stations Same than 6.2 + tariff : charge free parking at the ends of the branches ; 6.25 €/day at the other stations
	IMPROVING INTERMODALITY AT RAILWAY STATIONS
7.1	Decrease of the access time to rail stations located in the periphery by 5 minutes, whatever the access mode
7.2	Same than 7.1 + tariff for parking at the end of the RER branches : 6.25 €/day (+ at the intermediary stations, non located at the end

	of branches : capacity restricted to the use in the 2021 reference scenario)
	OPTIMISING THE TRANSPORT NETWORKS DRIVING USERS TOWARDS THE RER
8.1	Increase of the commercial speed of the local buses driving the users towards the RER stations by 20 %
8.2	Alternative operating scheme for the Regional Railway Express : “goose foot” type operating scheme instead of a radial-type operating scheme Compared to the radial scheme (which is the reference scheme included in all the other simulations), the “goose foot” type operating scheme better serves the secondary urban centres located in the periphery and offers higher levels of service for the tangential trips from periphery to periphery.
	CHANGES IN THE FARES OF PUBLIC TRANSPORT
9.1	Measure applied to low income households, for home-work trips Fare : - 20 %
9.2	Measure applied to low income households, for home-work trips Fare : - 100 % (charge free public transport)
9.3	Measure applied to low income households, for home-work trips Fare : + 20 %
9.4	Measure applied to all users making home-work trips Fare : - 20 %
9.5	Measure applied to all users making home-work trips Fare : + 20 %
9.6	Measure applied to all users (home-work trips + other purposes) apart from the scholars/students Fare : - 20 %

Fig. 8 : Effect of the measures on the number of induced households in the Brussels-Capital Region

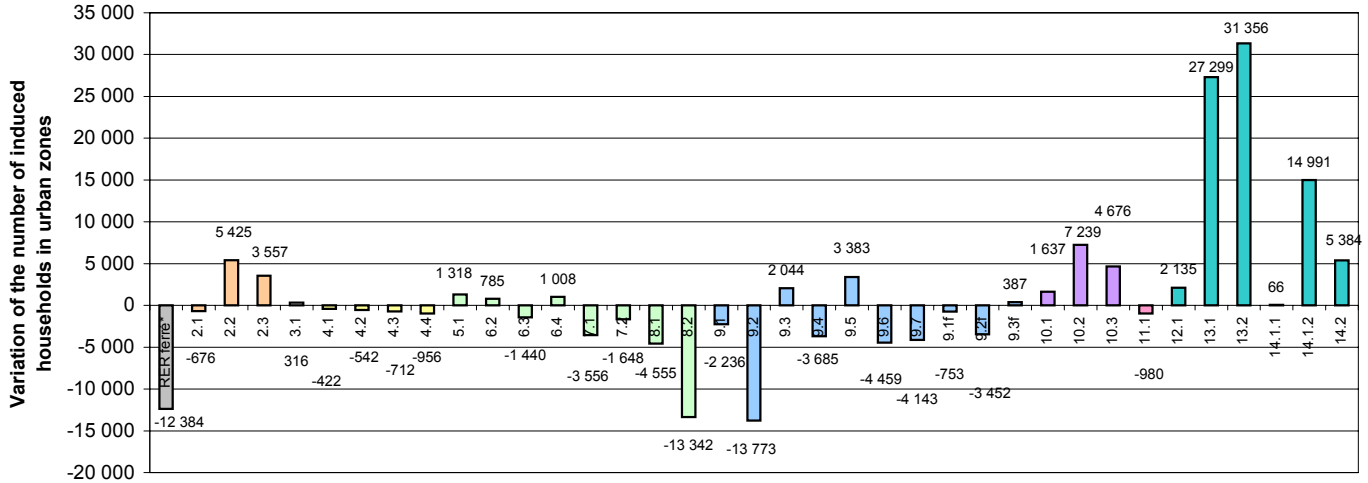


Scenarios :

- 2021 RER alone
- Parking restriction
- HOV lanes, regional express buses (RER bus)
- PT quality of service and intermodality
- PT fare
- Car use cost
- Specialisation of the road network
- Land use

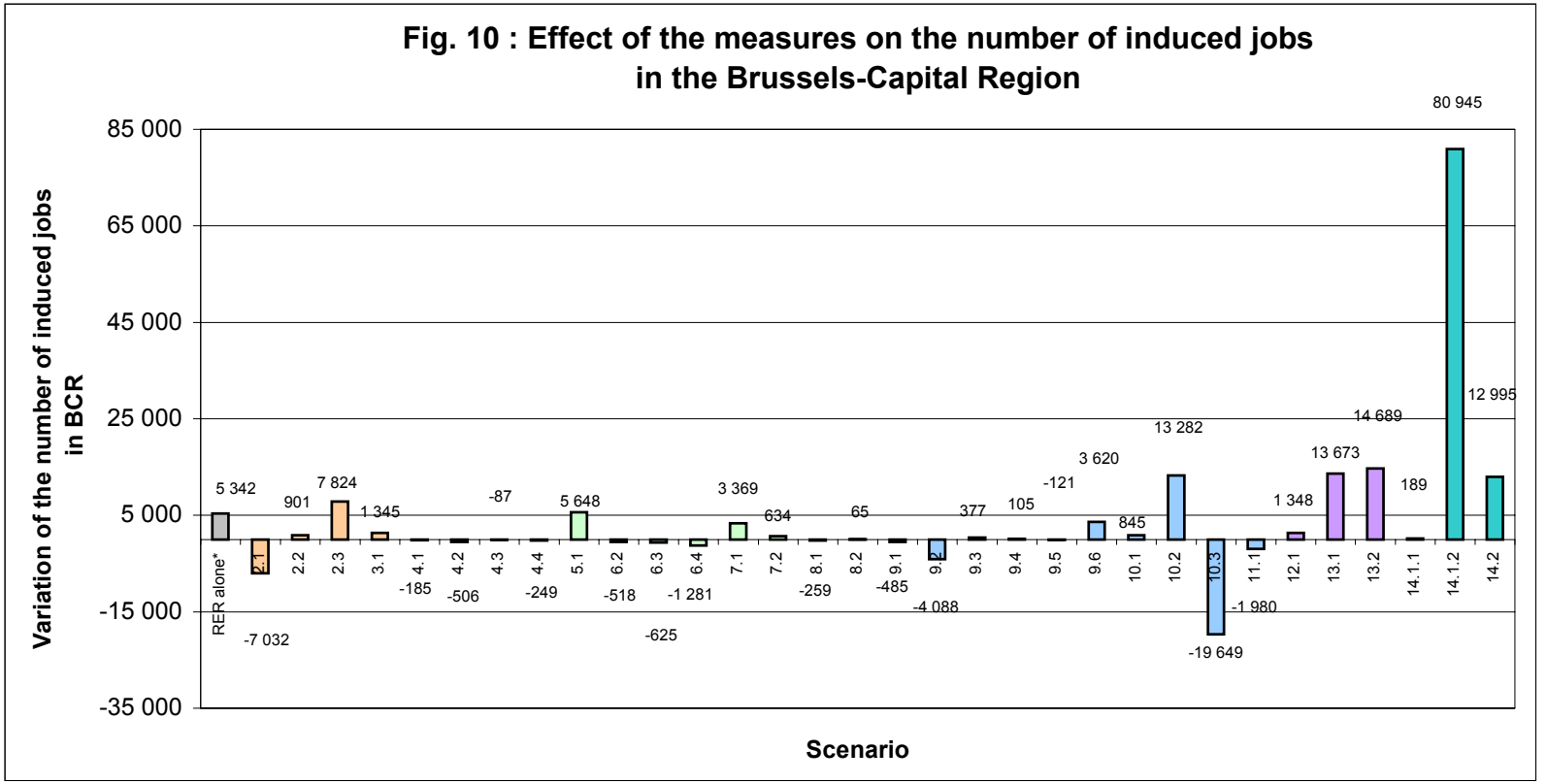
* The effect of the RER is calculated by comparison with the 2021 reference scenario without RER.
The effect of the other scenarios is calculated by comparison with the scenario 2021 with RER.

Fig. 9: Effect of the measures on the number of induced households in urban zones



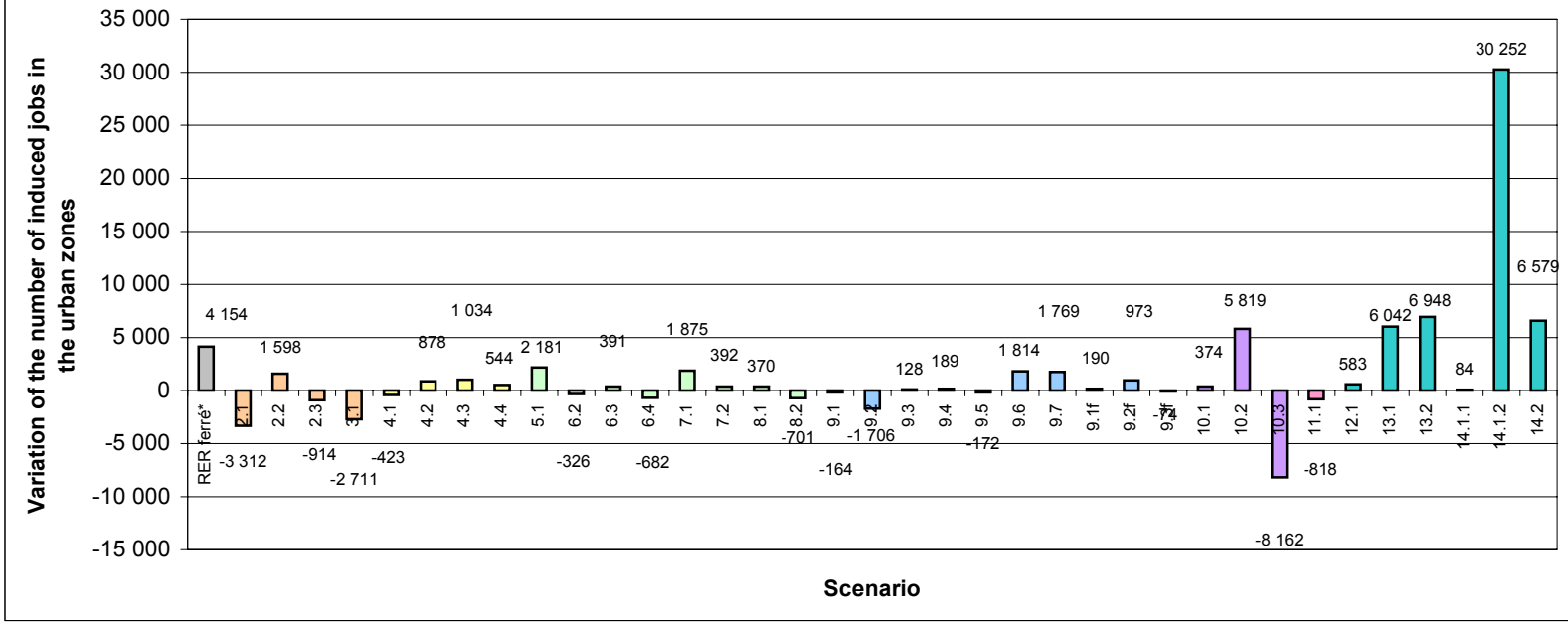
* The effect of the RER is calculated by comparison with the 2021 reference scenario without RER.
The effect of the other scenarios is calculated by comparison with the scenario 2021 with RER.

Fig. 10 : Effect of the measures on the number of induced jobs in the Brussels-Capital Region



* The effect of the RER is calculated by comparison with the 2021 reference scenario without RER.
The effect of the other scenarios is calculated by comparison with the scenario 2021 with RER.

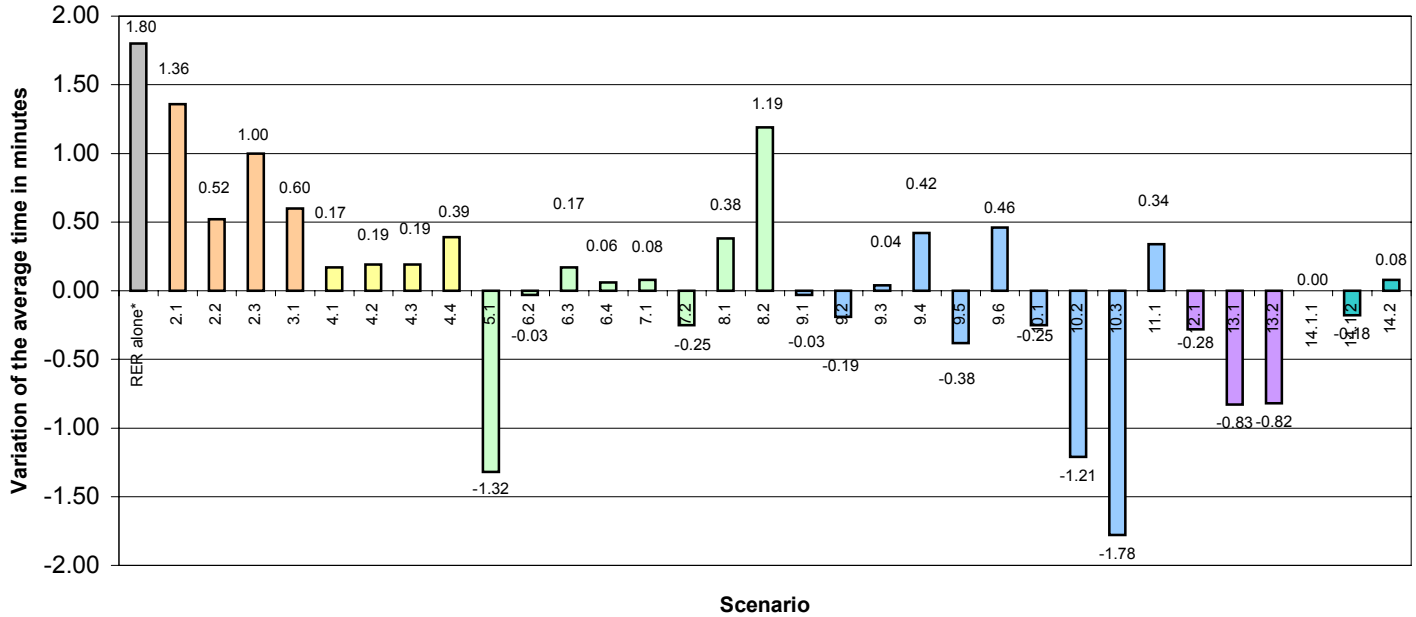
Fig. 11: Effect of the measures on the number of induced jobs in the urban zones



* The effect of the RER is calculated by comparison with the 2021 reference scenario without RER.
The effect of the other scenarios is calculated by comparison with the scenario 2021 with RER.

Fig.12 : Effect of the measures on the average home-work travel times towards BCR for medium-high income households

(inter-zonal trips at the morning peak period (7h-9h) towards BCR, except commuters from outside and out-going)

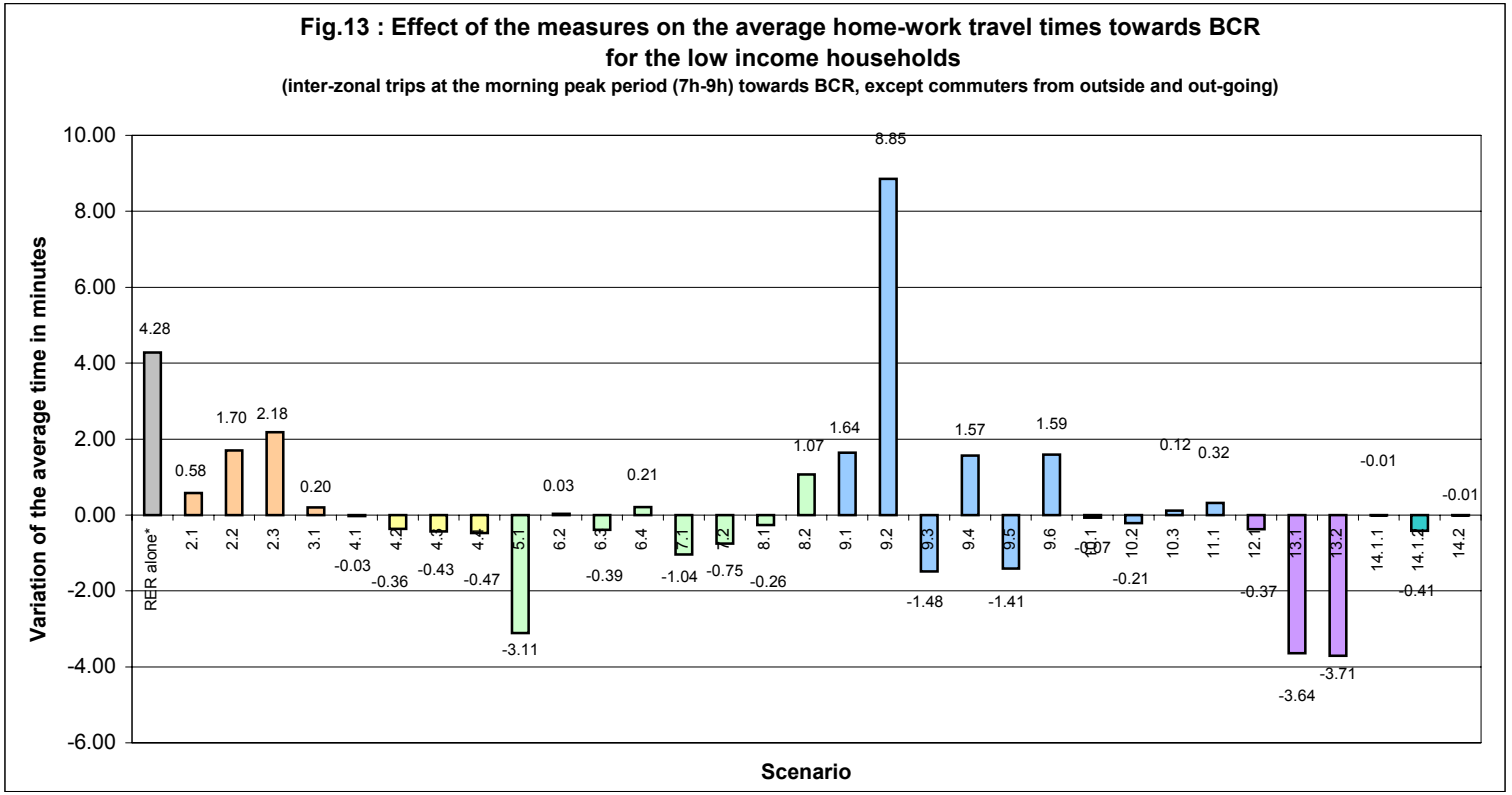


Remark : 0.5 min variation in the average time for these households represents a variation by 1.4 % compared to the 2021 scenario with RER alone.

* The effect of the RER is calculated by comparison with the 2021 reference scenario without RER.
The effect of the other scenarios is calculated by comparison with the scenario 2021 with RER.

Fig.13 : Effect of the measures on the average home-work travel times towards BCR for the low income households

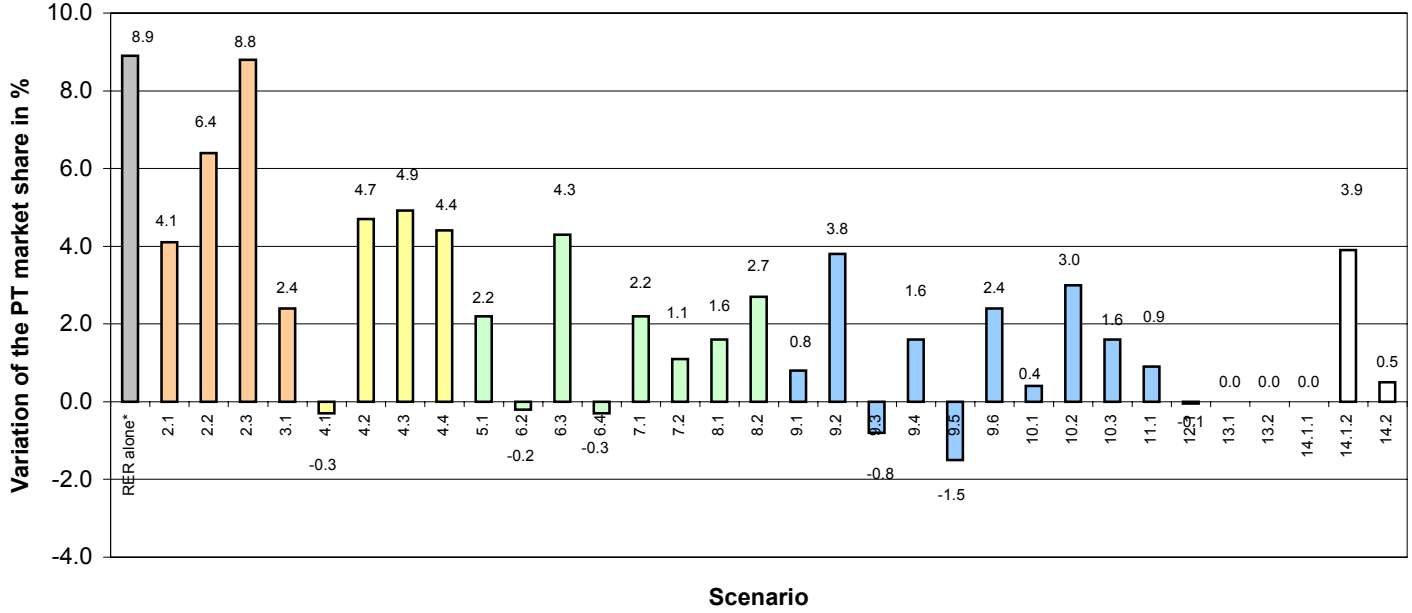
(inter-zonal trips at the morning peak period (7h-9h) towards BCR, except commuters from outside and out-going)



Remark : 2 min variation in the average time for these households represents a variation by 4.5 % compared to the 2021 scenario with RER alone.

* The effect of the RER is calculated by comparison with the 2021 reference scenario without RER.
The effect of the other scenarios is calculated by comparison with the scenario 2021 with RER.

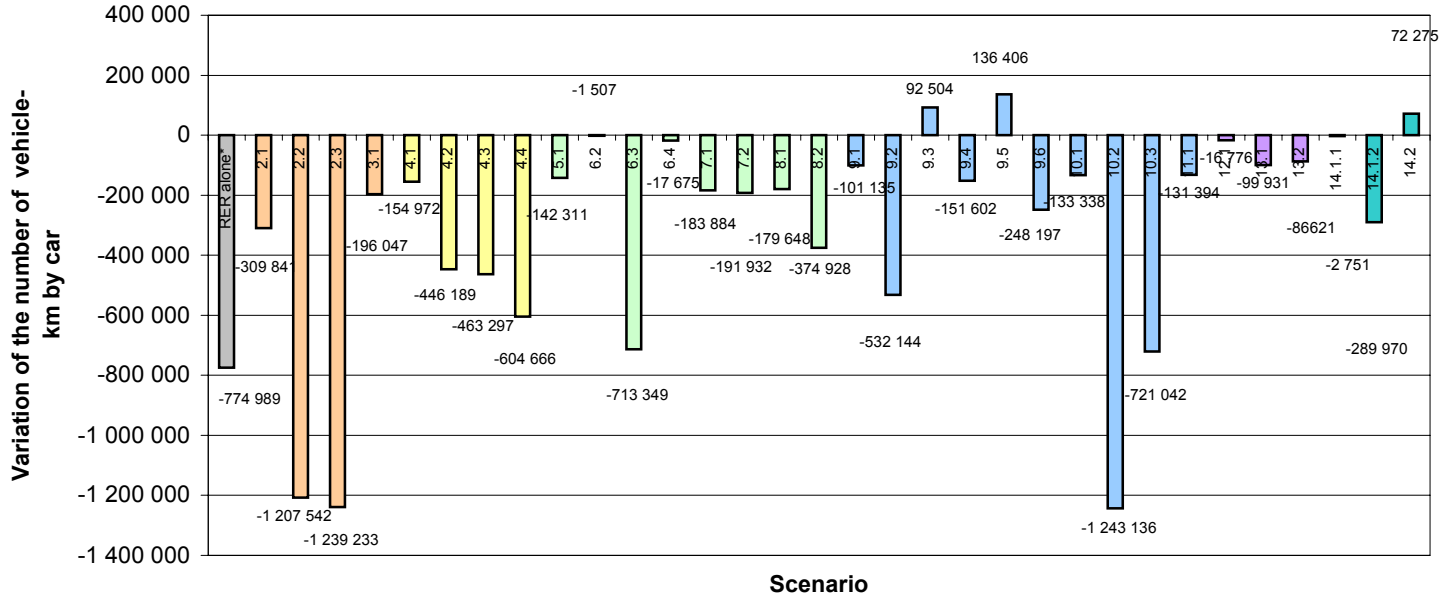
Fig. 14 : Effect of the measures on the market share of public transport in the study area



* The effect of the RER is calculated by comparison with the 2021 reference scenario without RER.
The effect of the other scenarios is calculated by comparison with the scenario 2021 with RER.

Fig. 15 : Effect of the measures on the number of vehicle-km travelled by car in the study area

(morning peak period (7h-9h), all trip purposes, including commuters from outside and out-going)



* The effect of the RER is calculated by comparison with the 2021 reference scenario without RER.

The effect of the other scenarios is calculated by comparison with the scenario 2021 with RER.

8. CONCLUSIONS

At two thirds of the project life, some conclusions already emerge. Urban sprawl is a complex and highly multi-dimensional phenomenon, involving many private and public players. Political decision-makers, as well as researchers, are now aware of this complexity, as well as of the negative effects of sprawl.

The statistical analysis showed that well-designed statistical indicators can contribute to quantify urban sprawl and that sprawling cities exhibit de-concentration behaviours characterised by different modalities. Statistical indicators may thus help authorities to better distinguish the local specificities and to better fit their actions.

On the other hand, integrated simulation tools able to highlight the long term effects of policies are a much valuable decision-support tool to build an integrated strategy to tackle urban sprawl : these simulation tools allow the assessment of isolated policies, the comparison between the impacts of alternative policies, and possibly the optimisation of a package of policies.

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NOTES

[1]Historically, the urban sprawl phenomenon was first a peculiarly British and American phenomenon, due probably to the relatively lower density of cities in both Britain and America and to the notion that home-ownership with a garden are core values of the Anglo-Saxon heritage. In continental European, the conditions for urban growth have more recently begun to mirror those in Britain and North America. Towns in continental Europe have tended to remain more compact with higher and more uniform densities.
As an illustration, between the 70s and 80s, 'growth management' legislation started in several American States leading to an attempt to control the spread of urbanisation. In the same time, in European countries, there was the first important wave of uncontrolled sprawl.

[2]The sustainability concept is made up of three components : environment, economy, social aspects.

[3]For more detail see the paper "Designing accompanying measures for the suburban railway scheme of Brussels", AET Conference 2001, F. Boon, H. Duchâteau, S. Gayda, STRATEC.

[4]ESTEEM : European Scenarios on Transport - Energy - Environment for Metropolitan Areas, European Commission, DG Research, project of the 4th Framework Programme

[5]The TRANUS software has been developed by the Professor Tomas de la Barra, Venezuela, whose company is MODELISTICA (www.modelistica.com).

[6]PROPOLIS : Planning and Research of Policies for Land Use and Transport for Increasing Urban Sustainability, European Commission, DG Research, 5th Framework Programme (www.ltcon.fi/propolis)

[7]"Induced" or "endogeneous" households or jobs : it means that the spatial distribution of these households or jobs among the zones of the model is generated by the model, as a function of the maximisation of utility by the households and the companies.

[8]The ABC policy which was designed in The Netherlands is based on a typology of the activity sectors, founded on the needs in transport and the transport demand induced by the sector, and a typology of locations (A, B, C locations), founded on the level of accessibility of the locations by road and by PT. The ABC policy consists in achieving a proper match between the types of activities and the types of locations, which could be summarised by " the right activity at the right place". For example, according to that policy, offices inducing a large amount of home-work trips or visitors trips, but which do not need fret transport by road, must locate in central areas served by high quality public transport. Practically, the ABC policy is therefore a regulatory policy.

[9]The home-work trips of the low-income households represent 15.3 % of the inter-zonal trips at the morning peak-period (7h-9h) ; the home-work trips of the medium and high income households represent 37.1 %.