10. QUANTITATIVE EVALUATION OF POLICIES : POLICY TESTING BY SIMULATIONS WITH INTEGRATED LAND-USE/TRANSPORT MODELS

10.1. Introduction

This section presents the results of the simulations of policies aiming to reduce urban sprawl and the results of the policy impact assessment. The simulations were achieved in three case cities: Brussels, Helsinki and Stuttgart, using integrated land-use/transport models.

In the 3 case cities, new regional-level public transport infrastructures or services will be implemented (in Brussels and Helsinki) or were implemented these last years (in Stuttgart). The question is first to assess to what extent these investments could launch (or launched) an urban sprawl process, by providing faster (and/or cheaper) access to the city centre from the suburban areas. Then, the next question is which accompanying measures implement to go against, or simply reduce, the expected relocation of activities and population, if it is shown that it would have negative effects.

The land-use/transport models which have been used are most appropriate tools for evaluating the effectiveness of policies against urban sprawl, as they simulate the interactions between the transport subsystem and the land use subsystem. They make it possible to assess long term impacts of (transport or land use) policies on the spatial structure of activities and population and on the mobility pattern (travel times, distances, etc.).

The following sub-section gives the definition of the measures which were simulated (the *common* measures[1] which were tested in all 3 cities, or at least 2 of them). The next sub-sections present detailed simulation results for a few scenarios (policy combinations), the results of the comparative analysis performed on the 3 cities, and the conclusions which can be drawn from the simulation results.

10.2. Definition of the common simulated measures

In the 3 case cities, the first scenarios simulated are scenarios of implementation of a new radial transport infrastructure (or service) which decreases the travel times between the centre and the periphery.

Further to these infrastructure scenarios, scenarios of policy measures have been defined and simulated.

10.2.1. Scenarios of new transport services between the urban centre and suburban areas

The transport investments simulated are as follows:

- in Brussels:
    - the future Regional Express Railway Network (REN)

[1] Also *local* measures were simulated, i.e. measures tested only in one of the 3 cities. For more detail on the local scenarios: see Deliverable D5-D6, downloadable from the SCATTER website www.casa.ucl.ac.uk/scatter.

- an alternative operating scheme of the REN with more orbital connections ("called "goose-foot type" scheme)

- in Helsinki:
  - the full Helsinki Metropolitan Area investment plan, with the distinction between the road components and the public transport components
  - the development of orbital connections by public transport

- in Stuttgart:
  - the extension of a light-rail line S1 (S-bahn), parallel to the motorway A81 (in 1992)
  - the completion of a missing link of the motorway A81 (in 1978).

10.2.2. Scenarios of policy measures

The selection of the policy measures to be simulated was based on the elements highlighted in the previous work packages of the project, as well as on the particular interests of the regional or national administrations supporting the project, in the field of control of sprawl. Roughly, urban sprawl is essentially due to:

- a decrease of the travel costs;
- a decrease of the travel times;
- an increase of household's income;
- unsuitability between the real estate and the demand for housings;
- an aspiration to a better quality of life or a new way of life.

Therefore, to reduce, control or avoid urban sprawl, the measures should consist in:

- increasing travel time and costs, specially regarding private car transport, as it is more polluting compared to the public transport mode;

- regulatory measures; for example: "containment policies" corresponding for example to apply urban growth boundaries (UGB): it consists in imposing (by regulations) ground assignment (the distribution between residential, open space, offices and other assignments) and controlling on a statutory way the urban growth of the city;

- fiscal measures on the location of residential developments or on offices, leading to a control of their location.

Various types of measures were simulated in SCATTER.

The common simulated policies are summarised in the table below.

Table 10.1: Common simulated policies

Land use policies
Impact fee on suburban residential developments, combined with land tax reduction in urban areas
Regulatory measure on office location: obligation for offices to locate in zones served by high quality public transport (measure applied to a part of the tertiary sector)
Fiscal measure applied to offices: tax on offices located in areas poorly served by public transport (measure applied to a part of the tertiary sector)
Transport pricing
Road pricing (increase of the car use cost per km)
Cordon pricing
Reduction of the fare of public transport

One of the objectives of the simulations was therefore to compare the effects and global effectiveness of land-related fiscal measures and transport pricing measures.

It has to be noted that in each case city, different reference scenarios were defined for the following reason:

- the effects of the new transport supply were assessed against a reference scenario *without* that new supply
- the effects of the accompanying measures were assessed against a scenario *with* the new supply.

The common policies are defined in more detail in the table below.

Table 10.2: Definition of the common policy scenarios in the 3 case cities

Policy code	**Description of the common policy**		
	Brussels	**Stuttgart**	**Helsinki**
0	***Reference scenarios***[2]	***Reference scenarios***	***Reference scenarios***[3]
001	**001B**: Horizon 2021 without the REN (Regional Express Railway Network)	**001S**: Situation 1995 without motorway A81 / without extension of S1 light rail / without road tunnel Kappelberg	**001H**: Horizon 2021 without any transport investment
002	**002B**: Horizon 2021 with the REN (=111B)	**002S**: Horizon 2015 with motorway A81 / with extension of S1 light rail / without road tunnel Kappelberg	**002H**: Horizon 2021 with the Helsinki metropolitan area (HMA) general transport plan-Car I transport investments
003	**003B**: Horizon 2021 with the REN and the local investment	**003S**: Horizon 2020 with motorway A81 / with	**003H**: Horizon 2021 with PLJ-public transport

[2] Only one scenario (002B) was tested on 001B. Most of the other scenarios have been simulated on 002B, while some of them have been tested on 003B (local investment plan), which is indicated in the tables. The simulations on reference 003B were made to be able to select the final combinations of measures.

[3] Most of the scenarios are compared to the 004H scenario, equal to the 111H scenario.

	plan (=711B)	extension of S1 light rail / with road tunnel Kappelberg	investments from HMA plan
004			**004H**: Horizon 2021 with the full HMA plan investments (=111H)
1	***Transport infrastructures / services, decreasing travel times between centre and periphery: railway, motorway, buses, HOV***		
11	***Radial transport infrastructure***		
111	**111B**: Horizon 2021 with the REN (=002B)	**111S:** Extension of the light rail (S bahn) line S1 **112S**: Completion of a missing link of the motorway A81, without S1 **113S**: 111S + 112S **114S**: 111S + 112S + park & ride facilities **115S**: 114S + building of a new road tunnel (Kappelberg)	**111H**: Horizon 2021 with the full HMA plan investments (=004H)
12	***Radial transport infrastructure with tangential components***		
121	**121B**: "Goose foot" alternative scheme for the REN railway (with more orbital connections)		**121H**:Devlopment of orbital connections of public transport
3	***Land use measures having an influence on urban sprawl***		
31	***Fiscal measures applied to residential developments***		
311	**311B**: Development impact fee in non urban areas + fiscal incentive in urban areas *311B has been tested on reference 003B*	**311S**: Development impact fee in non urban areas + fiscal incentive in the urban areas	**311H**: Development impact fee in non urban areas + fiscal incentive in urban areas
32	***Regulatory measures applied to offices***		
321	**321B:** ABC-type policy applied to the "business services"	**321S:** ABC-type policy applied to a part of the tertiary sector	**321H:** ABC-type policy applied to a part of the tertiary sector
33	***Fiscal measures applied to offices***		
331	**331B**: ABC-type policy applied to the "business services" *331B has been tested on reference 003B*	**331S**: ABC-type policy applied to a part of the tertiary sector	**331H**:ABC-type policy applied to a part of the tertiary sector
4	***Increase of travel costs or time by private car***		
41	***Increase of car use cost***		
411	**411B**: Increase by 50% of the cost per km	**411S**: Increase by 50% of the cost per km	**411H**: Increase by 50% of the cost per km
412	**412B**: Cordon pricing with a tariff of 7.5 euro/day	**412S**: Cordon pricing with a tariff of 2.1 euro/day	**412H**: Cordon pricing with a tariff of 2.5 euro in orbital cordons and 1.3 euro in radial cordons (per day)
5	***Decrease of travel costs or time by public transport or by Park&ride facilities***		
51	***Decrease of public transport travel costs***		
511	**511B**: Decrease by 20% of the public transport fare for the home-work trips		
512	**512B**: Decrease by 20% of the public transport fare for all users	**512S**: Decrease by 20% of the public transport fare for all users	**512H**: Decrease of public transport fare for all users by 20%
8	***Combinations of measures***		
811	811B = 411+511+311	811S = 411+511+311	811H = 411+512+311
812	812B = 411+511+331	812S = 411+511+331	812H = 411+512+331
813	813B = 411+511+311+331	812S = 411+511+311+331	813B = 411+512+311+331

10.3. Detailed evaluation results for the policy combination scenarios

To better illustrate the evaluation framework, this section presents some indicator values and maps for one set of scenarios, namely the policy combinations (scenarios 811, 812, 813), in the three case cities.

Besides, the whole set of indicator values is appended, for all the common policies, for the three case cities.

The definition of the policy combination scenarios is as follows:

- scenario 811: increase of car use cost by 50 % + reduction of the fare of public transport by 20 %[4] + tax (impact fee) applied to suburban residential developments, combined with a tax reduction in urban areas

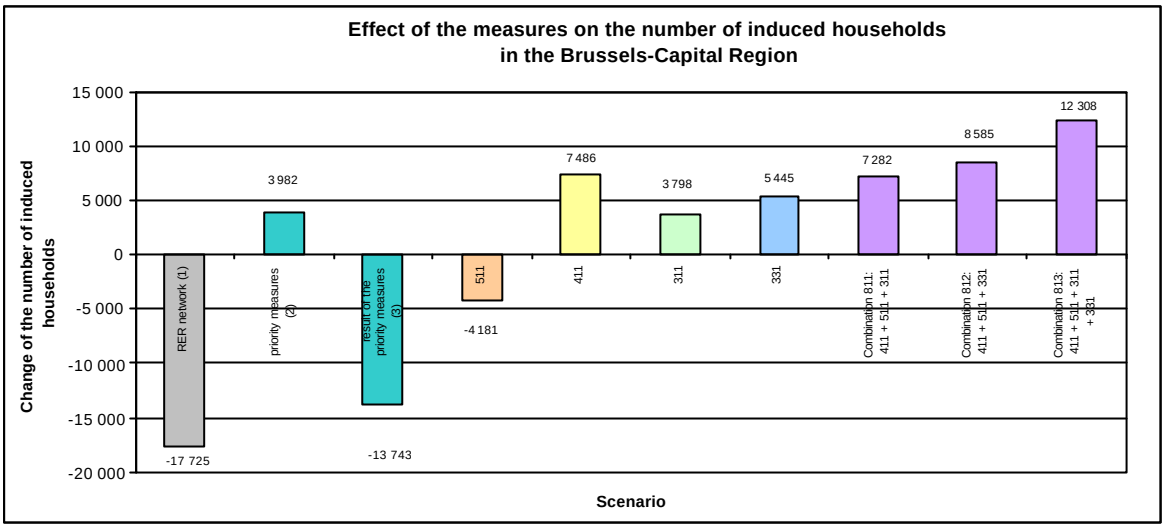
- scenario 812: increase of car use cost by 50 % + reduction of the fare of public transport by 20 % + tax applied to offices not located in "A zones" (zones served by high quality public transport)

- scenario 813: increase of car use cost by 50 % + reduction of the fare of public transport by 20 % + tax (impact fee) applied to suburban residential developments, combined with a tax reduction in urban areas + tax applied to offices not located in "A zones".

10.3.1. Evaluation results of the policy combinations in Brussels

The diagrams below illustrate how the scenario 813 which combines 4 measures, together with the programme of "priority measures", compensates the out-migration of households due to the implementation of the Regional Express Railway Network. Scenario 813 also reinforces the effect of reduction of the CO_2 emissions. The "priority measures" consist in a set of measures which go in the sense of the objectives of the federal and regional authorities and which very probably will be implemented in the near future.

[4] In the Brussels case city, the reduction of the fare of public transport by 20 % is applied only to home-work trips.

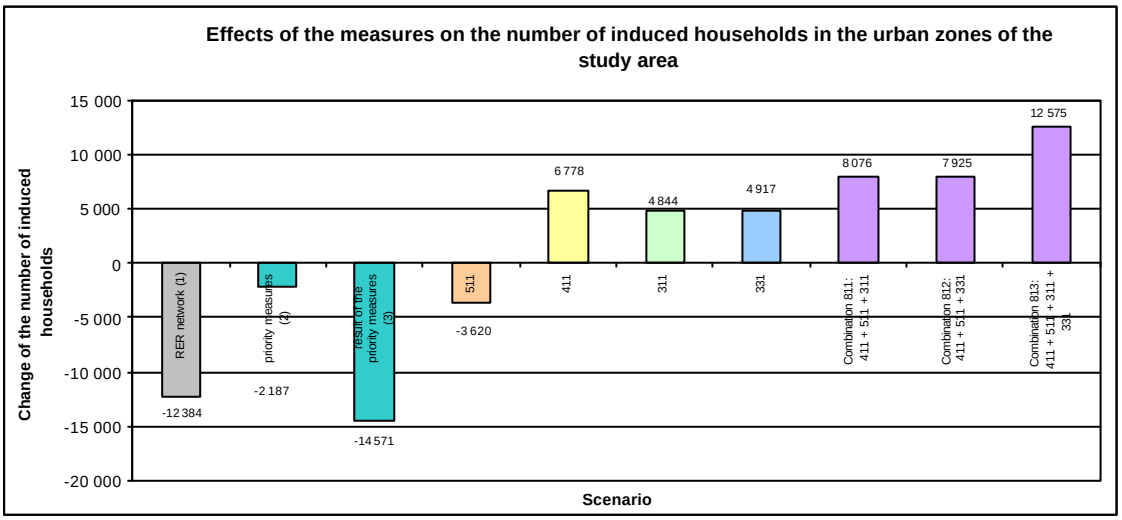


Types of scenarios:

- 2021 RER network
- Priority measures (new 2021 reference)
- Decrease of PT fare
- Increase of car use cost
- Fiscal measure on housholds
- Fiscal measure on services to business
- Combination of measures

(1) The effect of the RER network is calculated in comparison with the 2021 reference scenario
(2) The effect of the priority measures is calculated in comparison with the 2021 RER scenario
(3) The effect of the priority measures is calculated in comparison with the 2021 reference scenario
The effects of the other meaures are calculated in comparison with the priority measures

Figure 10.1: Effect of the measures on the number of induced households in the Brussels-Capital Region

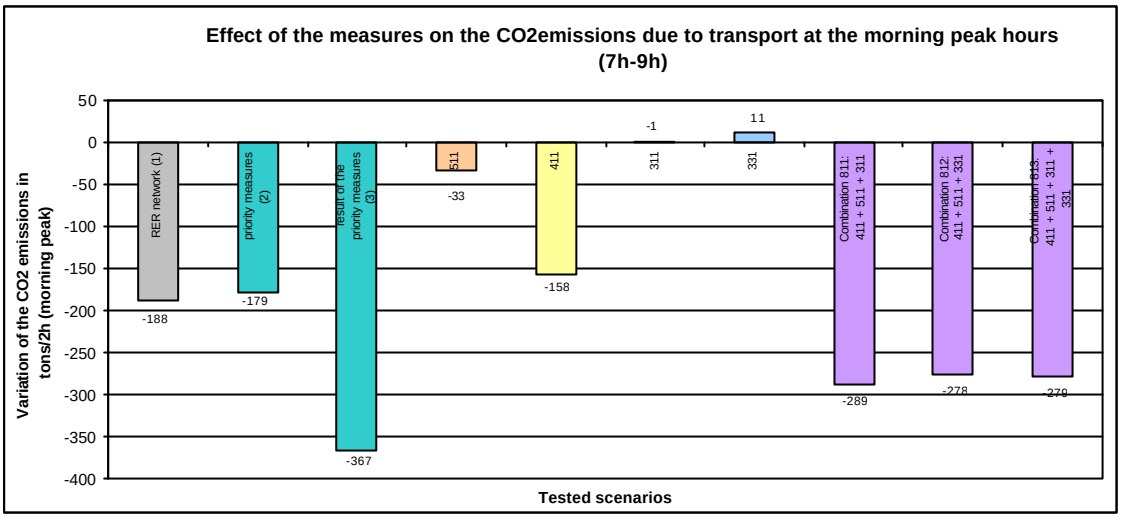


Types of scenarios:

- 2021 RER network
- Priority measures (new 2021 reference)
- Decrease of PT fare
- Increase of car use cost
- Fiscal measure on housholds
- Fiscal measure on services to business
- Combination of measures

(1) The effect of the RER network is calculated in comparison with the 2021 reference scenario
(2) The effect of the priority measures is calculated in comparison with the 2021 RER scenario
(3) The effect of the priority measures is calculated in comparison with the 2021 reference scenario
The effects of the other meaures are calculated in comparison with the priority measures

Figure 10.2: Effect of the measures on the number of induced households in the urban zones of the study area



(1) The effect of the RER network is calculated in comparison with the 2021 reference scenario
(2) The effect of the priority measures is calculated in comparison with the 2021 RER scenario
(3) The effect of the priority measures is calculated in comparison with the 2021 reference scenario
The effects of the other meaures are calculated in comparison with the priority measures

Figure 10.3: Effect of the measures on the CO2 emissions due to transport at the morning peak hours (7h-9h)

10.3.2. Evaluation results of the policy combinations in Helsinki

The policy combinations consist of car operating cost increase and PT fare reduction combined with alternative land (pricing) policies. The urban sprawl variables and the sustainability indeces for these policies are presented in the table and in the figure below.

Table 10.3: Urban sprawl variables in Combinations policies

SCATTER		Base		Combinations		
		PRESENT	Base 2021	Comb. 411+512+311	Comb. 411+512+331	Comb. 411+512+311+331
Helsinki case city		2001	000	811	812	813
Variable	**Unit**					
Overall mobility						
Average travel time (all modes)	minutes	29,8	29,2	0,8%	1,1%	-0,2%
Public transport						
Modal share of modes	%	44,1	42,3	6,1	12,3	12,2
Passenger-km by public modes	km/inhabitant/a	5232	5734	16,8%	16,9%	16,2%
Road traffic						
Private vehicle-km	km/inhabitant/a	2451	2930	-16,1%	-15,9%	-17,6%
Greenhouse gases from transport	eq.ton/inhabitant/a	1,41	1,78	-10,7%	-10,6%	-12,0%
Average road traffic speed	km/h	37,3	31,6	1,8%	1,9%	2,6%
Land use						
Households in urbanised zones	#	639565	772313	0,6%	-0,1%	0,6%
Households in core metropolitan area	#	265432	304320	0,1%	-0,5%	0,2%
Households in the city centre	#	28812	36485	-0,7%	-1,4%	-0,6%
Employees in urbanised zones	#	698209	904015	0,6%	0,5%	0,7%
Employees in core metropolitan area	#	392807	499005	0,9%	0,8%	1,2%
Employees in the city centre	#	109706	127650	2,3%	2,1%	2,5%
Accessibilities						
Average home-work travel distance	kilometres	16,2	15,0	0,5%	0,9%	-0,3%
Accessibility to city centre	minutes/trip	29,3	29,8	-2,1%	-2,3%	-2,6%
Accessibility to services	minutes/trip	27,7	28,2	0,0%	0,1%	-0,1%
Productivity gain from land use	%	0,0	0,0	0,3	0,4	0,7
	HMA		diff. in % units			

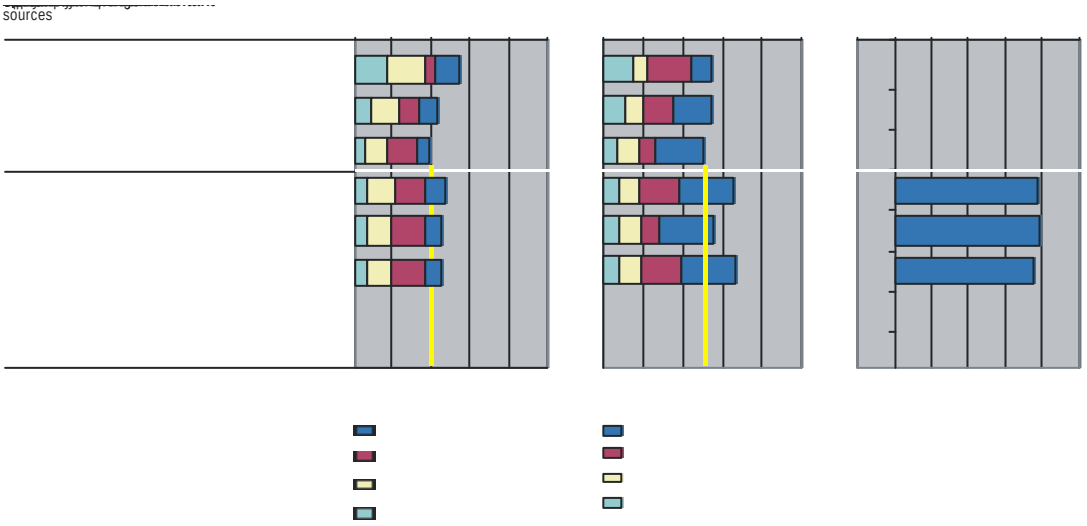


Figure 10.4: Urban sustainability indicators in combinations policies

The land use effects of the policy combination 813 are illustrated in the figures below.

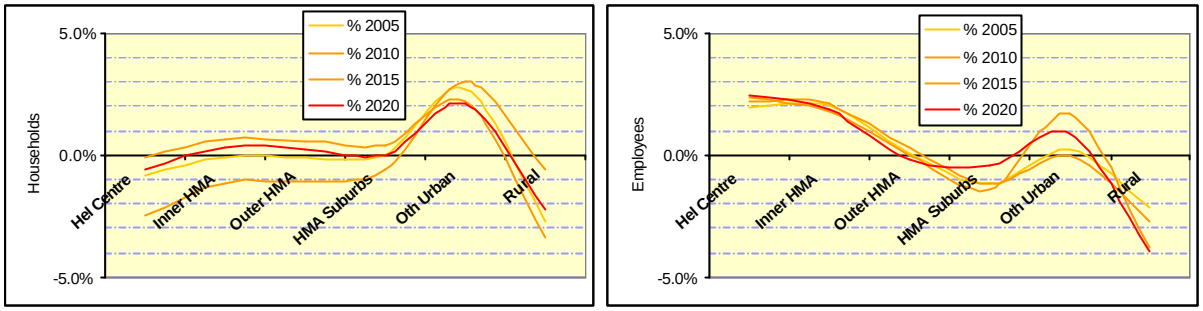


Figure 10.5: Combination policy 813 H (411 - vehicle operating costs +50%, 512 - public transport fares –20% , 311 – land use development fee and 331 – land use pricing) impacts on sprawl

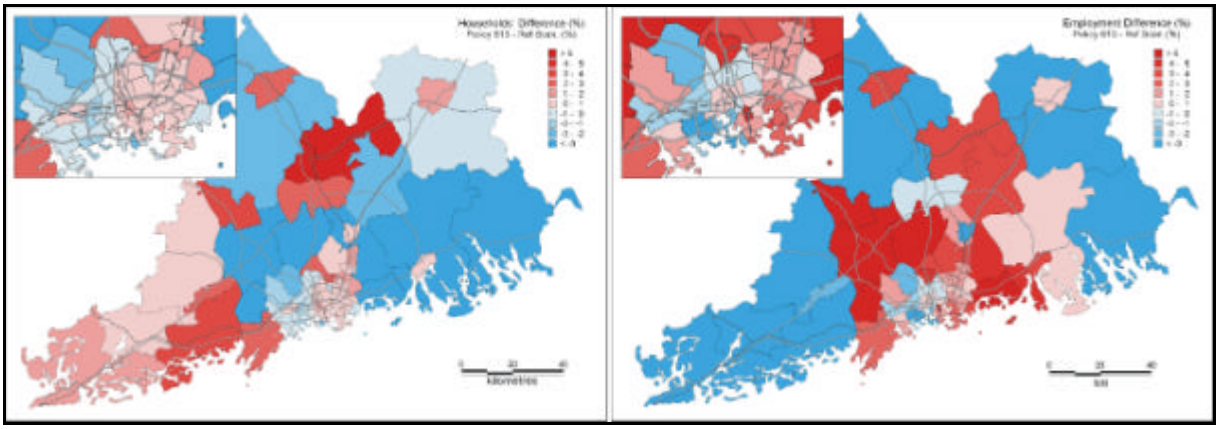


Figure 10.6: Combination policy 813 H (411 - vehicle operating costs +50%, 512 - public transport fares –20% , 311 – land use development fee and 331 – land use pricing)

The combinations work efficiently against urban sprawl, car kilometres and emissions are radically reduced and also accessibilities are mainly improved. Thus the most effective way to tackle sprawl is to create policy packages that combine the best qualities of individual policy measures and even out some inevitable side-effects or problems of the used main measures. What is still particularly difficult to control are both the household and employment sprawl at the same time.

The sustainability evaluation shows that the policies are able to simultaneously improve all the dimensions of sustainability compared with the base scenario alternative. In some cases they also maintain or improve the current level of sustainability.

10.3.3. Evaluation results of the policy combinations in Stuttgart

The combinations of policy measures (scenarios 811S-813S) were simulated via the STASA model and the overall evaluation of the possibility to reduce sprawl through the scenario 813 is given in the next subsection. As reference scenario 003S is used with time horizon 2020.

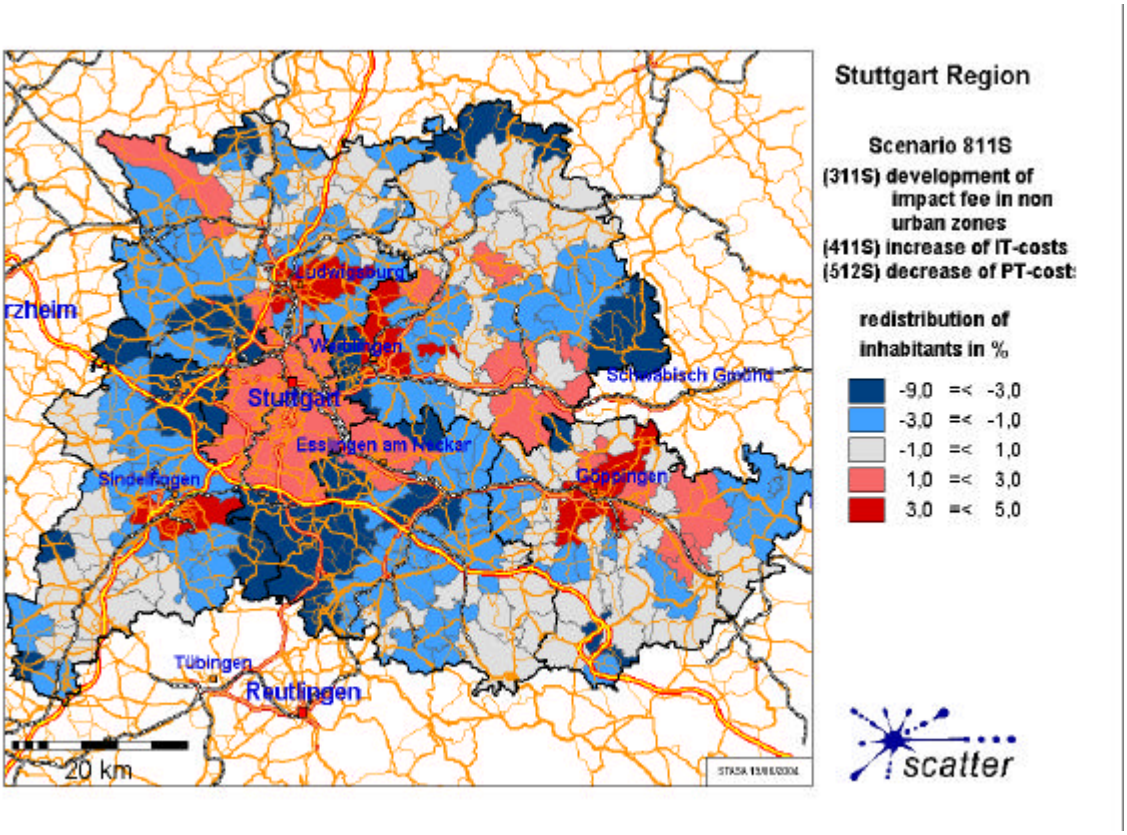


Figure 10.7: Scenario 811S: Redistribution of inhabitants in %

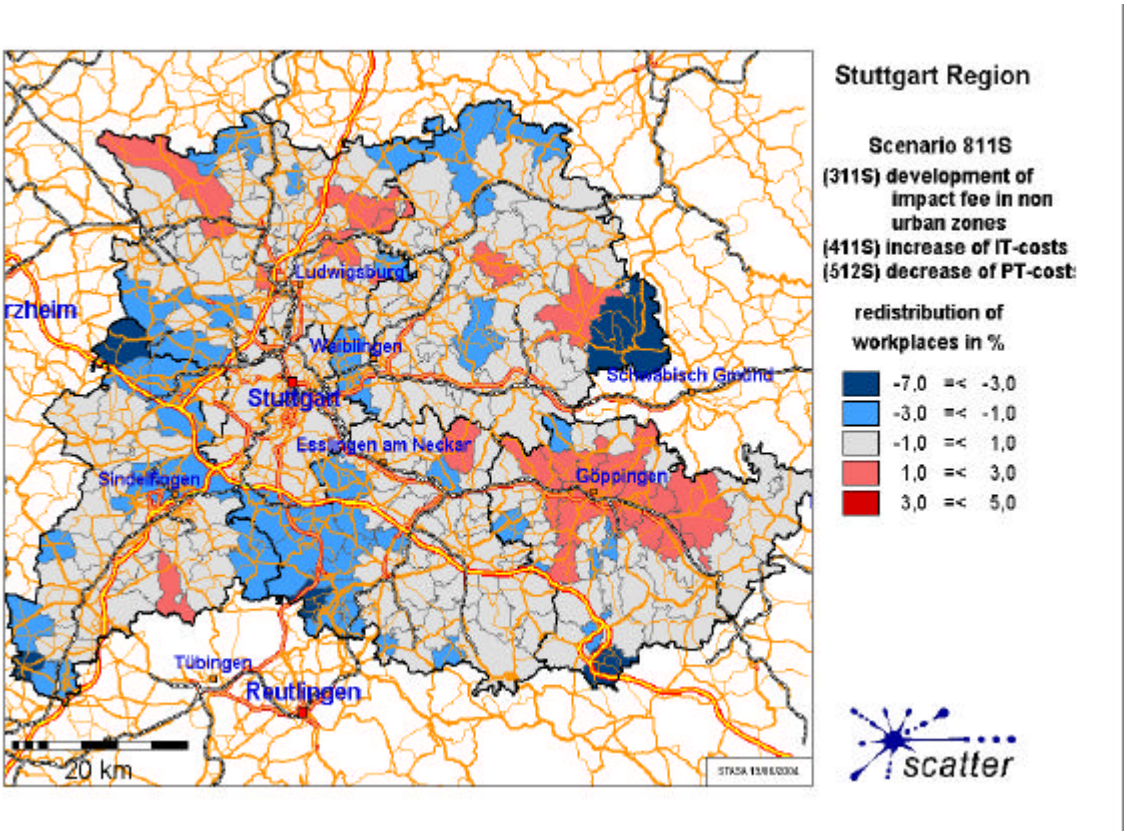


Figure10.8: Scenario 811S: Redistribution of workplaces in %

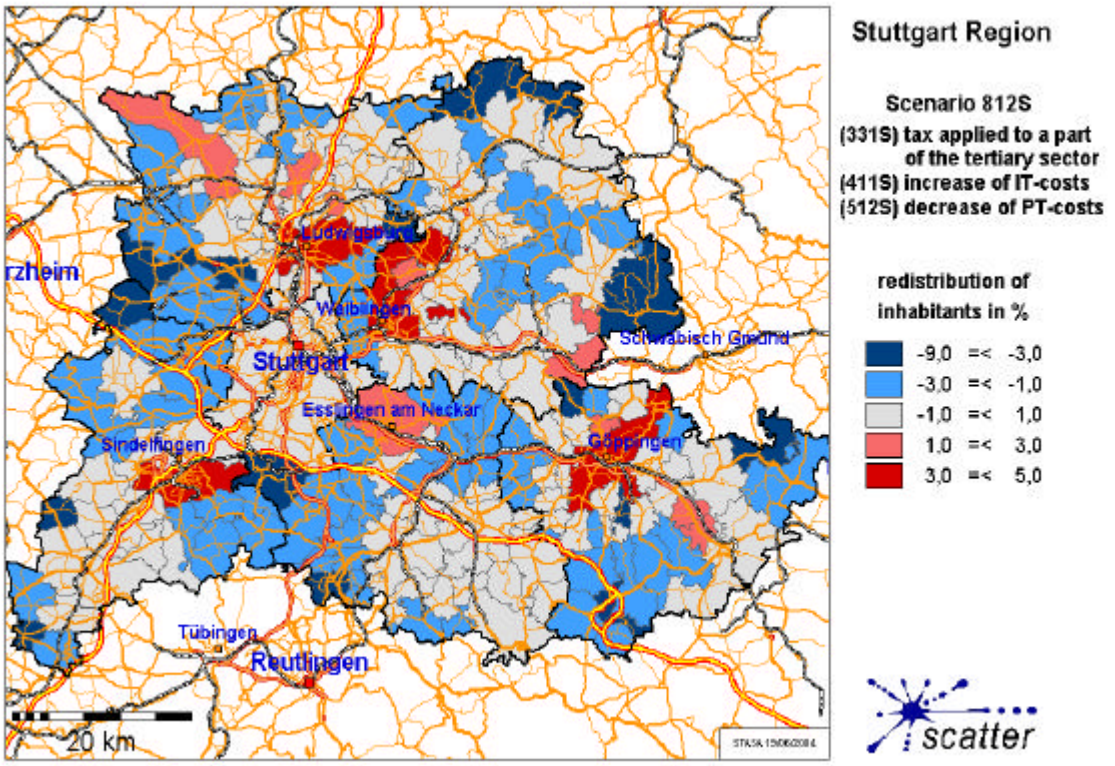


Figure 10.9: Scenario 812S: Redistribution of inhabitants in %

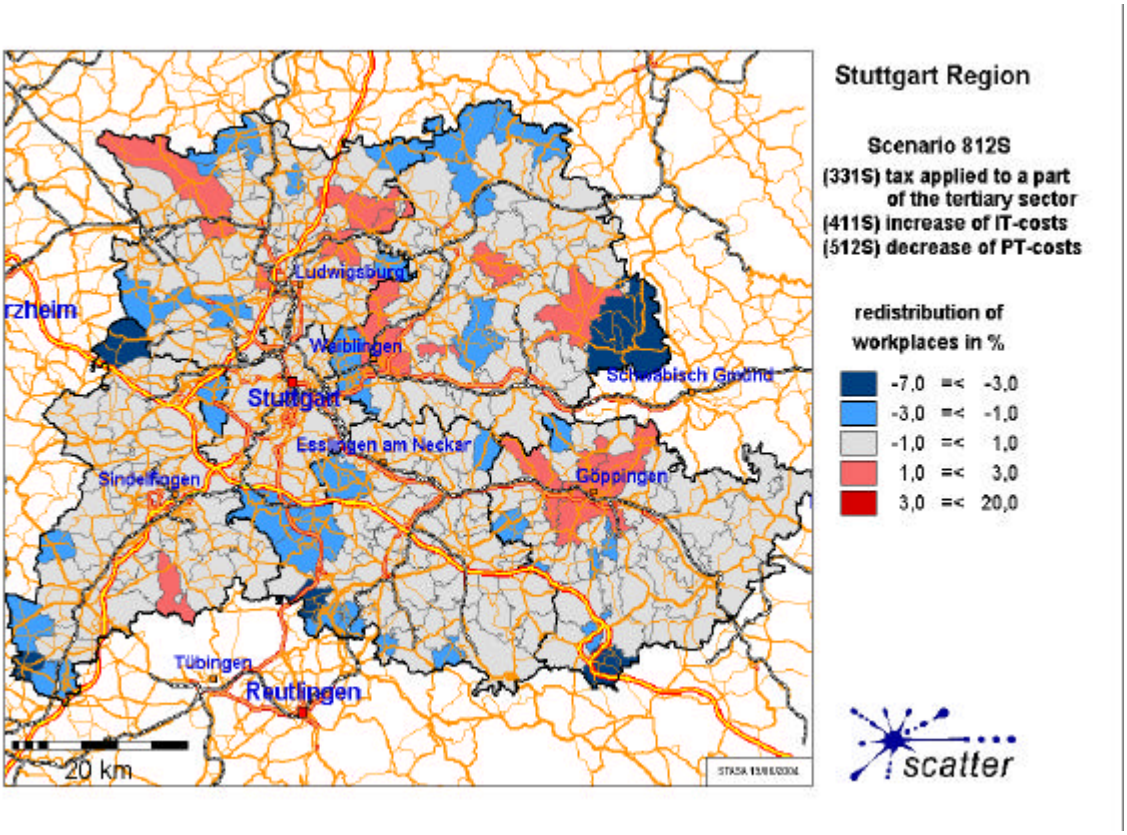


Figure 10.10: Scenario 812S: Redistribution of workplaces in %

The policy 813S consists of an increase by 50% of the private car cost/km applied to all drivers, a decrease of PT fare by 20% for all trips and a fiscal measure on residential developments, together with an ABC-type policy applied to a part of the tertiary sector.

A combination of the different policy measures (policy 813) has the strongest effect on the reduction of spraw. A strong concentration of households in the urban zones (+1.0%) and urban centre (+2.8%) must be stated. The jobs follow the same pattern, namely an increase of jobs in the urban zones (+0.2%) and in the urban centre (+0.6%). This is also confirmed by the variation of the relative *H*-measures.

The total car mileage in the study area decrease by about –5.0% accompanied by a corresponding decrease of CO_2 emissions. The average modal share of public transport in the study area increases by about +7.7 points. The passenger-kilometres by public transport per inhabitant increase by about 9.4%.

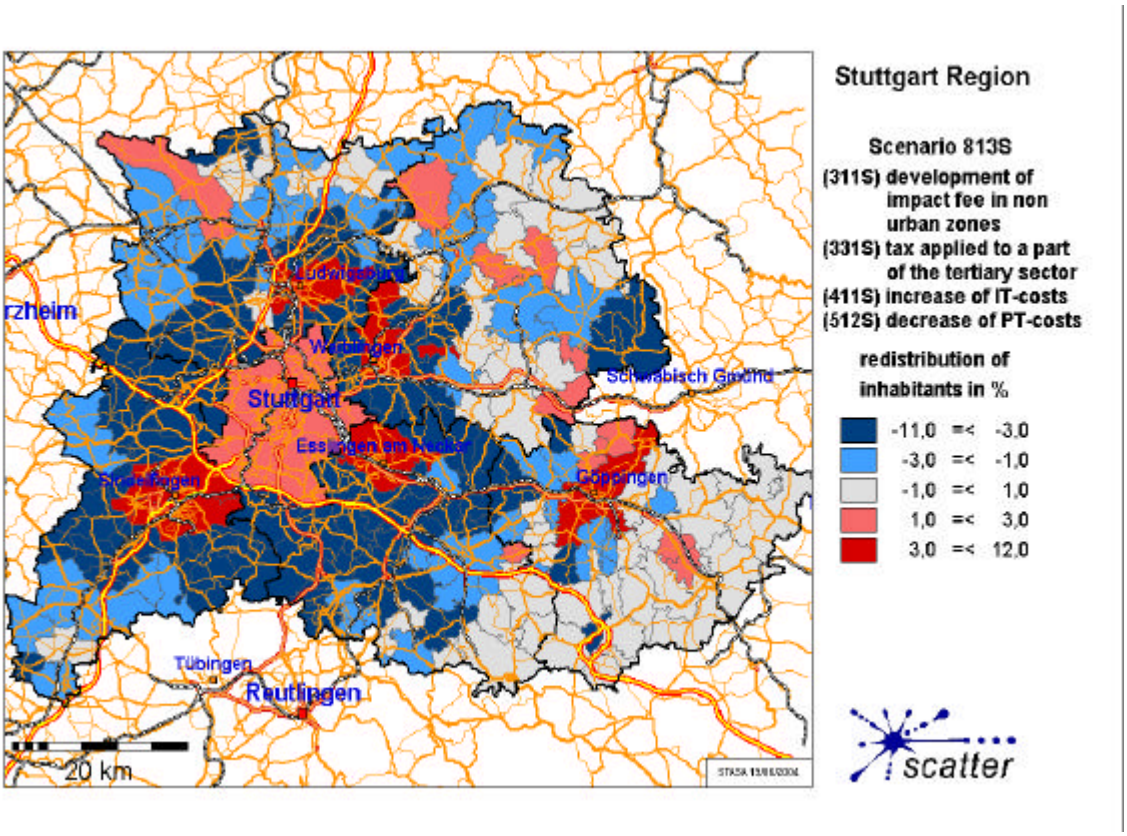


Figure 10.11: Scenario 813S: Redistribution of inhabitants in %

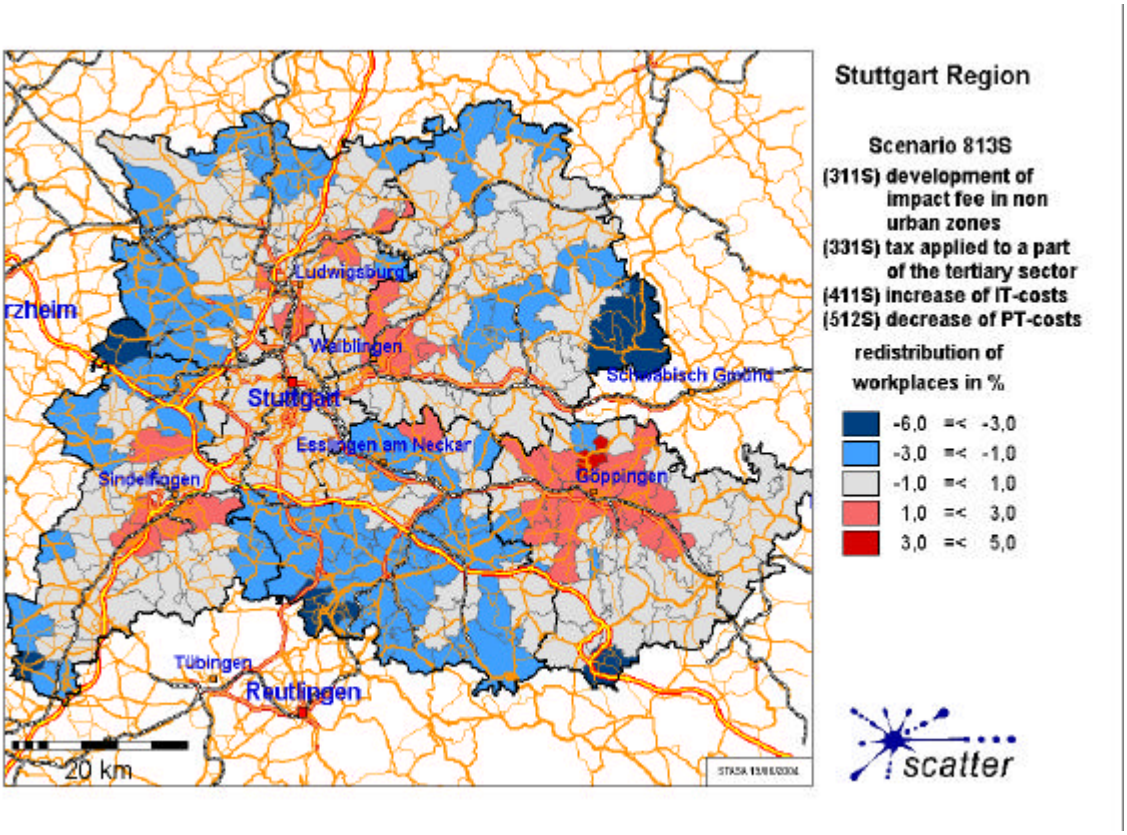


Figure 10.12: Scenario 813S: Redistribution of workplaces in %

10.4. Inter-city comparison of policy impacts

The whole set of indicator values is appended, for all the common policies, for the three case cities. This section focuses on the comparative analysis between the 3 cities. This analysis tackles 2 issues:

- firstly, what are the impacts of the rail investments in the 3 cities ? do the rail investments generate sprawl in all cases ? and to what extent ?

- secondly, whether sprawl is generated by the particular transport investments under study in SCATTER or by a general migratory trend, which policies are most effective to control sprawl and reduce its negative effects ?

10.4.1. Brief comparison of the spatial structure of the 3 cities

This section briefly reminds the overall spatial structure of the 3 case cities. The maps below show:

- the current densities in the 3 cities
- the macro-zones in the 3 cities

- the zones considered as urbanised in the 3 cities[5]
- the new transport services whose effects on activity location are investigated.

The "urban centre" (the central macro-zone) is defined as follows:

- in the case of Brussels: the Brussels-Capital Region (average density: 2 900 households/km²)
- in the case of Helsinki: the city centre of Helsinki (3 000 households/km²)
- in the case of Stuttgart: the city of Stuttgart (1 400 households/km²).

The zones which were considered as "urban zones" in the calculation of the indicators "number of households/jobs in urban zones" are defined as follows:

- in the case of Brussels: the Brussels-Capital Region (light blue on Figure 10.15), the surrounding ring of urban Flemish communes (yellow), the other communes defined as urban in the regional land use plans (grey), i.e. 60 communes in all (average density: 680 households/km²)

- in the case of Helsinki: the inner Helsinki Metropolitan Area (HMA), the outer HMA, the HMA suburbs, other urban conurbations outside HMA (i.e. all zones except the light yellow zones in the map) (50 households/km²)[6]

- in the case of Stuttgart: the city of Stuttgart and all the communes of the so-called "outer urban ring" (37 communes in all) (710 households/km²).

[5] This intervenes in the calculation of the indicators "number of households in the urban zones" and "number of jobs in the urban zones".

[6] In the case of Helsinki, the average density of the "urban zones" is relatively low because the other urban centres outside the HMA (in orange on the map) are small old towns including large sparsely populated areas inside their administrative borders, which have been the statistical base outside the HMA.

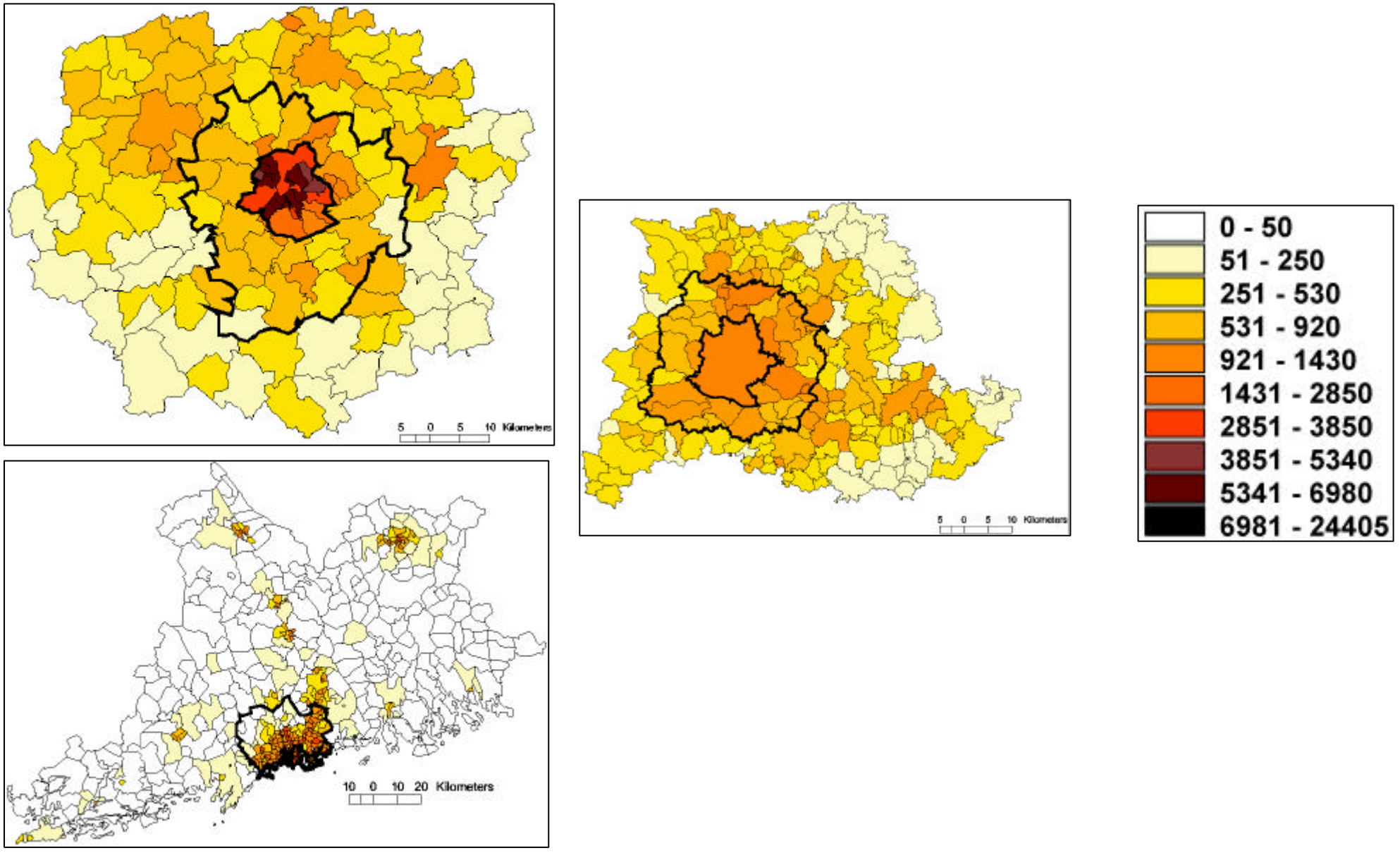


Figure 10.13: Population density in the study areas of Brussels (2001), Helsinki (1999) and Stuttgart (2000) (persons/km²)

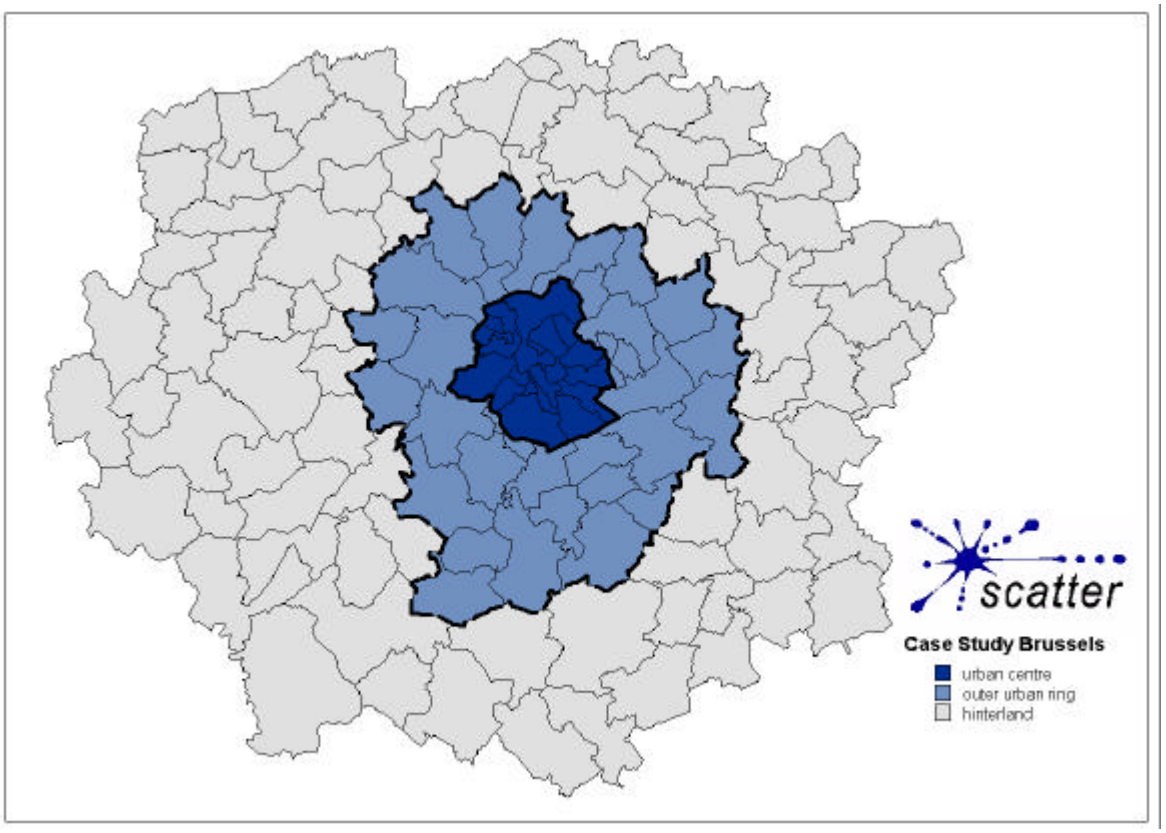


Figure 10.14: The Brussels study area and its 3 macro-zones

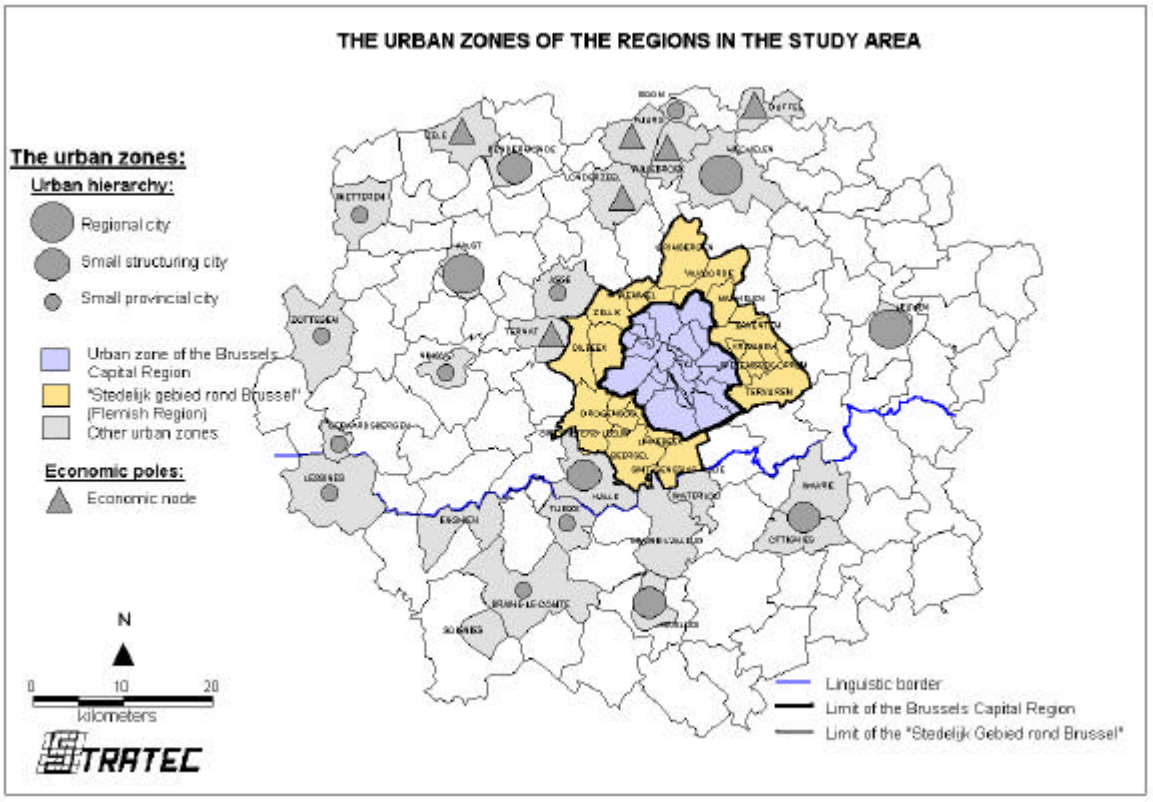


Figure 10.15: The Brussels study area – Urban zones

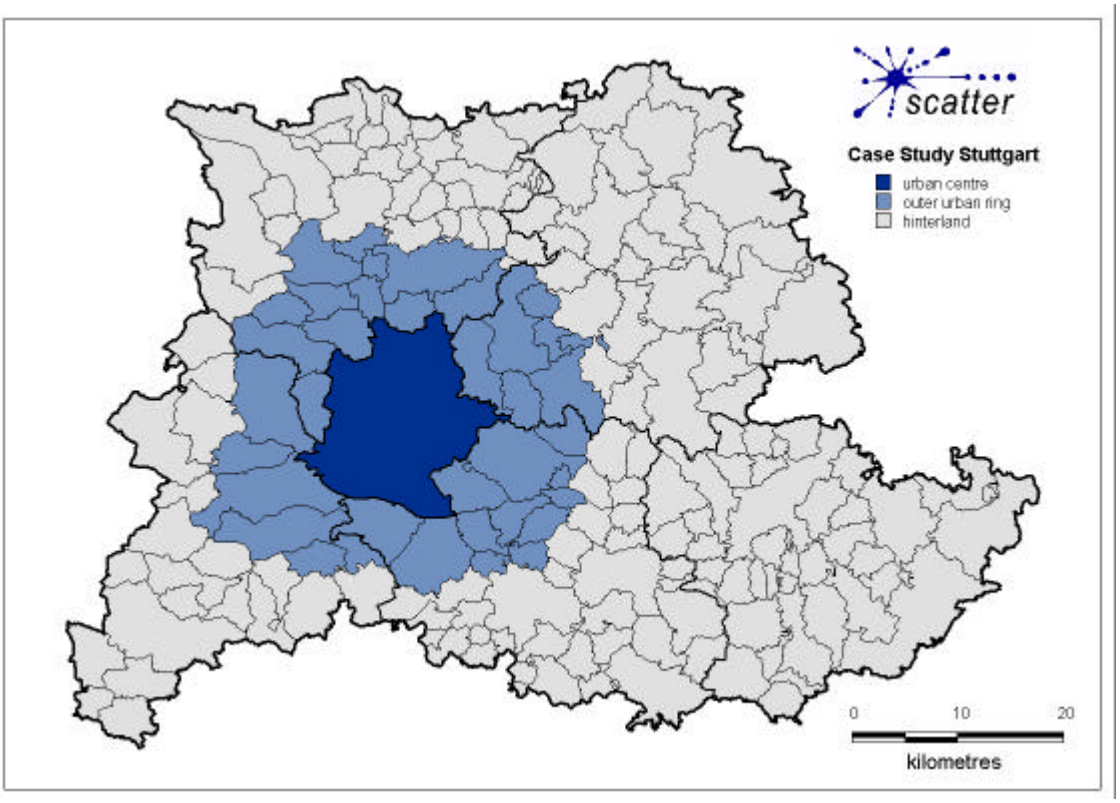


Figure 10.16: The Stuttgart study area and its 3 macro-zones

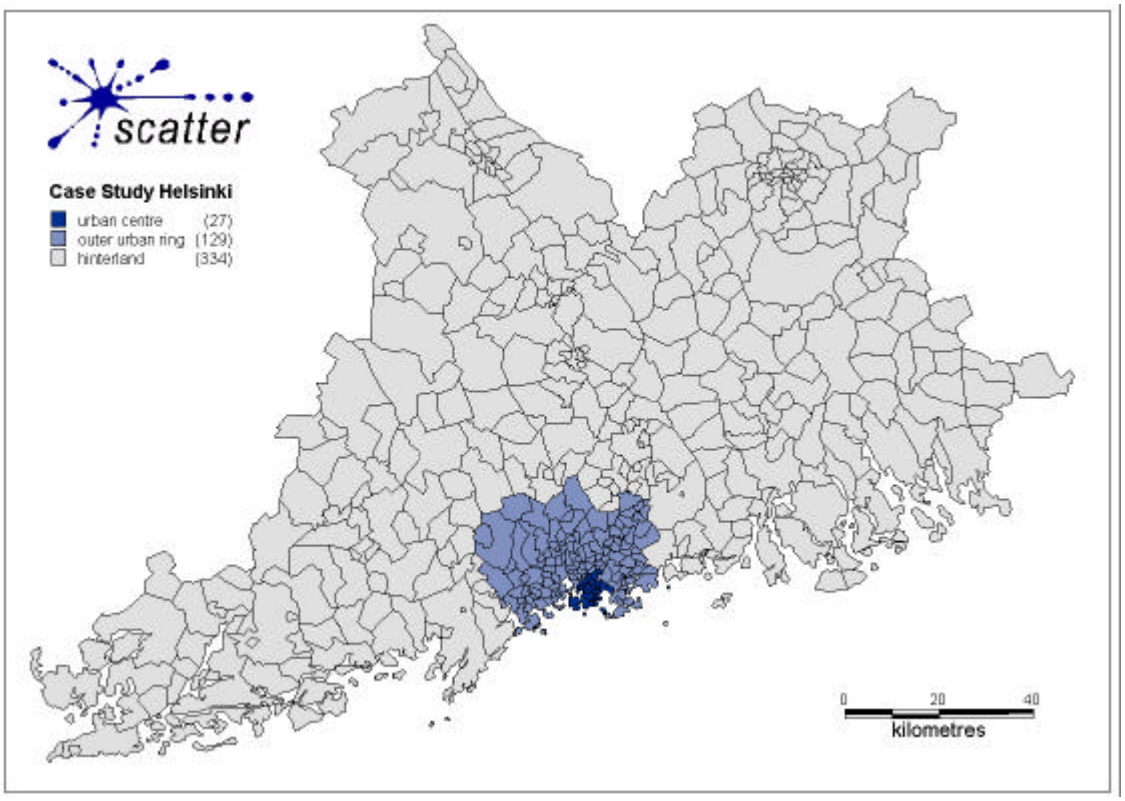


Figure 10.17: The Helsinki study area and its 3 macro-zones

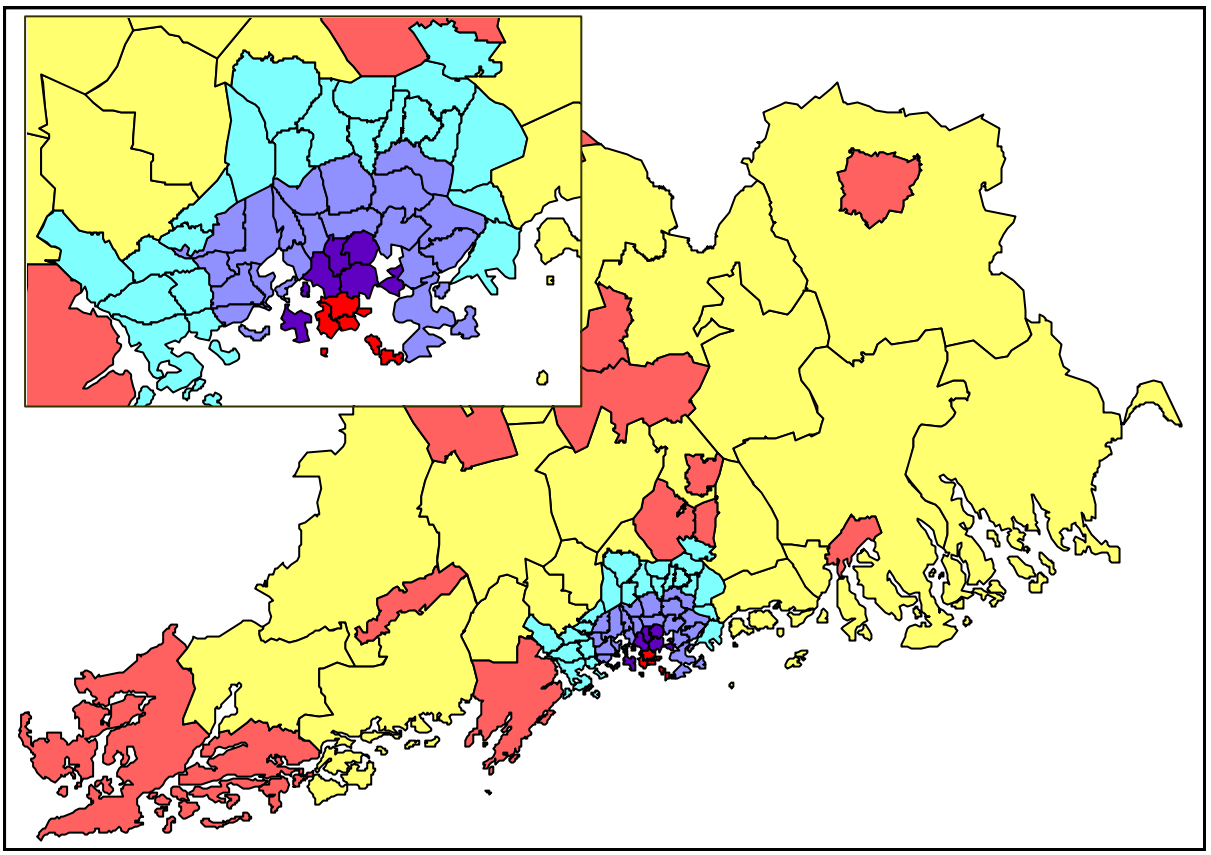
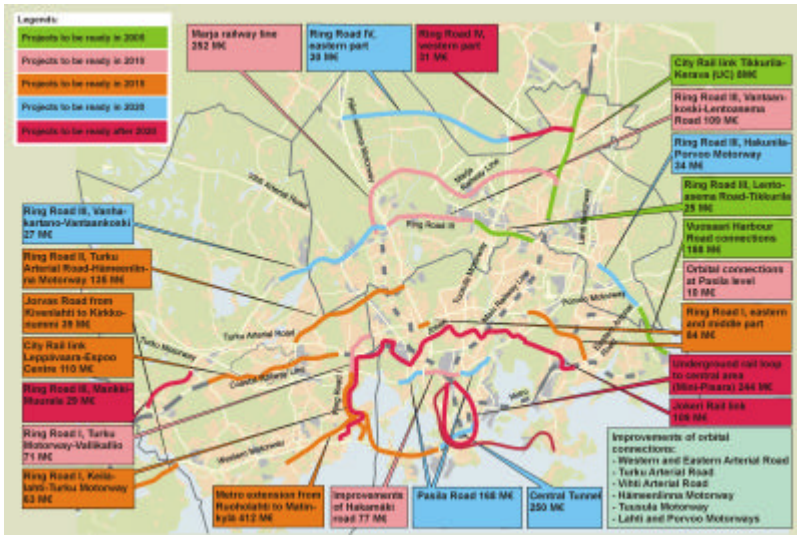
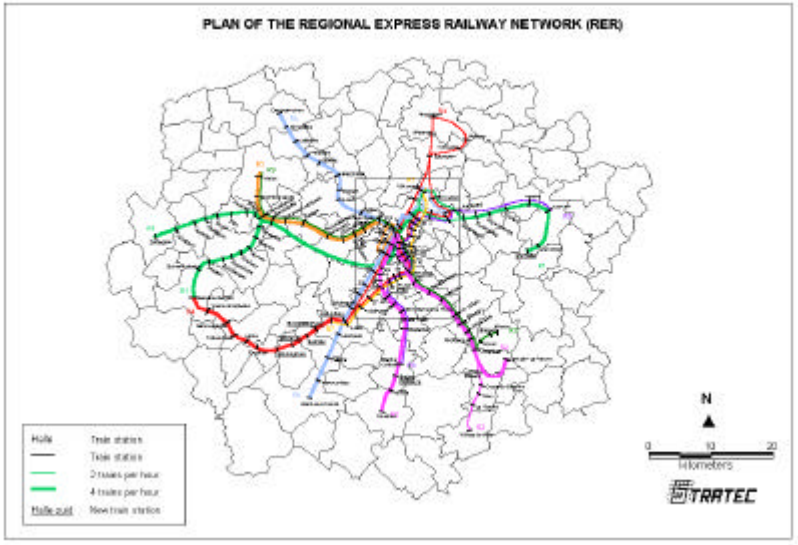


Figure 10.18: Helsinki: The study area and detailed super-zone definitions used in the analysis of sprawl : Helsinki centre (red), Inner Helsinki Metropolitan Area (HMA) (dark blue), outer HMA (mid-blue), HMA suburbs (light-blue), other urban conurbations outside HMA (orange) and rural municipalities (yellow).





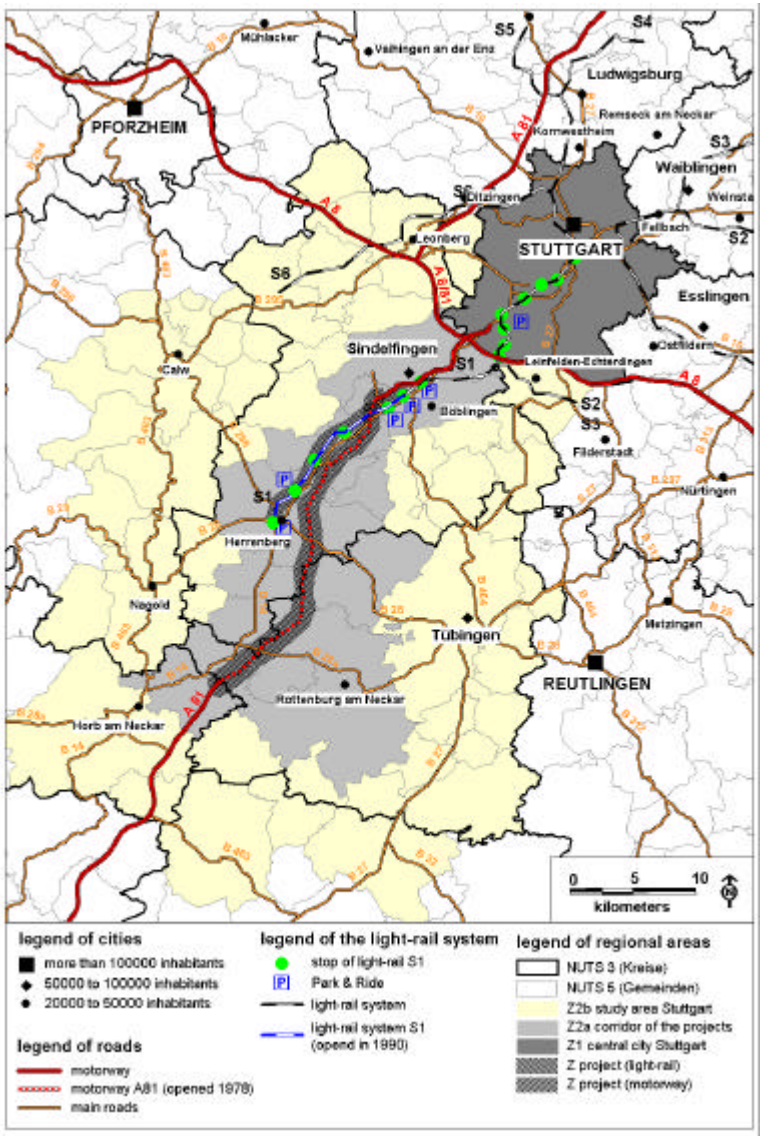


Figure 10.19: Brussels, Helsinki, Stuttgart: the new public transport services whose influence on activity location was investigated

Regarding the transport services, it is worth noting that their size or extent is quite different between the 3 cities: a whole network in the case of Brussels (replacing an existing network but with a drastic improvement), extensions of an existing network in the case of Helsinki, extension in one direction in the case of Stuttgart. It is therefore likely that the resulting effects in Stuttgart will be smaller than in the 2 other cities.

10.4.2. Comparison of the effects of the public transport investments in the 3 cities

The public transport investments which were simulated are as follows:

- in the case of Brussels:
    - the future Regional Express Railway Network (REN) ("*Réseau Express Régional" – RER*) which will run on the existing rail tracks. The REN is made up of 8 new lines. It will serve Brussels and the surrounding area within a radius of 30-35 km. It will provide high quality, rapid and frequent train services. The total investment cost is estimated to about 900 millions € (scenario 111B=002B)
    - an alternative operating scheme of the REN, with more orbital connections, to facilitate trips from periphery to periphery (called "goose-foot" operating scheme) (scenario 121 B)
    - the effects of these both scenarios were assessed against the reference scenario without REN, at horizon 2021 (scenario 001B)
- in the case of Helsinki:
    - the Helsinki Metropolitan Area (HMA) full investment plan: this plan includes public transport investment as well as road investments (scenario 111H=scenario 004H) ; the public transport investments include extensions of metro lines and of urban rail lines ;
    - the same transport plan, with additionally speeding up the rail services by 25 % (scenario 116H)
    - development of orbital connections of public transport (scenario 121H)
    - the effects of these 3 scenarios were assessed against the reference scenario which includes the HMA road investments only (scenario 002H)
- in the case of Stuttgart:
    - the extension of the light rail line S1 (S-bahn), parallel to the motorway A81 (scenario 111S)
    - the same extension of S1, with additional investments: completion of missing link of the motorway A81 and park & ride facilities (scenario 114S)
    - the same extension of S1, with additional investments: completion of missing link of the motorway A81, park & ride facilities and a new road tunnel (tunnel Kappelberg) in the Eastern direction (scenario 114S, assessed against the scenario 001)

- the effects of these 3 scenarios were assessed against the reference scenario 001S (without S1 extension and without the missing link of A81).The values of some key indicators are given for these 8 transport investment scenarios in the table below.

Table 10.4 Effects of the new public transport services in the 3 case cities

	Variation in the number of households in the urban centre (%)	Variation in the number of households in the urban zones (%)	Variation in the indicator H-relative for population (%)	Variation in the number of jobs in the urban centre (%)	Variation in the number of jobs in the urban zones (%)	Variation in the average home-work trip distance (%)	Variation in the total car mileage (%)	Variation in the public transport modal share (points)	Variation in the total CO_2 emission (%)
Brussels – future REN (scenario 111B assessed against 001B)	-3.6	-1.4	1.8	0.7	0.3	8.1	-6.2	8.8	-8.1
Brussels – alternative REN with more orbital connections (scenario 121B assessed against 001B)	-5.5	-2.8	1.9	0.8	0.3	12.4	-9.2	11.5	-11.5
Helsinki – HMA full investment plan scenario 111H assessed against 002H)	0.0	0.2	-0.5	0.2	0.0	-1.0	1.6	1.4	1.0
Helsinki – HMA full plan + speeding up the rail services by 25 % (scenario 116H assessed against 002H)	-1.6	-0.5	2.3	1.7	0.5	12.2	-0.8	5.3	-1.5
Helsinki – developing orbital connections of public transport (scenario 121H assessed against 002H)	-0.1	0.1	-0.2	0.1	0.0	-1.3	0.7	1.5	0.0
Stuttgart – extension of the light rail line S1 (S-bahn)	-0.3	-0.4	0.0	-0.1	-0.7	-2.7	0.4	0.5	0.4

(scenario 111S assessed against 001S)									
Stuttgart – extension of the light rail line S1 (S-bahn) + missing link of motorway A81 + park & ride facilities (scenario 114S assessed against 001S)	-0.5	0.0	0.5	-0.4	0.6	-1.0	7.2	-0.1	7.2
Stuttgart – extension of the light rail line S1 (S-bahn) + missing link of motorway A81 + park & ride facilities + new road tunnel Kappelberg (scenario 115S assessed against 001S)	-1.8	0.7	0.7	-0.4	0.6	0.3	10.1	-0.7	10.1

Legend of colours:

ð sprawl of population

ð concentration of jobs

ð lengthening of home-work trips

ð positive effects of the PT investments, which might be higher without the sprawl

According to these figures, it appears that the answer to the first question “to what extent do public transport investments generate sprawl” is that they generate sprawl if they extend to the suburban or rural areas, if they provide a significant improvement in the accessibility from the suburban or rural areas to the centre or urban zones (where most of the work places are located), and whether the network is radial or radial *and* orbital.

Indeed, in the case of Brussels (both scenarios) and Helsinki (scenario 116H), the variation in number of households in the urban zones and other indicators reflect that the households move outside the urbanised zones. Simultaneously, the new public transport investments incite employment to concentrate in the urban centre.

The resulting change in the home-to-work mobility pattern is the lengthening of the home-work trips (by about 10 % in all 3 concerned scenarios).

Note that in the case of Brussels, the rail scheme with more orbital connections leads to even more sprawl, and to a higher increase in the home-work trip distance.

These effects of a significant improvement in the regional transport system also occur in the scenarios simulating a decrease of PT fare by 20 % (scenarios 512B-512H-512S).

On the other hand, the PT investments lead evidently to an improvement of the indicators related to the modal share: decrease of the car mileage and increase of the PT share. However, the total short-term improvement (i.e. the improvement which would have occurred if there was no change in activity location, neither lengthening of the trip distances) would have been even higher. In other words, one negative effect of sprawl is to “consume” a part of the potential benefits of the public transport investments, with regard to the modal shift and the reduction of car mileage.

Finally, sprawl causes negative effects directly because of the consumption of non-urban land, such as loss of high quality open space and agricultural land and higher costs of infrastructures and equipments.

Some of the results shown in the table, however, do not reflect sprawl, at least not clearly: the Helsinki investment plan (111H), and the extension of the light-rail line in Stuttgart (111S-114S). In the case of the HMA plan, the impact on sprawl is small because the investments are mainly orbital extensions. There is indeed no lengthening of the average home-work trip distance.

In the case of Stuttgart, the effects on sprawl are often smaller than in the 2 other cities for several reasons: first, the public transport investment consists only in one extension of line, which at the scale of the whole region cannot have as much effect as the improvement of a whole network; secondly, in some cases, movements of households occur from the urban centre (city of Stuttgart) towards a peripheral but still urban zone. However, the detailed analysis of the Stuttgart simulation results at communal level also shows that the extension of radial transport lines accompanied with a drastic reduction of travel times to the city centre support sprawl. It also clearly appears in the simulation results that the effects caused by the S1 on the population distribution are not as strong as those caused by the motorway: this reflects the fact that the road network allows for more diffusion than the public transport network.

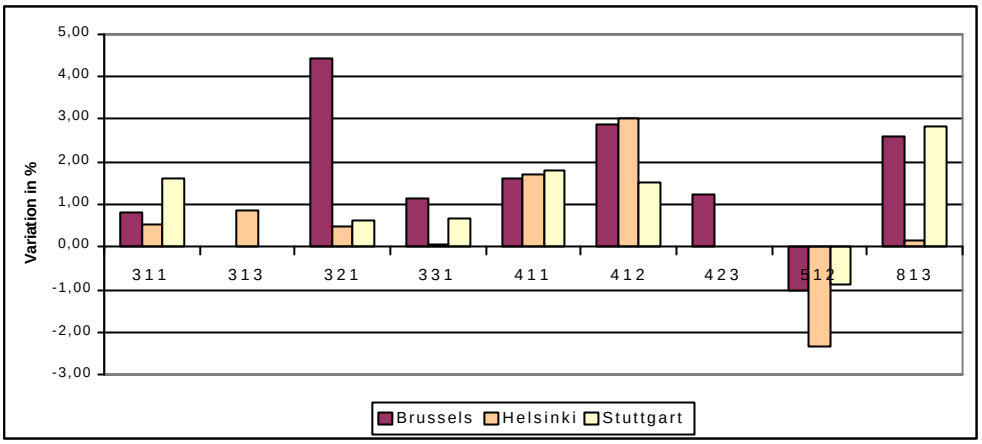
In conclusion, the answer to the question “to what extent do public transport investments generate sprawl” is that they actually generate sprawl if they extend to the suburban or rural areas, if they provide a significant improvement in the accessibility, and whether the network is radial or radial *and* orbital.

10.4.3. Policies most effective to reduce urban sprawl

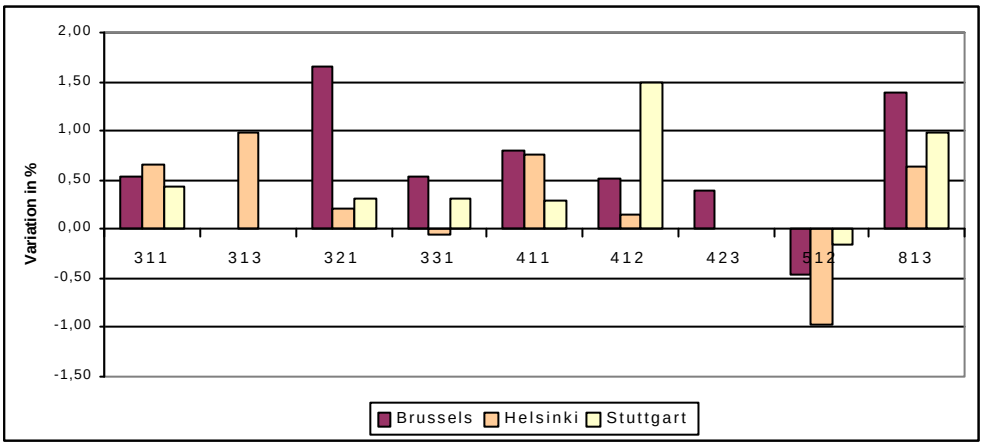
To answer the second question “which policies are most effective to control sprawl and reduce its negative effects”, the simulation results from the 3 cities have been brought together into comparative diagrams as follows. The definition of the scenarios is given in the Table 10.2 in section 10.2.2. The question is “do some policies appear as more effective in all 3 cities ?”.

Conclusions from the comparison of the simulation results on the *individual measures* (i.e. not the combinations) are given in the 2 next sub-sections, following the comparative diagrams.

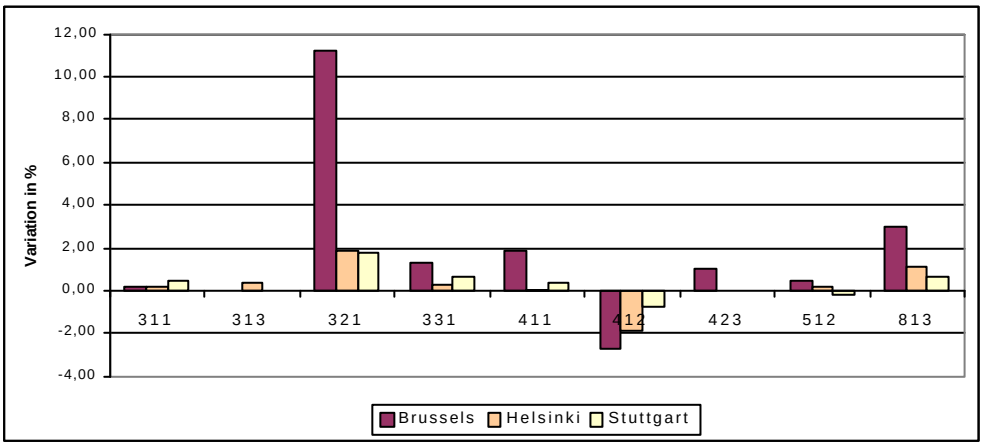
Variation of the number of households in the urban centre



Variation of the number of households in the urban zones

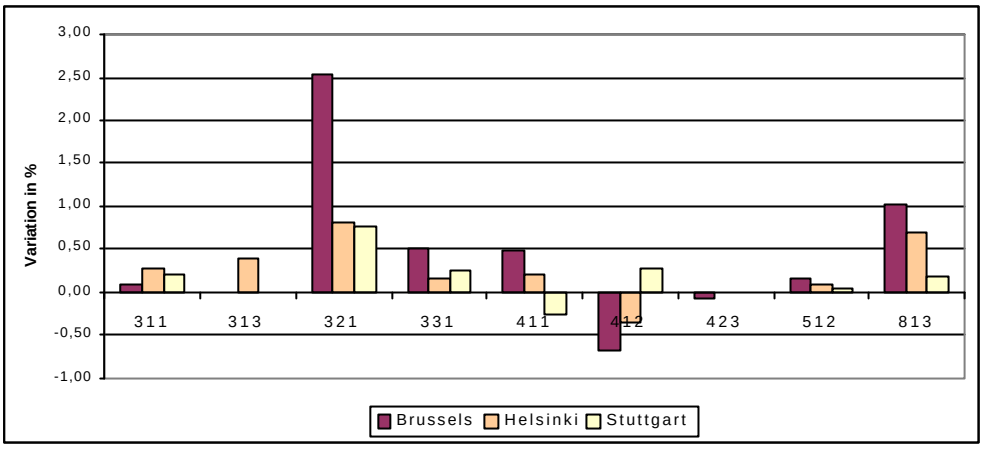


Variation of the number of jobs in the urban centre

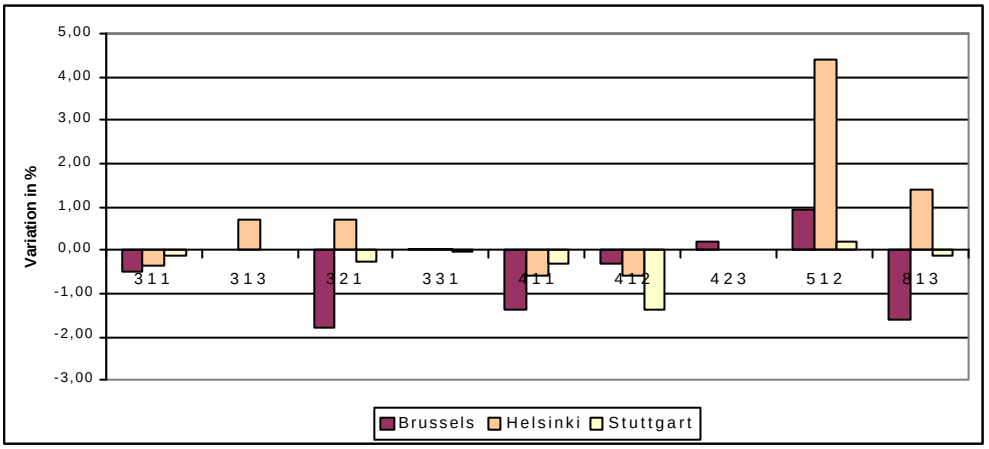


Figures 10.20: Impacts of the common scenarios in the 3 case cities

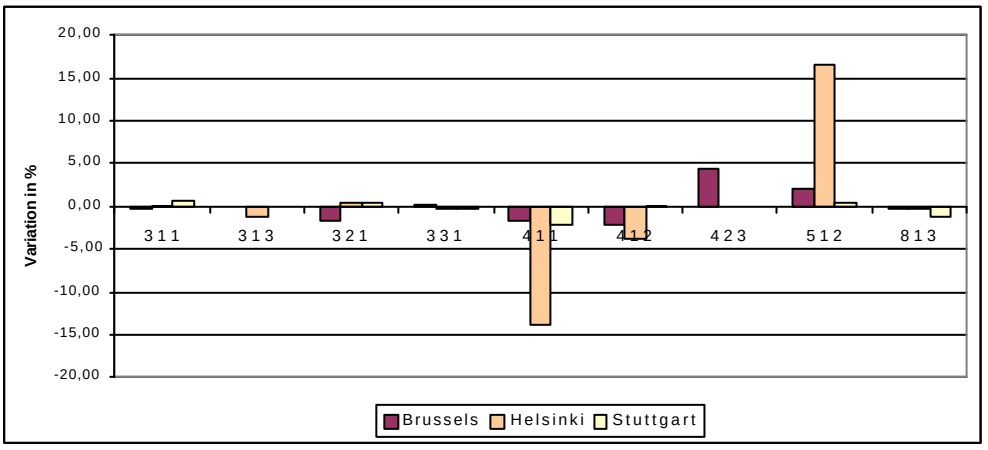
Variation of the number of jobs in the urban zones



Variation of the indicator H relative for population (%)

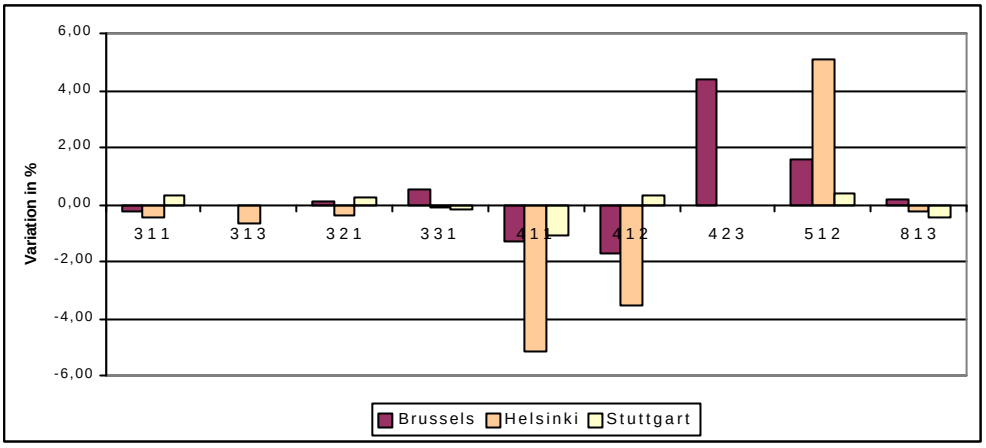


Variation of the home-work travel distance in the study area

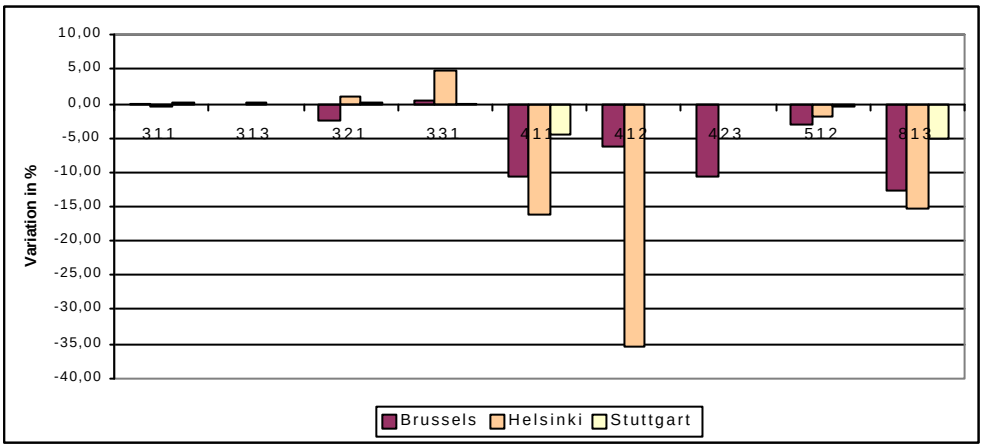


Figures 10.21: Impacts of the common scenarios in the 3 case cities (cont.)

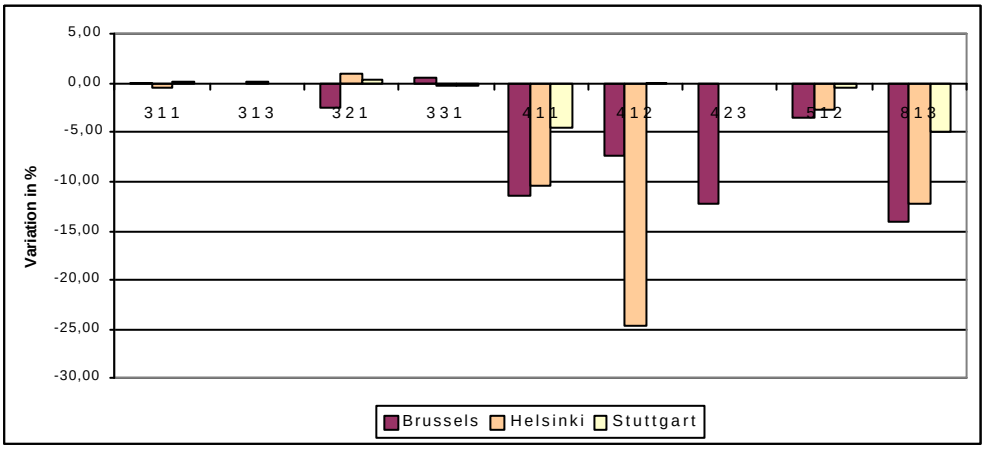
Variation of the average travel time in the study area



Variation of the total car mileage in the study area



Variation of the CO2 emissions in the study area



Figures 10.22: Impacts of the common scenarios in the 3 case cities (cont.)

Variation of the public transport share (points)

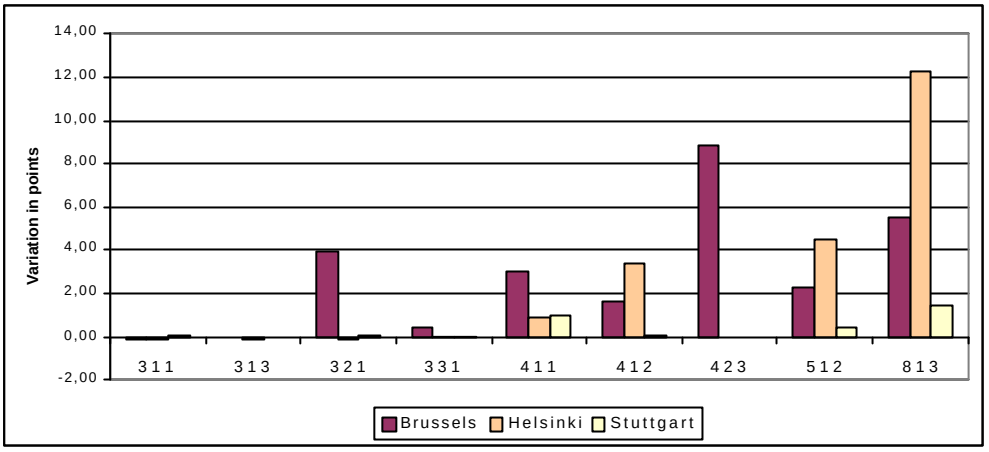


Figure 10.23: Impacts of the common scenarios in the 3 case cities (cont.)

10.4.3.1. Objective of urban concentration

The growing urbanisation is related to topics such as: consumption of land, loss of high quality agricultural land and open space, destruction of biotopes and fragmentation of eco-systems, changes in the streaming coefficient, but also: social segregation and social interactions, and higher costs for equipments and infrastructures.

Now, with regard to ***urban concentration*** and ***land consumption***, the most effective policies in the 3 cities are:

- road pricing: effective in all 3 cities
- impact fee on new suburban residential developments: effective in all 3 cities
- in some cases, fiscal measure to incite services (offices) to locate in zones served by high quality public transport (e.g. around rail stations), or constraining regulatory measure with the same purpose. For this type of measure, the potential effectiveness depends of the percentage of jobs already located in that kind of zones, in the reference scenario. For example, the percentage was 37 % in Brussels, versus 70 % in Helsinki, which explains that the policy appeared to be much more effective in Brussels than in Helsinki.

When looking at the indicators "number of households in the urban zones", the impact fee policies (311 – 313) score roughly as well as the car use cost increase (411). This result of course depends on the level of the respective parameters (new fee and cost increase). In 311, the impact fee tested is 670 €/housing/year (which corresponds to a 13 400 € one-shot tax distributed on 20 years). In 313, the impact fee was 1 000 €/housing/year. In 411, the car use cost increase is + 50 %.

It is therefore an original result from SCATTER to have demonstrated through the simulations that, with regard to improving the urban concentration, a policy of impact fee on new suburban residential developments is as effective as the better known policies of road pricing.

That kind of fiscal measure (impact fee) has been among others recommended by the European Conference of Ministers of Transport[7]. It is used for more than 3 decades in the United States, to control urban sprawl and to "internalize" to some extent the external costs of the suburbanization. It appeared in the years 70' and has the form of a one-shot tax imposed to the developers for new suburban developments. Roughly, it aims at financing the infrastructures and equipments on the area to be urbanised and also the works to connect these new infrastructures and equipments to the existing networks. Currently, 23 States impose this tax to any new housing development to cover the long-term marginal cost of the improvements to be provided to infrastructures, equipments and services.

Still regarding the urban concentration, cordon pricing (412) and parking policies (423) are effective too. However, they were not kept in the final packages (i.e. 811-813) because they produce a repulsive effect on employment. In scenario 423 (Brussels only), the parking restrictions are carefully balanced between the urban centre (the Brussels-Capital Region) and the urban centres of the 2 other Regions, so that the Brussels Region undergoes no employment decrease.

[7] *Politiques spatiales et transports – Le rôle des incitations réglementaires et fiscales, Conclusions de la Table Ronde de la CEMT n° 124*, Paris, 7-8 November 2002.

With regard to the effectiveness of the land fiscal measures, again, it is worthwhile comparing the effects on employment of the scenarios 321, 331 and 411. The regulatory measure 321 (obligation for *all* jobs of some tertiary sectors to locate in A-type zone[8]) is the most effective one, with regard to the concentration of jobs, but is difficult to implement. The measure 331 works towards the same objective, but through a fiscal means: it consists in a tax amounting to the actual cost of a yearly public transport season ticket (1 985 € for Brussels, 710 € for Helsinki, 976 € for Stuttgart). When looking at the indicator "number of jobs in the urban zones", the measure 331 appears to be at least as effective than the measure 411. Again, as above, the results of course depend on the level of the respective parameters (tax and cost increase).

A final remark is that, generally speaking, the level of the variations is low (a few percents). It has to be reminded, when interpreting these results, that some categories of households, and some categories of economic activities are not affected by the variation of the travel times or costs. For example, the retired or old people are likely to not be encouraged to move towards suburbs, whatever the travel times. In the case of Brussels, for example, this category represents about 25 % of the households (in 2001). Similarly, central administrations, universities, as well as heavy industries do not respond to a local demand, but rather to an inter-regional or national demand; their location is therefore not or little influenced by the local accessibilities.

10.4.3.2. Objective of reduction of emissions due to transport

With regard to ***climate change*** and ***air pollution***, the most effective policies are: road pricing and parking policies.

Although they were the most effective with regard to these criteria, the cordon pricing and the parking strategies were discarded from the final selection of measures for the combinations, because of their negative effects on employment (for more details on the effects of parking policies on job location, see the case of Brussels – scenarios 421, 422, 423, 424).

In all 3 cities, land use policies seem to have only little impact on the transport indicators and especially on the CO_2 emissions due to transport, except the measure 331B in Brussels, which is quite drastic (regulatory measure forcing all jobs in the business services sector to locate in A-type zones). Several comments can be made on this result. Several experts have already stated that, although land use policies are not much effective by themselves to change the mobility pattern and the level of emissions, they set up a general context more favourable for the effectiveness of transport policies. Other potential explanations are as follows: in the case of Brussels for example, the modal share of public transport (rail) for the trips between the furthest periphery to the centre is relatively high; if the inhabitants of these areas move towards the urban centre or secondary urban centres, it may be that the benefit in modal shift be low (however, there will still be the benefit in terms of land consumption, etc). A second possible explanation is that in scenarios 321 and 331, where offices are moving towards urban centres, a part of the home-work travel distances decreases and another part increases, which again would lead to only a small benefit or no benefit. Finally, some observed facts seem to confirm the fact that land use policies alone have poor impact on congestion and transport emissions: Dutch researchers have analysed ex-post the long-term effects of the very firm land use planning strategy implemented by the Dutch government during the last decades. Roughly, this strategy aimed to a decentralised concentration (through the ABC and VINEX approaches). They came to the conclusion that

[8] According to the ABC land use theory developed in The Netherlands, "A-type" zones are zones very well served by public transport, at regional or even national scale (e.g. locations served by inter-city railway stations).

these strategies were not effective (or not as effective as expected) to reach the objectives of reducing congestion and emissions due to transport[9].

10.4.3.3. Evaluation through the sustainability indexes

With regard to the sustainability indicators and indexes which were calculated in the case of Helsinki only, the results show that the car pricing policies have significant positive effects on all the dimensions of sustainability (environmental, social, economic), whereas the effects of the land use pricing policies on the 3 sustainability indexes are very small. However, it is worth noting that some negative aspects of the suburbanisation, which are reduced by the land use policies, such as loss of the high quality agricultural land and open spaces, and the higher costs of infrastructures and equipments, are not taken into account in the sustainability indexes[10].

10.4.3.4. Combinations of policies – Integrated strategies

Also combinations of individual policies were tested and these simulations confirm that the best strategy is a combination of transport policy and land use policy. The table below resumes the values of some key indicators for the combination 813, which provides the best scores on the different criteria, in the 3 cities.

The best combination proposed by SCATTER (i.e. the scenario 813) combines congestion pricing, reduction of the public transport fare, impact fee on suburban residential measures and a fiscal measure intended to services (offices), to incite them to locate in areas well served by public transport.

With regard to congestion pricing, the measure actually simulated was an increase of car use cost during the peak period; the practical recommendation is congestion pricing (road pricing in congested areas, during congestion period).

The reduction of the public transport fare at a regional level encourages sprawl, but has a positive effect on the modal share and the emissions due to transport. In fact, the most adequate measure should be to implement the reduction of fare only inside the central city. Indeed a simulation in the Brussels case (local scenario 517B) has shown that a reduction of the transport generalised cost (increase of the commercial speed of public transport, as it was) territorially limited to the central area increases the attractiveness of the central area both for population and for jobs.

The combination 813 includes several pricing measures. Generally, pricing policies (either pricing land use or transport) can be more easily adjusted to the observed problems (congestion, land consumption, spatial competition, etc) than regulatory actions, and hence can be more effective, but on the counter-side their acceptability is generally lower.

Sustainability indexes were calculated in the Helsinki case city. The sustainability evaluation shows that the combinations (scenarios 811-813) are able to simultaneously improve all the dimensions of the sustainability. The most effective way to tackle sprawl is to create policy packages that combine the best qualities of individual policy measures and even out some

[9] Ex-post evaluation of Dutch spatial planning and infrastructure policies, K. Geurs, B. Van Wee, A. Hoen, A. Hagen, European Transport Conference, Strasbourg, 2003.

[10] Some other effects of the consumption of suburban or rural land are not or incompletely taken into consideration in the sustainability evaluation: the change in the water streaming coefficient, the social segregation or social interactions. This is a perspective for future research.

inevitable side-effects or problems of the used main measures (what is for example difficult to control are both the household and employment sprawl at the same time).

Table 10.5: Effects of the scenario 813 in the 3 case cities

	Variation in the number of households in the urban centre (%)	Variation in the number of households in the urban zones (%)	Variation in the indicator H-relative for population (%)	Variation in the number of jobs in the urban centre (%)	Variation in the number of jobs in the urban zones (%)	Variation in the average home-work trip distance (%)	Variation in the total car mileage (%)	Variation in the public transport modal share (points)	Variation in the total CO_2 emission (%)
Brussels – combination 813B (scenario 813B assessed against 003B)	2.6	1.4	-1.6	3.0	1.0	1.1	-12.6	5.5	-14.1
Helsinki – combination 813H (scenario 813H assessed against 111H)	0.2	0.6	1.4	1.2	0.7	-0.3	-15.2	12.2	-12.2
Stuttgart – combination 813S (scenario 813S assessed against 003S)	2.8	1.0	-0.1	0.6	0.2	-1.2	-5.0	1.5	-5.0

Combination 813 is made up of 4 measures:

- increase by 50 % of the car use cost/km
- reduction of the public transport fare by 20 %, either for the home-work trips only (Brussels) or for all trips (Helsinki and Stuttgart)
- impact fee on suburban residential developments, combined with a reduction of land tax in urban zones
- tax on tertiary employment (offices) locating in areas non well served by public transport.

The conclusions on the overall effectiveness of the policies also depend on the context to what the impacts are compared: in the case of Brussels, the indicators values have shown that the combination 813B (i.e. 4 measures combined with the local investment plan) could roughly counter-balance the loss of population in the Brussels-Capital Region which would be due to the REN. In the case of Stuttgart also, the combination 813S brings back about 3 % of the households to the urban centre. In the case of Helsinki, the relative effects of the combination 813 on the household location are smaller, probably due partly to land use regulatory constraints; the combination 813H could however counter-balance an intensive transport investment policy (such as scenario 116H); but the overall effect of the policy 813 is small compared to the general trend of sprawl in the Helsinki region, due to the population growth[11] and the welfare growth.

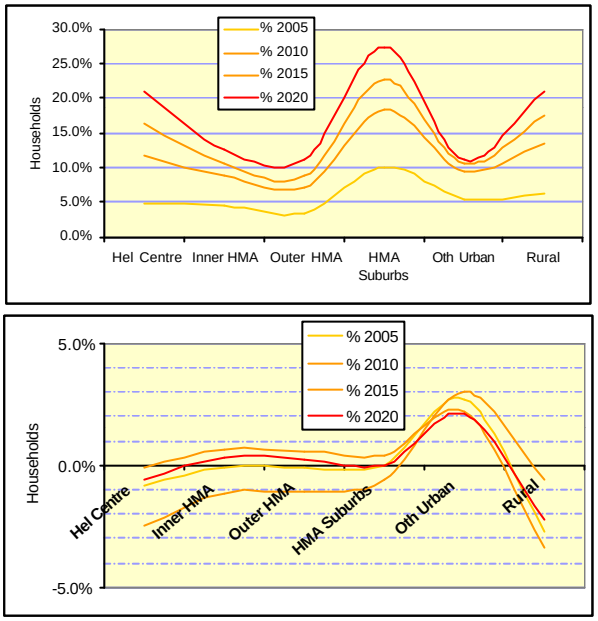
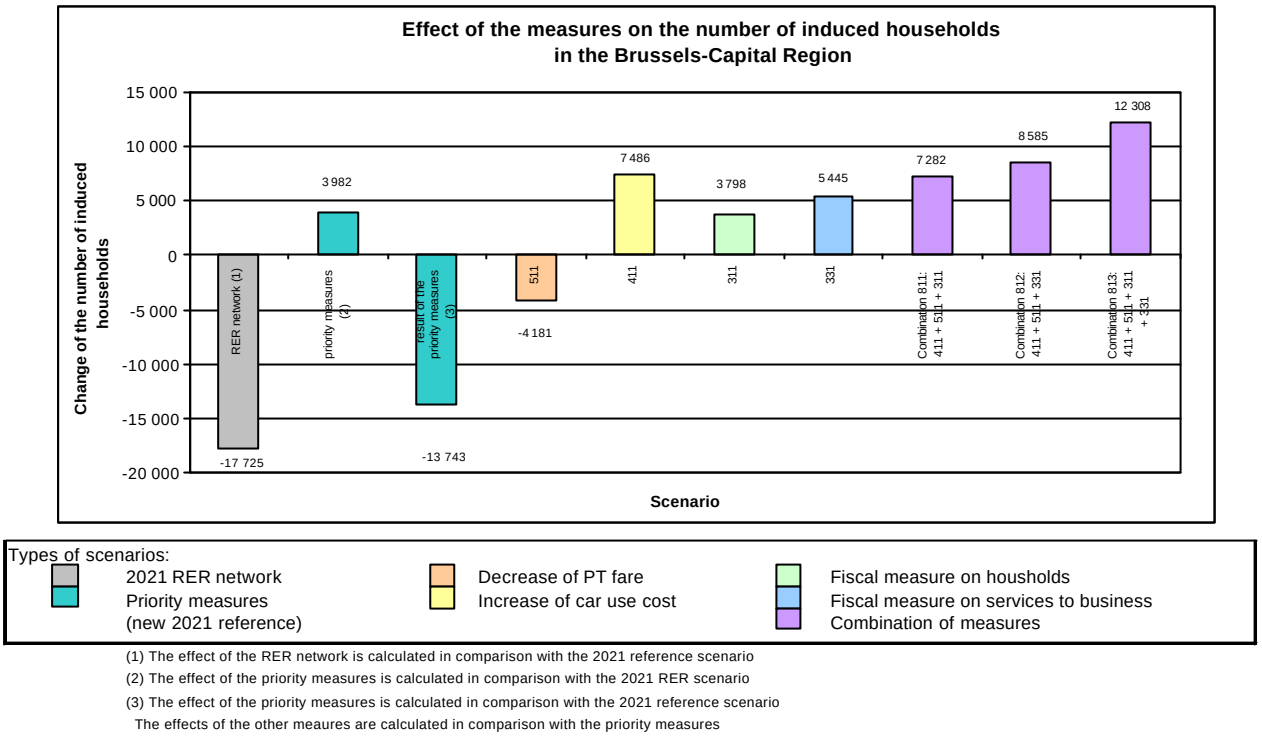


Figure 10.24: Helsinki –Top: evolution 2000-2020 due to the base trend; bottom: effect of combination 813

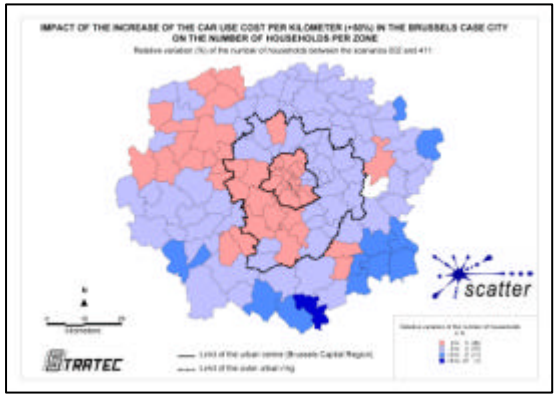
[11] The population growth is supported by a strong trend of migration from rural areas towards the metropolitan area. This was also highlighted in work package 3 (statistical analysis). These last years, the strong growth due to the national migration towards the few urban agglomerations of high technology employment has created a crowding effect in the Helsinki region causing the sprawling effect towards the fringes of the Helsinki Metropolitan Area and outside it. Moreover, the Helsinki Metropolitan Area (which is made up of Helsinki, and 3 other smaller cities) will face a rapid population growth from now to 2020 (an increase by 19.6 % is expected). This increases the pressure for urban sprawl as well as the use of natural and other green areas. It is expected that Helsinki can accommodate less than ¼ of the growth, the rest being redirected to the other cities of the HMA. However, this does not influence the net assessment of the policies, as the policy results are compared to the 2020 situation.

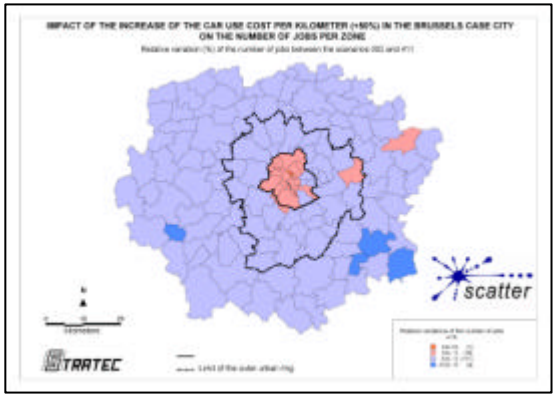


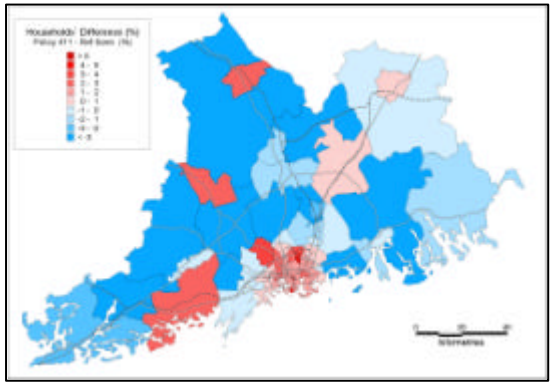
(1) The effect of the RER network is calculated in comparison with the 2021 reference scenario
(2) The effect of the priority measures is calculated in comparison with the 2021 RER scenario
(3) The effect of the priority measures is calculated in comparison with the 2021 reference scenario
The effects of the other meaures are calculated in comparison with the priority measures

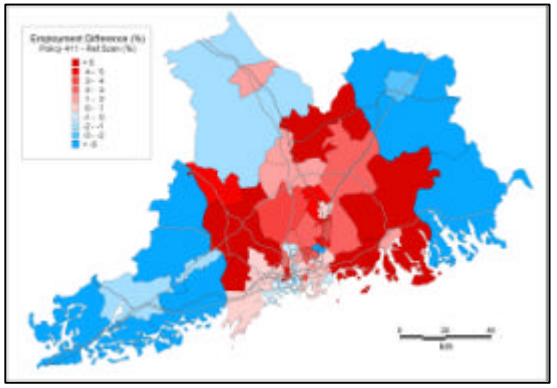
Figure 10.25: Brussels: how the scenario 813 together with the local investment plan ("priority measures") compensate the out-migration of households due to the REN

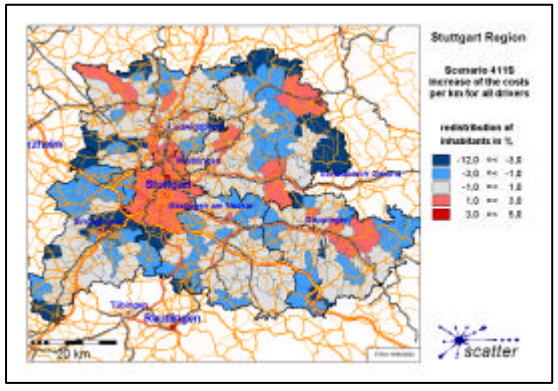
Figure 10.26: Effects of the scenario 411 on household location and job location, in the 3 case cities (411: car use cost increase by 50 %)











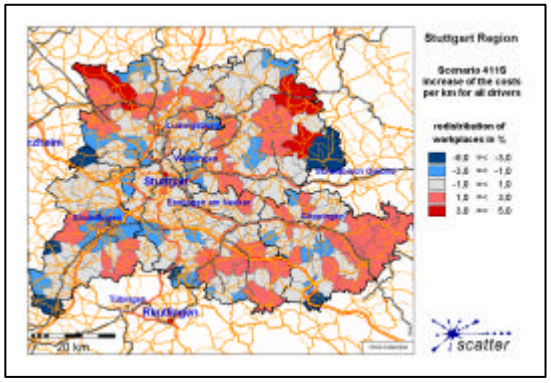
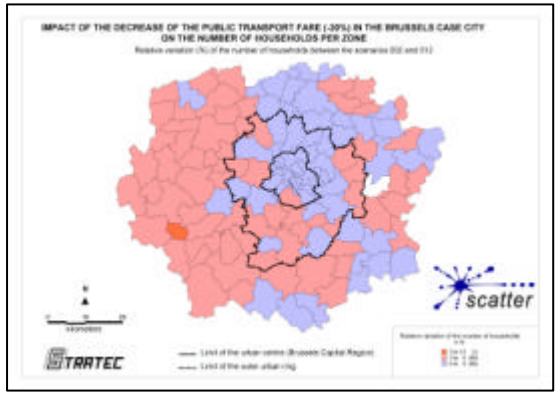
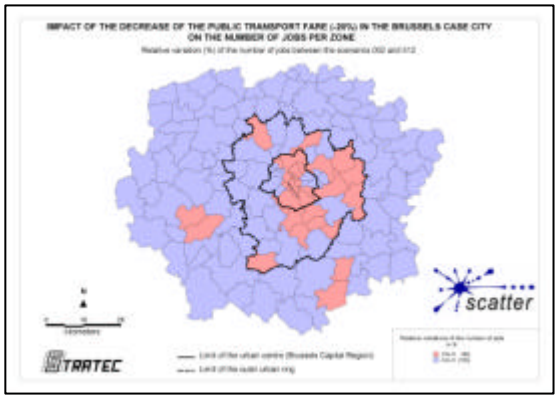
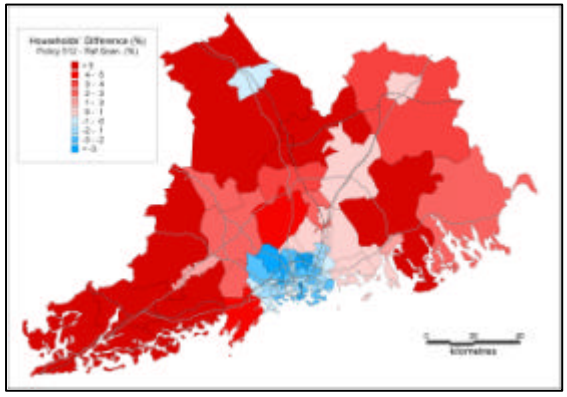
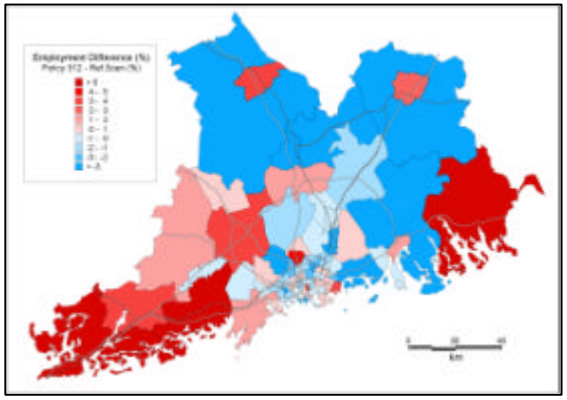


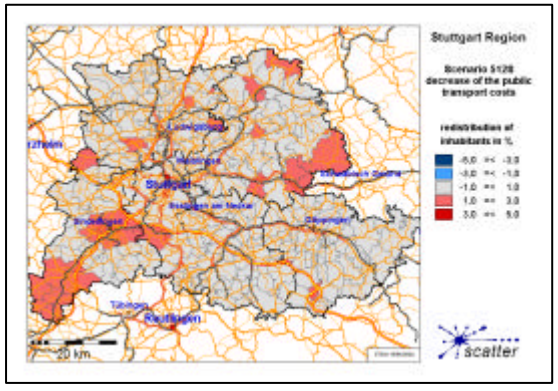
Figure 10.27: Effects of the scenario 512 on household location and job location, in the 3 case cities
(512: reduction of public transport fare by 20 %)











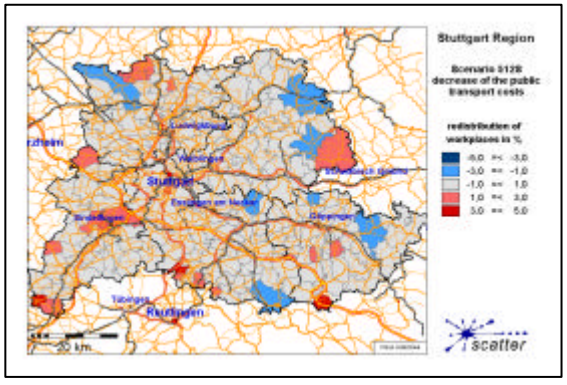
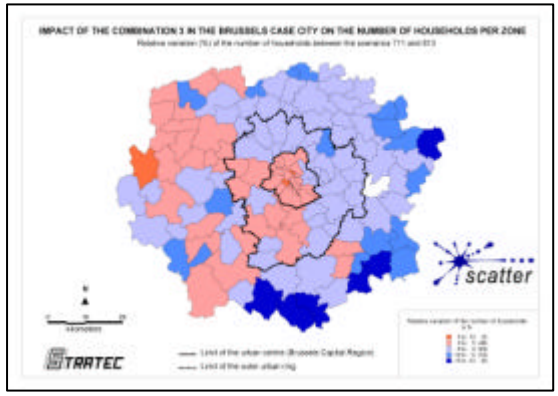
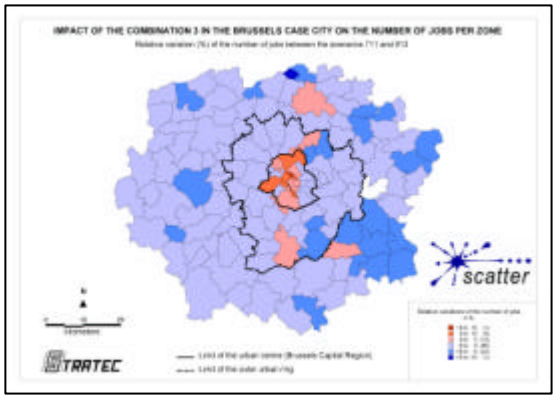
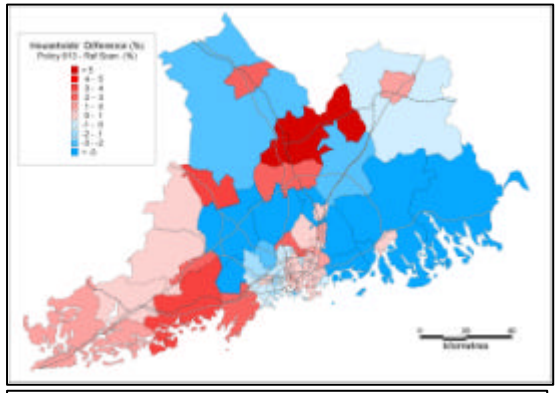
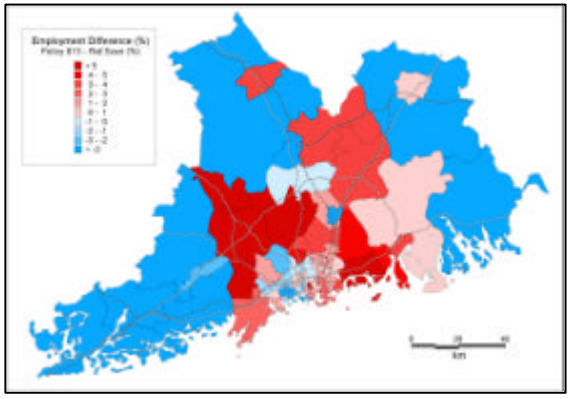


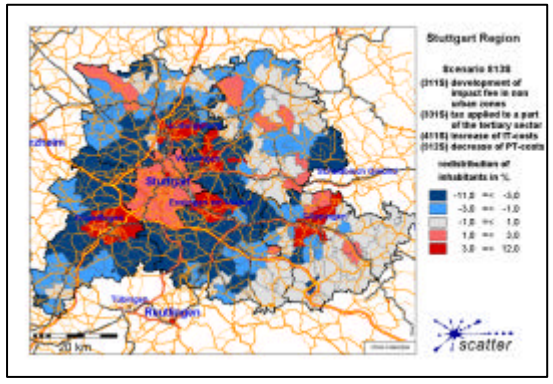
Figure 10.28: Effects of the scenario 813 on household location and job location, in the 3 case cities (813: combination of 4 measures)

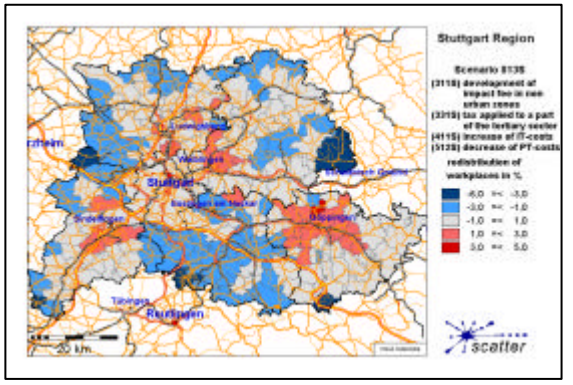












10.5. Conclusions

In conclusion, to the question "to what extent do public transport investments generate sprawl", the simulations provide the answer that they actually generate sprawl if they extend to the suburban or rural areas, if they provide a significant improvement in the accessibility, and whether the network is radial or radial *and* orbital.

With regard to ***urban concentration*** and ***land consumption***, the most effective policies in the 3 cities are:

- road pricing
- impact fee on new suburban residential developments
- in some cases, fiscal measures to incite services (offices) to locate in zones served by high quality public transport (e.g. around rail stations), or constraining regulatory measure with the same purpose. For this type of measure, the potential effectiveness depends of the percentage of jobs already located in that kind of zones, in the reference scenario.

Cordon pricing and parking policies are effective too. However, they were not kept in the final packages because they produce a repulsive effect on employment.

With regard to ***climate change*** and ***air pollution***, the most effective policies are road pricing and parking policies. In this respect, land use policies seem to have only little impact, except a drastic regulatory measure on office location in Brussels.

On the basis of the simulations, the final recommendation of SCATTER is to combine 4 approaches:

- ***congestion pricing: i.e. car use cost increase in congested areas, at peak hours***
- ***reduction of the public transport fare territorially limited to the central agglomeration (indeed a reduction of fare at regional level encourages sprawl, whereas a reduction of fare inside the central area should increase its attractiveness – both measures have of course a positive effect on the modal share)***
- ***impact fee on new suburban housing developments***
- ***fiscal measure to incite offices to locate in areas well served by public transport at regional level (e.g. rail stations).***

The policies selected to be combined in the final package 813 are pricing policies or fiscal measures. Three of them appeal to the general principle "polluter pays" which is considered by the economists as the most adequate means to distribute among users the external costs of transport. Besides, pricing policies (either pricing land use or transport) can generally be more easily adjusted to the observed problems (congestion, land consumption, spatial competition, etc) than regulatory actions, and hence can be more effective. But on the counter-side, their acceptability is generally lower.

Another point is that there are close interactions between the cost of transport and the land rent. Measures increasing the travel cost (and in particular the car use cost) can have significant effects on the land market. The more costly the transport is, the more this contributes to reduce the urban sprawl, the more there will be a pressure to an increase of

the urban land rent. This increase in land rent may in turn have effects on the socio-spatial repartition, and the social segregation. This effect is to some extent taken into consideration in the models[12].

But pricing polices also provide the governments with revenue which enable them to make public transport investments or to make investments to increase the attractiveness of the cities (embellishment, open spaces, etc).

[12] The Helsinki and Stuttgart models include a sub-model of land market or housing market.