Scenarios for the
Transport
system and
Energy supply
and their
Potential
effectS

STEPs

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List of project partners

1 Buck Consultants International (BCI), The Netherlands (Project Coordinator)
2 AUEB, Greece
3 ITS, United Kingdom
4 JRC IPTS, Spain / EU
5 KUL - SADL, Belgium
6 LT, Finland
7 Novem, Netherlands
8 Spiekermann und Wegener (S&W), Germany
9 Stratec, Belgium
10 TIS, Portugal
11 TRL, United Kingdom
12 TRT, Italy
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14 UPM, Spain

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Executive summary

The STEPs (Scenarios for the Transport System and Energy Supply and their Potential Effects) project has the objective of developing, comparing and assessing possible scenarios for the transport system and energy supply of the future taking into account the state of the art of relevant research within and outside the 6th RTD Framework. Strategic modelling is one of the key instruments to achieve such an objective and Workpackage 4 'Scenarios impacts' is the core of the research activities of the project.

The WP4 objective is 'running a set of inter-linked models at the European and urban-regional level to produce forecasts of relevant impacts of the scenarios'. The impacts addressed include: transport demand, energy consumption, greenhouse and polluting emissions, regional development, local accessibility and others, and are considered both at European and local/regional level.

The first deliverable produced in WP4 (Deliverable D4.1) was issued in June 2005 to introduce the features of the different tools used for the modelling exercise. Since then, activities of Workpackage 4 have proceeded and this second deliverable (D4.2) reports the final outcome of the modelling exercise as well as the methodology used to implement the scenarios variables in the models.

The methodology

Several modelling tools are used in the STEPs project in order to simulate the scenarios on transport and energy supply and to provide quantitative responses on the effects of such scenarios on various respects. The models can be classified into two main categories (see table 1):

- models operating at the European level: the ASTRA System Dynamics Model, the SASI socio-economic model and the POLES energy model;
- models operating at the urban/regional level: Dortmund model, South Tyrol Meplan model, Helsinki Meplan model, Brussels IRIS model, Edinburgh SPM model.

Table 1 List of the models involved in STEPs project

European models	Urban/regional models
ASTRA Model	Brussels IRIS model
SASI model	Dortmund model
POLES model	Edinburgh SPM model
	Helsinki Meplan model
	South Tyrol Meplan model

The models cover a range of different methodologies. Even if the ASTRA and the SASI model are both European models, they work with two different approaches. Based on a coarse geographical system, ASTRA is a system dynamics model where the input/output relationships between sectors play a major role to explain the linkages between transport, economy and environment. SASI is a recursive model (i.e. looking for equilibrium) aimed at analysing the impacts of infrastructures and other major changes in the transport system to the local economies where such impacts is modelled by regional production functions in which spatially disaggregate accessibility indicators are included. Therefore, even though both models provide a response about how changes on the transport side affect the economy, their response is given from two well separate perspectives.

Also in the regional models some differences can be noted. From the point of view of the methodology, in almost all models land use and transport interact in some way, even if not in the same way. For example, the Helsinki and the South Tyrol model share the same software and are more similar, the Dortmund and the Edinburgh model are built with different relationships. Also the local contexts are different: the Brussels and Dortmund models are focused on very densely populated metropolitan areas with millions of inhabitants. The Helsinki and Edinburgh models cover wider regions with a major city centre where most of the population lives. Finally, the study area of the South Tyrol model is the whole province, sparsely populated and where the major city counts no more than 100.000 inhabitants.

So, each different model used for simulating the scenarios provides a different way of looking at the impacts of the policies; specific mechanisms that play a major role in one tool could be secondary in another one and therefore lead to different effects.

The scenarios

Eight main different modelling scenarios have been defined in STEPs; seven other additional modelling scenarios have been also identified. These scenarios are a development of the initial six scenarios established in Workpackage 3.

The six scenarios defined in Workpackage 3 resulted from crossing two diverse policy strategies in two contexts of future energy supply until the year 2030. From the point of view of *energy availability,* two groups of scenarios have been identified:

- Scenarios ‘A’, based on a generally accepted energy supply forecast, which means that oil price is assumed to increase 2% per year on average. In the following, these scenarios will be named **‘Low oil price growth scenarios’** or just **‘Scenarios A’**;
- Scenarios ‘B’ is based on the assumption of energy, scarcity i.e. oil price is meant to increase 7% per year on average. In the following, these scenarios will be named **‘High oil price growth scenarios’** or just **‘Scenarios B’**.

At the same time, two contrasting *policy strategies* have been considered:

- Policy strategy ‘1’, concentrating on investments in technologies (i.e. improving energy efficiency, supporting innovative vehicles). In the following, these scenarios will be named **‘Technology investments scenarios’** or just **‘Scenarios 1’**;
- Policy strategy ‘2’, focussed on demand regulation (i.e. reducing the need of travel, reducing trip lengths, shifting demand on public modes, etc.). In the following, these scenarios will be named **‘Demand regulation scenarios’** or just **‘Scenarios 2’**.

These two strategies have been put next to **Business as Usual** alternatives (labelled as **‘Scenarios 0’**), where only a limited number of policy measures (coherently to the current transport and energy policy approach) are assumed. The final result was a matrix of six alternative scenarios (see table 2)[1].

Table 2 STEPs Scenarios as defined in Workpackage 3

	Business as usual	Technology investments	Demand regulation
Low oil price growth	A0	A1	A2
High oil price growth	B0	B1	B2

1 Details on the scenarios developed in Workpackage 3 can be found in the STEPs Deliverable D3.1, ‘Framework of the scenarios & description of the themes’.

In a later stage, this set of six scenarios has been enlarged from three separate perspectives.

- *Isolate energy price impact*. As specified above, the 'Business as usual' scenarios defined in Workpackage 3 contain some policy measures beside the assumptions concerning the development of the energy price. Such measures represent the expected 'policy environment' for the future years and therefore their inclusion in a 'Business as usual' scenario is justified; however, from a modelling point of view, it is important that the effect of the development of energy price can be isolated. For that reason, a set of scenarios where only the assumption concerning the oil price growth is considered has been defined. These scenarios have been labelled **'Scenarios –1'** and in the following they will be named **'No-policy scenarios'**.

- *Simulating more 'pessimistic' assumptions about fuel price*. The assumptions concerning the development of energy price do not enter directly in all the modelling tools in terms of *fuel price* development. Instead, the assumptions relate to the *oil price* development and, as such, are a direct input only for the POLES model. The POLES model simulates the reaction of worldwide demand and supply to oil price and produce forecasts of fuel price; this fuel price is the actual input for the other modelling tools. As explained in the following chapters, the mechanisms modelled in POLES lead to an adjustment of demand such that fuel price increases much slower than the 7% p.a. assumed for oil in the high oil price growth scenarios (scenarios 'B'). This means that the difference in terms of energy price between scenarios 'A' and scenarios 'B' is not as large as the different assumptions concerning oil price would suggest. In scenarios 'A' where a low oil price development is assumed, the growth rate is 2% p.a. over the next 30 years, while in the high oil price growth case the rate is 7% p.a. Instead, pure fuel price grows on average of 1% p.a. in scenarios 'A' and 4% in scenarios 'B'. With the objective of allowing for the simulation of a larger fuel price difference, to test an 'extreme' case, a new group of scenarios has been defined in a later stage. In such group of scenarios, pure fuel price grows at 7% per year. These scenarios have been labelled as **Scenarios 'C'** and in the following they are named as **'Extreme fuel price growth scenarios'**.

- *Simulating an integrated policy approach*. Demand regulation and investments in technology are simulated as alternative approaches in scenarios '1' and scenarios '2' respectively. However, especially when a fast growth of energy price is assumed, both types of policy measures could be applied. Therefore, a further set of scenarios have been defined to allow for testing a policy approach where both investments in technology and demand regulation are put into practice. These scenarios have been labelled as **'Scenarios 3'** and are referred in the following as **'Integrated policy scenarios'**.

Table 3 summarises the whole set of scenarios, which includes 15 different elements, i.e. the original set of scenarios defined in Workpackage 3 is more than doubled.

Table 3 Full set of STEPs scenarios

	No policies	**Business as usual**	**Demand Regulation**	**Technology investments**	**Integrated policies**
Low oil price growth	A-1	A0	A1	A2	A3
High oil price growth	B-1	B0	B1	B2	B3
Extreme fuel price growth	C-1	C0	C1	C2	C3

(blue)	Main STEPs modelling scenarios	(yellow)	Additional modelling scenarios

Within the time and the resources available in the project, implementing, testing and reporting 15 different scenarios was a challenging task, especially for some models. For that reason, it has been decided to identify a sub-set of *main scenarios* to be simulated by each modelling tool. The remaining scenarios have been considered additional scenarios, whose simulation could be carried out on a voluntary basis. This has led to the 'Extreme fuel price growth scenarios' (Scenarios 'C') and 'Integrated policy scenarios' (Scenarios '3') (coloured yellow) to be considered as additional scenarios. The larger part of the modelling application has been maintained on the six scenarios defined in Workpackage 3, with the addition of the 'No-policy scenarios' A-1 and B-1, in order to identify the effect of a higher oil price (coloured blue).

In the end, the 'Extreme fuel price growth scenarios' and the 'Integrated policy scenarios' have been simulated in the SASI European model and in the Dortmund regional model as the structure of these two models allows for implementing and simulating several scenarios quite easily, once the underlying framework of input is defined. In the other STEPs models, only the eight main scenarios have been simulated.

The quantification of the different scenarios (i.e. the value assumed for each key variable) has been completed in Workpackage 3, as yearly variations in relation to the base year values. Table 4 provides a summary of the quantitative assumptions for each scenario group.

Table 4 Quantitative assumptions for the policy strategies

	Measure	Indicator	A0/B0	A1/B1	A2/B2
			Annual change (%)		
Socio-economic	Pure Fuel price	Gasoline	2% / 7%		
		Diesel	2% / 7%		
	Car sharing etc.	Car ownership	+1%	As A0	-0.6%
	Fuel tax	Gasoline	+0.7%	As A0	+4.7%
		Diesel	+1.5%	as A0	+4.7%
		Kerosene (% of gasoline tax, from 2012)	50%	as A0	200%
	Travel cost due to tax increases	Car/lorry cost per km	+0.5%	+0.5%	+3%
		Air cost per km	-0.5%	-0.5%	+3%
	Telework	Work trips saved	0%	as A0	+0.3%
Spatial	Residential	Central	+	as A0	++
		Inner urban	++	as A0	+++
		Outer urban	+++	as A0	0
	Services	Central	0/+	as A0	+
		Inner urban	+	as A0	++
		Outer urban	++	as A0	0
	Industrial	Central	0	as A0	0
		Inner urban	+	as A0	+++
		Outer urban	+++	as A0	0/+
Travel	European rail	European rail speed	+0.8%	+2.0%	as A0
	Regional rail	Regional rail speed	+0.4%	+1.7%	as A0
	Public transport	Local public transport speed	+0.3%	+1.1%	as A0
	Traffic calming	Average speed reduction for cars	-0.4 or -1.5% every 5 years	as A0	-1.0% or -4% every 5 years
	Road pricing	Average cost of car km	+2.0%	as A0	+6.0%
	Public transport cost	Bus cost	+0.8%	as A0	-1.7%
		Train cost	+0.8%	as A0	-1.7%
Freight	Traffic calming	Average speed reduction for trucks	-0.4 or -1.5% every 5 years	as A0	-1.0% or -4% every 5 years
	Road pricing	Average cost of road ton-km	+2.0%	as A0	+6.0%

Measure		Indicator	A0/B0	A1/B1	A2/B2
			Annual change (%)		
	City logistics	Freight average distance	-0.2%	-0.5%	as A0
		Freight load factor (short distance)	+0.8%	+2.4%	as A0
	Rail freight	Rail freight speed	+0.7%	+2.0%	as A0
		New freight rail network cost	-0.6%	-1.5%	as A0
Energy	Energy efficiency for cars and lorries	Gasoline fuel consumption per car	-0.5%	-2.0%	as A0
		Diesel fuel consumption per car	-1.0%	-3.0%	as A0
	Alternative vehicles	Emissions per km	-50% every 9 year (new EURO) or -8.1%/year	-50% every 5 year (new EURO) or -16%/year	as A0
		Car fleet	<u>Share:</u> Conventional:72% Hybrids: 15% CNG: 10% Electric: 1% Hydrogen: 2% <u>Annual increase</u>: Conventional: -1% Hybrids: +12,5% CNG: +10% Electric +3% Hydrogen + 3%	<u>Share:</u> Conventional:55% Hybrids: 20% CNG: 15% Electric: 5% Hydrogen: 5% <u>Annual increase</u>: Conventional: -2.1% Hybrids: +13,5% CNG: +12% Electric +7% Hydrogen + 7.8%	as A0
	Energy use rail	Train fuel consumption rate [l/(vhc*km)] (diesel trains), Electric Consumption Factors [kWh/km]	-0.8%	-5.0	as A0
	Energy use ship	Ship diesel consumption [kg/km]	-0.4%	-1.6%	as A0

The STEPs scenarios have been implemented in the modelling tools according to their specific features and capabilities. As stated in the proposal, Workpackage 4 of the STEPs project was aimed at using existing tools to simulate a set of scenarios. Existing tools means that, excluding some limited adaptation and re-calibration, the models have been used using their original structure and parameters without a dedicated work for checking and homogenising definitions, common variables, etc. Furthermore, the modelling tools have not been linked in a tight way and have worked as independent models.

One important consequence of the specificity of each tool is that none of the several modelling tools used is capable of simulating all measures included in the scenarios. Some of the scenario variables were not present 'as such' in the models and therefore each model has implemented a 'customised' version of the scenarios. Although each tool has been applied as an independent model, there are at least four conditions that ensure results can be compared at least in broad terms:

1. First, whenever possible, the same measure has been implemented in the same way and this is true for key variables like fuel taxes, public transport performance or vehicle energy efficiency.

2. Second, although significant differences exist between the European models, as their focus is different, they are broadly comparable in terms of the basic common trends and assumptions and therefore the policy measures affect the same evolution of the economic, transport and energy systems through time.

3. Third, even if models have worked as independent tools, a linkage was actually activated through an iterative procedure that made use of the POLES and ASTRA models to forecast the effect on *fuel prices* of the assumptions concerning *oil price,* given the development of transport demand. Forecasts obtained with this procedure have represented an input for all other tools.

4. Finally, to guarantee consistency between the European models and the local models, exogenous information such as energy price or fleet development adopted by local models has been drawn from European models forecasts.

The definition of the scenarios was based on oil price as this is the primary variable, which drives the cost of all fossil fuels. However, even if there is a clear correlation between oil price and fuels price, it would not be correct to assume that the hypothesis concerning the former could be applied as such to the latter. It was the energy market POLES model which took care of the simulation of the fuel price development as a consequence of the oil price hypothesis assumed in the scenarios. And since one crucial variable affecting the development of fuel price is transport demand, this was provided to POLES form the ASTRA model. Transport demand affects price but also the reverse is true, so there is a feed-back relation to take into account. For that reason, the POLES and ASTRA models have worked interactively in a feed-back process.

Modelling results

In the A-1 scenario, where only the lower growth rate of oil price is modelled, transport demand grows both for passengers and for freight. Such a trend of growing demand for the future years is common to Europe-wide models as well as to regional models. Even if population in the EU25 is forecasted as stable or even decreasing in the future years, the modelling results suggest that the mobility of people will continue to grow in terms of passengers-km until 2030. Higher motorisation rates (the number of cars per 1000 inhabitants is forecast to be 25% higher in 2030 than nowadays) and higher average personal income can explain a slightly larger number of trips; at the same time, average trip length distances are also increasing. With reference to freight transport, the number of tonnes-km is forecast to grow faster than the economic growth, thus continuing the past trend observed in the last 30 years[2]. As far as the economic development is concerned, forecasts range from an average GDP growth rate of 1.8% p.a. (SASI model) to an average rate of 2.7% p.a. (ASTRA model).

The picture is not too different in the business-as-usual scenario (A0). Although policies aimed at increasing costs and times for road modes (and conversely favouring rail modes) are already implemented in this scenario, their effect on the overall mobility level is minor: passenger and freight transport demand continue their growth until the year 2030.

Cars and trucks are currently the dominant transport modes and their role is confirmed or even enhanced in the future, according to the No-policy (A-1) scenario. On the freight side, also sea shipping maintains a significant role. As far as passenger transport is concerned, car share is stable or even increasing although on long distance trips the role of air transport is rapidly growing.

In the A0 scenario, car and road freight continue to be the main modes of transport, even though their shares are slightly reduced. The growth of the overall mobility does not trigger a proportional increment of the energy consumption in the sector: in fact total fuel consumption in the A0 scenario is substantially unchanged over the simulation period. Such an effect is due to the evolution of the vehicle fleet: the scenarios assume that innovative vehicles (electric, fuel cells, etc.) will amount to about 10% of the fleet at 2030 in the A0 scenario. A greater efficiency of the vehicles explains why more or less the same amount of fuel is used even if demand is increasing.

Improved efficiency of road vehicles is clearly visible also when considering the environmental effects (table 5). Polluting emissions are sharply decreasing already in the no-policy scenario (A-1), with the only (though relevant) exception of the greenhouse emissions (CO_2). Actually, for technical reasons, the gain in terms of reducing unitary emissions of pollutants that can be obtained in the newest conventional vehicles (EURO IV, EURO V, etc.) does not have a correspondence on the greenhouse gases side. However, as far as elements like CO or PM are concerned, the reduction of the emissions is huge at

2 See for instance EU Energy and Transport in figures 2004 page 3.1.3.

the extent that the absolute value of emission in the future year will be significantly lower despite the traffic growth.

Table 5 Change of total emissions in the no-policy scenario (A-1) under the low oil price growth assumption 2005 - 2030 and innovative fleet share at 2030

Model	CO_2 emissions	CO emissions	NO_x emissions	PM emissions	VOC emissions	% innovative vehicles in the fleet
European models						
ASTRA	↑	≈	↓	n.a.	↑	↑
Local models						
Brussels[1]	↑	↑	↑	n.a.	↑	≈
Dortmund	≈	↓	↓	↓	↑	↑
Edinburgh[2]	≈	n.a.	↓	↓	n.a.	↑
Helsinki[1]	↑	↓	↓	↓	n.a.	↑
South Tyrol[1]	↑	↓	↓	↓	↓	↑

↑	Increment with respect to 2005
↓	Decrement with respect to 2005
≈	Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020
2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

The measures simulated in the A0 scenario do not add much to the base trend of the A-1 scenario, even if direct greenhouse emissions are reduced in the final years of the simulation period. It seems this is not the case when well-to-wheel emissions are considered, as it happens in the Edinburgh model.

On the economic side, the impact of the Business as Usual policy measures (especially pricing and taxing of road modes) is to slightly reduce the growth of GDP and employment, but the base trend of the No-policy scenario is not significantly changed.

According to the model simulations, the average European accessibility for passengers and freight is increasing in the future years in the No-policy scenario because of the underlying assumptions on further European integration. This growing trend is consistent with the dynamics of the past years, while the Business as Usual scenario gives rise to a break in the trend, slightly reducing average accessibility (especially for freight) as a consequence of higher cost of road transport (see figure 1).

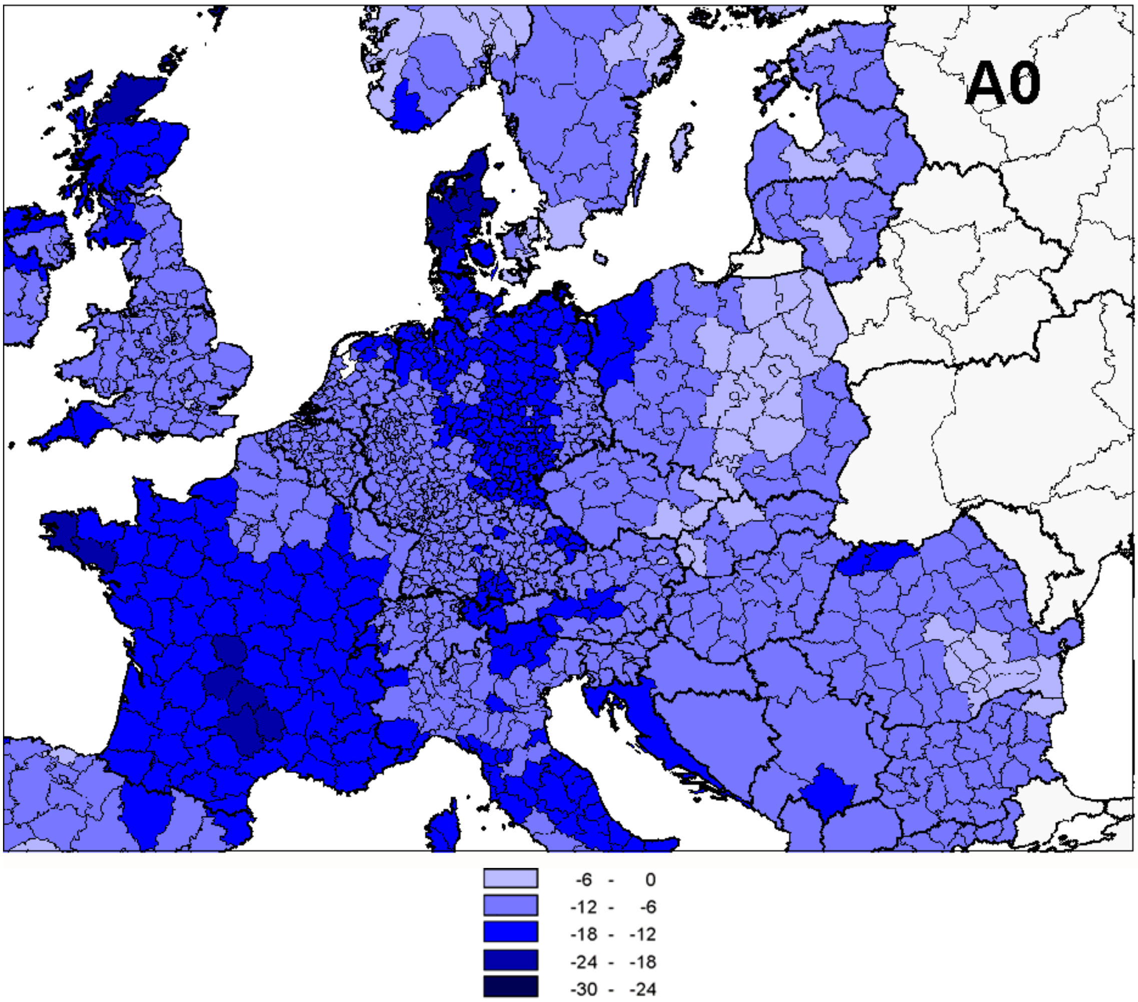


Figure 1 Accessibility road/rail/air travel, Scenario A0 with respect to Scenario A-1 2031 (SASI model results)

The main consequence of a faster growth of oil price (B scenarios) seems to be a strong pressure for improving efficiency and using alternative sources of energy. On the transport demand side, the impact is also visible (although not so dramatic) and consists partially of a reduction of total mobility and partially of a shift to non-road modes. Passenger demand seems more elastic than freight demand and the faster growth of fuel price significantly affects car ownership as well (see figure 1).

The impact of a higher assumption on fuel price growth is more evident when looking at the vehicle fleet. The number of vehicles in the year 2030 is shrunk with respect to the No-policy and Business as Usual base trends and its size is reduced even if compared to the present day. In addition, the internal composition of the fleet is significantly changed, with a higher share of cars – and especially large cars – substituted with innovative cars.

Table 6 *Change of Passengers-km and tonnes-km 2005-2030: comparison between A-1 and B-1 scenarios*

Model	Passengers-km		Tonnes-km	
	A-1	B-1	A-1	B-1
European models				
ASTRA	↑	↑ (red)	↑	↑ (green)
Local models				
Brussels[1]	n.a.	n.a.	n.a.	n.a.
Dortmund	↑	↑ (red)	n.a.	n.a.
Edinburgh	↑	↑ (yellow)	n.a.	n.a.
Helsinki[1]	↑	↑ (red)	n.a.	n.a.
South Tyrol[1]	↑	↑ (red)	↑	↑ (yellow)

(green) Increment change with respect to A-1
(yellow) Not significant change with respect to A-1
(red) Decrement with respect to A-1

↑ Increment with respect to 2005
↓ Decrement with respect to 2005
≈ Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.

With a lower motorisation rate and higher costs for travelling, total passenger demand grows at a lower rate and especially the performance of cars falls below the base year (2005) value at the end of the simulation period. Instead, freight demand is more rigid and the higher fuel price is unable to reduce significantly the growth of tons-km as well as to cut the mode share of road freight.

This rigidity can be partially explained with the limited effect that a faster dynamic of the oil price has on the economic growth. According to the modelling simulations, there is a minor difference between GDP values in the 'high oil price growth' and in the 'low oil price growth' scenarios and also employment is only slightly reduced. Also, the accessibility of regions (and so their opportunity of development) is not dramatically damaged. In brief, modelling simulations suggest that the European economy is able to put into practice strategies to improve efficiency and that the economic system as a whole can cope with more expensive energy (see table 7).

Table 7 Change of GDP and Employment 2005-2030: comparison between A-1 and B-1 scenarios

Model	GDP		Employment	
	A-1	B-1	A-1	B-1
ASTRA	↑	↑	↑	↑
SASI	↑	↑	↑	≈

(green)	Increment change with respect to A-1	↑	Increment with respect to 2005
(yellow)	Not significant change with respect to A-1	↓	Decrement with respect to 2005
(red)	Decrement with respect to A-1	≈	Near constant with respect to 2005

There is no need to say that fuel consumption decreases significantly as consequence of its higher price. At the year 2030, fuel consumption is reduced of about 25% with respect to the scenarios featuring low oil price growth. At the same time, renewable sources are further fostered with respect to the A-1 scenario.

On the environmental side (table 8), the impact of a higher energy price is positive, reinforcing the base trend of the Low oil price growth scenario. In addition, CO_2 emissions are significantly reduced below the A-1 level, even though not necessarily under the current level.

Table 8 Change of emissions 2005-2030: comparison between A-1 and B-1 scenarios

Model	CO2		CO		NOx		PM		VOC	
	A-1	B-1	A-1	B-1	A-1	B-1	A-1	B-1	A-1	B-1
European models										
ASTRA	↑	↑	↓	↓	↓	↓	n.a.	n.a.	↑	↑
Local models										
Brussels[1]	↑	↓	↑	↓	↑	↓	n.a.	n.a.	↑	↓
Dortmund	↓	↓	↓	↓	↓	↓	↓	↓	↑	↓
Edinburgh[2]	↓	↓	n.a.	n.a.	↓	↓	↓	↓	n.a.	n.a.
Helsinki[1]	↑	↑	↓	↓	↓	↓	↓	↓	n.a.	n.a.
South Tyrol[1]	↑	↑	↓	↓	↓	↓	↓	↓	↓	↓

(green)	Increment change with respect to A-1	↑	Increment with respect to 2005
(yellow)	Not significant change with respect to A-1	↓	Decrement with respect to 2005
(red)	Decrement with respect to A-1	≈	Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.
2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

As explained above, two diverse policy strategies have been simulated, one pivoted around technology investments (scenarios 1) and the other aimed at transport demand regulation (scenarios 2). Both strategies do not affect dramatically the size of demand, as total passengers-km and tonnes-km increase in all scenarios. Not surprisingly, demand regulation measures have a stronger impact and slow down the dynamic of transport demand (see tables 9 and 10). This trend is visible even though mobility does not fall below the base year level (also under the 'high oil price growth' assumption) and, as far as freight is concerned, the growth rate of tonnes-km is still higher than GDP growth rate.

Table 9 European models: Change of passengers-km and tonnes-km 2005-2030: comparison between demand regulation (scenarios 2) and technology investments scenarios (scenarios 1)

Model	**A-1**	**A1**	**A2**	**B-1**	**B1**	**B2**
Passengers						
ASTRA	↑	↑	↑	↑	↑	↑
Freight						
ASTRA	↑	↑	↑	↑	↑	↑

Increment change with respect to A-1
Not significant change with respect to A-1
Decrement with respect to A-1

↑ Increment with respect to 2005
↓ Decrement with respect to 2005
≈ Near constant with respect to 2005

Table 10 Local models: Change of Passengers-km and tonnes-km 2005-2030: comparison between demand regulation and technology investments scenarios

Model	**A-1**	**A1**	**A2**	**B-1**	**B1**	**B2**
Passengers						
Brussels[1]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Dortmund	↑	↓	↓	↑	↓	↓
Edinburgh	↑	↑	↑	↑	↑	↑
Helsinki[1]	↑	↑	↑	↑	↑	↑
South Tyrol[1]	↑	↑	↑	↑	↑	↑

Increment change with respect to A-1
Not significant change with respect to A-1
Decrement with respect to A-1

↑ Increment with respect to 2005
↓ Decrement with respect to 2005
≈ Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.

A specific circumstance affects this result: the demand regulation measures provoke a modal shift towards rail and ship and such modes have higher average distances than road for most of the O/D pairs. In fact, modes like rail and shipping often need feeder modes from true origin to starting terminal and from arrival terminal to final destination. Furthermore, sea shipping routes can be much longer than land routes. Therefore, total distance travelled is often actually higher and this effect should not be underestimated: shifting goods from road to other modes means increasing the total amount of tonnes-km. These aspects are considered in the ASTRA model[3] and thus when scenarios are effective in terms of modal shift, a larger number of tonnes-km results.

The rigidity of freight and passenger demand with respect to the policy strategies is consistent with the limited effects on the economic growth of all scenarios. On the one side, the simulations suggest that the technology investments scenarios (scenarios 1) are neutral for the economic development as they slightly reduce accessibility. However, at the same time they can have a positive effect due to the additional investments, the acceleration of the renewal of the fleet and therefore a positive development of intermediate and final consumptions. On the other side, demand regulation scenarios have double negative effects. Firstly, they penalise the road transport sector and thus have a negative impact on the whole economy as predicted through the input/output mechanism; secondly they reduce accessibility of regions and consequently hinder their development. However, even if the reduction of GDP growth (and, correspondingly, of employment) is significant relative to the No-policy scenarios, economy is sharply growing in absolute terms; even in the scenario B2, when the demand regulation measures are associated to the high oil price growth assumption.

In brief, there are different impacts on the economy, but the final result does not bring about a break of the base trend. Consequently, the economic determinants of freight demand (and, although less directly, of passenger demand) do not change much and this explains why the outcome of the scenarios shows adjustments on the demand side, but not large variations.

Table 11 Change of GDP and Employment 2005-2030: comparison between demand regulation and technology investments scenarios

Model	**A-1**	**A1**	**A2**	**B-1**	**B1**	**B2**
GDP						
ASTRA	↑	↑	↑	↑	↑	↑
SASI	↑	↑	↑	↑	↑	↑
Employment						
ASTRA	↑	↑	↑	↑	↑	↑
SASI	↑	↑	≈	≈	≈	↓

[3] Although, given the coarse geographical detail in ASTRA, the increment of trip length could be somewhat overestimated.

Increment change with respect to A-1
Not significant change with respect to A-1
Decrement with respect to A-1

↑ Increment with respect to 2005
↓ Decrement with respect to 2005
≈ Near constant with respect to 2005

On the environmental side, demand regulation measures prove to be more effective than technology investments (see tables 12 and 13). However, if compared to the no-policy trend, where polluting emissions are already reduced due to the fleet renewal, the additional gain is not always large. From a European perspective, the strategy of limiting demand and shifting on non-road modes is able to invert the trend of greenhouse emissions. If associated to the high oil price growth assumption, direct CO_2 emissions could be reduced of 30-50% with respect to the no-policy scenario and also well-to-wheel CO_2 emissions could be cut significantly. For pollutants, demand regulation strategy generates reductions that, especially at the local level, are not so large if compared to the effect of the technology investments and/or the only effect of higher oil price growth.

Table 12 Change of emissions 2005-2030: comparison between demand regulation and technology investments scenarios under the low oil price growth assumption

Model	**CO2**		**CO**		**NOx**		**PM**		**VOC**	
	A1	**A2**	**A1**	**A2**	**A1**	**A2**	**A1**	**A2**	**A1**	**A2**
European models										
ASTRA	↓	↓	↓	↓	↓	↓	n.a.	n.a.	≈	↓
Local models										
Brussels[1]	≈	↓	↓	↓	↓	↓	n.a.	n.a.	↓	↓
Dortmund	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Edinburgh[2]	↓	↓	n.a.	n.a.	↓	↓	↓	↓	n.a.	n.a.
Helsinki[1]	↑	↑	↓	↓	↓	↓	↓	↓	n.a.	n.a.
South Tyrol[1]	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓

Low Increment change with respect to A-1
High Increment change with respect to A-1
Not significant change with respect to A-1
Low Decrement with respect to A-1
High Decrement with respect to A-1

↑ Increment with respect to 2005
↓ Decrement with respect to 2005
≈ Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.
2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

Table 13 Change of emissions 2005-2030: comparison between demand regulation and technology investments scenarios under the high oil price growth assumption

Model	CO2		CO		NOx		PM		VOC	
	B1	**B2**	**B1**	**B2**	**B1**	**B2**	**B1**	**B2**	**B1**	**B2**
European models										
ASTRA	↓	↓	↓	↓	↓	↓	n.a.	n.a.	↓	↓
Local models										
Brussels[1]	↓	↓	↓	↓	↓	↓	n.a.	n.a.	↓	↓
Dortmund	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Edinburgh	↓	↓	n.a.	n.a.	↓	↓	↓	↓	n.a.	n.a.
Helsinki[1]	↑	↑	↓	↓	↓	↓	↓	↓	n.a.	n.a.
South Tyrol[1]	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓

Low Increment change with respect to A-1	↑ Increment with respect to 2005
High Increment change with respect to A-1	↓ Decrement with respect to 2005
Not significant change with respect to A-1	≈ Near constant with respect to 2005
Low Decrement with respect to A-1	
High Decrement with respect to A-1	

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.
2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

The effectiveness of technology investments for reducing harmful emissions is lower. In some cases differences are small; in other cases they are significant. In rough terms, the reason is that the advantages in terms of lower unitary emissions are not as high as the reduction of the emitting units obtained with the demand regulation. However, the strategy of using technology has more positive impacts on the total energy usage and development of renewable sources. When looking at fuel consumption the regulation of demand still seems more effective.

Given the direct linkage between the quantity of demand (especially road demand) and externalities like accidents, noise and congestion, the conclusion is clear that the strategy of controlling demand performs better, also when looking at transport external costs.

On the accessibility side, both demand regulation and technology investments provoke negative effects, as transport costs are increased (see table 14). The negative impact is almost negligible for passengers in the technology investments scenarios, while is quite significant for freight especially in the demand regulation scenarios. As almost all European regions depend heavily on road modes for freight transport, this result is coherent to the expectations. Instead, for passengers, the picture is more mixed and the policy measures aimed at developing technology can have also some positive effects especially on peripheral regions of EU (especially New EU10 countries).

Table 14 Change of accessibilty and cohesion 2005-2030: comparison between demand regulation and technology investments scenarios

	A1	A2	B1	B2
Passenger Accessibility				
SASI	≈	↓	↓	↓
Relative Cohesion (GDP)				
SASI	↑	↓	↑	↓

Light green	Low Increment change with respect to A-1
Dark green	High Increment change with respect to A-1
Yellow	Not significant change with respect to A-1
Orange	Low Decrement with respect to A-1
Red	High Decrement with respect to A-1

↑	Increment with respect to 2005
↓	Decrement with respect to 2005
≈	Near constant with respect to 2005

In terms of cohesion within EU25, measured as convergence of GDP, there is clear progress if an absolute indicator is used (see again table 14). This is because the impact of scenarios on the GDP of richer regions is higher and so differences between richer and poorer regions is reduced. More interesting is the analysis of relative cohesion (i.e. in terms of relative variations of GDP). Relative cohesion is lower in the demand regulation scenarios, independently from the assumptions relative to oil price. Instead, in the technology investments scenarios, the relative cohesion is higher, especially if the low oil price growth hypothesis is adopted. Therefore, from the simulations, it seems that investing on technologies has a better impact on poorer regions than the demand regulation, other things being equal.

Conclusions

From the simulation of the different scenarios, some conclusions can be drawn. The assessment of the scenarios, using a MCA methodology will be carried out in Workpackage 5.

When the high oil price growth scenarios are compared to the low oil price scenarios, positive and neutral effects are dominant: pollution diminishes (even if CO_2 is increasing with respect to year 2005) and so does energy consumption. Average travel time per trip is stable as well as GDP (even though a slight decrement is forecast) and relative cohesion. Instead negative effects can be found on accessibility.

In brief, according to the modelling simulations, a faster growth of fuel price could be economically sustainable for the European Union provided that the modelled reactions - in terms of improved efficiency - are actually put into practice.

The technology investments scenarios are able to realise improvements for almost all the variables considered, with some exceptions at local level. Progress is generally made also with respect to the year 2005, although CO_2 emissions are generally increasing and accessibility levels are diminishing. The demand regulation scenario also improves most of the variables. Progresses concern mainly the same variables that are positively affected by the technology investments scenario with the relevant exception of GDP (which is somewhat reduced in the demand management scenario). So, in terms of the directions of the impacts, the two policy strategies are comparable. However, the size of the impacts of the two scenarios is not the same and also quantitative aspects should be taken into account to compare the two policy strategies.

In terms of policy recommendations, it appears from the analysis of the STEPs process and outcome indicators that demand regulation is a more effective policy than the technology policy in terms of reducing total CO_2, car use and hence congestion. On the other hand, technology policies can be more effective in reducing total energy used.

However, there is a price to be paid, both politically and by the users of the transport system. In particular in demand regulation policies, the charges imposed on car use via the fuel tax increases and road user charges impose significant additional costs on the users. Simultaneously they significantly reduce accessibility, i.e. impose constraint to mobility, especially to passengers private mobility. Modal shift towards public modes is favoured, trip lengths are reduced, which brings in time benefits and significant revenue streams for governmental authorities[4]. Although this can be seen as a benefit from a collective point of view, these changes in travel behaviour are not voluntary but forced responses and might imply a loss of quality of life.

4 It should also be noted that fuel tax increases in demand regulation scenarios result in significant increases in costs for car use which may not be politically feasible

In the STEPs project we did not test whether the reduced levels of pollution, the lower greenhouses emission levels, the congestion relief, etc. are economically efficient, at least according to a welfare approach, via a more traditional cost benefit analysis. Neither have we been able to test whether the investments in technology are good value for money. In brief, the price paid for the success on the environmental side can be substantial in terms of money and quality of life. An overall assessment of all effects on these sides is beyond the scope of the project, however land use planning, if properly integrated and co-ordinated with transport planning might be considered to tackle these negative impacts. In a future with high fuel costs in which car driving is unaffordable for a large proportion of low and medium-income households, high-density mixed-use urban structures in which most daily mobility can occur on foot offer a higher quality of life than low-density suburbs at the fringe of metropolitan areas poorly served by public transport.

Finally we could conclude the following:

a) The impact of higher costs of energy in terms of economic growth is generally low, provided that the economic system reacts with improvement of energy efficiency.

b) Both technological investments and demand regulation can play an effective role in reducing environmental externalities - though we can expect a certain level of reduction from technology developments which are already in the ‘pipeline’.

c) Both technology and demand regulation can reduce total transport CO_2, but it will require some combined policies to reduce the levels significantly.

d) Demand regulation reduces the externalities associated with congestion whereas technology investments do not.

e) Increased energy costs, especially when coupled to demand regulation measures, have two effects - firstly they act to suppress demand for car use, second they drive the move towards a more efficient fleet and to alternative fuel technologies. As a consequence, mobility behaviour is severely constrained and quality of individual life can be undermined, even though transport externalities for the community are significantly reduced.

In terms of policy recommendations, there are two main points that should be considered.

First, the policy measures simulated can be useful to help policy makers in their action aimed at reducing energy usage and increase transport sustainability. However, the scenarios tested within this Workpackage have been intentionally biased towards the two strategies (demand regulation and investments in technology) in order to emphasize the models reactions, whereas the real policy actions and their means of enforcement should be carefully selected among the measures simulated taking into account also complementary measures to tackle side effects (e.g. land-use policies could be considered as a strategy to backup demand regulation and preserve mobility rights).

Second, there are some economic questions the modelling exercise carried out in STEPs cannot answer, in particular whether the ‘level’ of demand regulation tested is efficient from a welfare perspective and whether to accelerate the development in fleet technologies through a direct investment policy is cost-effective. Other EU projects are working on the issue of optimal levels of demand regulation.

Chapter 1 Introduction

1.1 Background

The STEPs (Scenarios for the Transport System and Energy Supply and their Potential Effects) project has the following overall objective: ‘to develop, compare and assess possible scenarios for the transport system and energy supply of the future taking into account the state of the art of relevant research within and outside the 6th RTD Framework and such criteria as the autonomy and security of energy supply, effects on the environment and economic, technical and industrial viability including the impact of potential cost internalisation and the interactions between transport and land use.’

These activities are organised into 6 Workpackages:

- WP1: assessing recent and ongoing developments in alternatives to fossil fuels and related needs in energy supply chains, analysing national policies on transport and energy;
- WP2: identifying relevant trends in transport and energy use and their interaction with the socio-economic, political and technological environment;
- WP3: defining three scenarios of the transport and energy supply system for the future;
- WP4: running a set of inter-linked models at the European and urban-regional level to produce forecasts of relevant impacts of the scenarios;
- WP5: assessing and comparing the impacts forecast for the three scenarios with respect to criteria and indicators which reflect the overall goal of transport and energy sustainability;
- WP6: drawing conclusions and to give policy recommendations and define needs for future research.

Strategic modelling is one of the key instruments to achieve such an objective and Workpackage 4 ‘Scenarios impacts’ is the core of the research activities of the project.

The WP4 objective is ‘running a set of inter-linked models at the European and urban-regional level to produce forecasts of relevant impacts of the scenarios’. The impacts addressed include: transport demand, energy consumption, greenhouse and polluting emissions, regional development, local accessibility and others, and are considered both at European and local/regional level. Therefore, the activities within WP4 start from the outcome of previous Workpackages and consist essentially in implementing the scenarios variables in the models in a coordinating way and then simulate the scenarios. The outcome of the models will be the main input for developing indicators in WP5.

These research activities are complemented by three more Workpackages which deals with co-ordination, comparison and dissemination activities. Such two lines of activities – co-ordination and research - are closely related and constantly influencing each other.

1.2 Aim of the report

The first deliverable produced in WP4 (Deliverable D4.1) was issued in June 2005 to introduce the features of the different tools used for the modelling exercise. Since then, activities of Workpackage 4 have proceeded and this second deliverable (D4.2) reports the final outcome of the modelling exercise as well as the methodology used to implement the scenarios variables in the models.

1.3 Structure of the report

In addition to this introduction, the report consists of four main chapters. In Chapter 2, the structure of the scenarios is recalled and the strategy used to translate the scenarios assumptions into input variables for the models is explained. In Chapter 3, a summary of the most significant results of the modelling exercise is presented, distinguishing the European level and the local level. In the following Chapters 4 and 5, detailed results for each model are described and commented for Europe and regional contexts respectively.

Chapter 2 Scenarios description and simulation strategy

This chapter deals with the methodology applied and the modelling tools to simulate the scenarios developed in Workpackage 3[5]. The chapter includes also the description of the assumptions adopted in the different models.

2.1 The models

Several modelling tools are used in the STEPs project in order to simulate the scenarios on transport and energy supply and to provide quantitative responses on the effects of such scenarios on various respects. The models can be classified into two main categories (see table 2.1):

- models operating at the European level: the ASTRA System Dynamics Model, the SASI socio-economic model and the POLES energy model;
- models operating at the urban/regional level: Dortmund model, South Tyrol Meplan model, Helsinki Meplan model, Brussels IRIS model, Edinburgh SPM model.

Table 2.1 List of the models involved in STEPs project

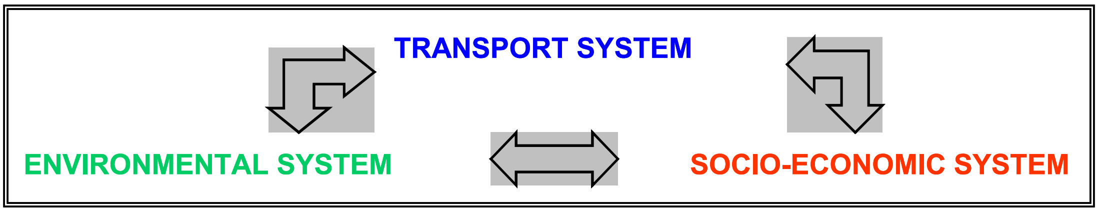
European models	Urban/regional models
ASTRA Model	Brussels IRIS model
SASI model	Dortmund model
POLES model	Edinburgh SPM model
	Helsinki Meplan model
	South Tyrol Meplan model

5 Details can be found in previous deliverables, namely deliverable D3.1 for the scenario description and deliverable D4.1 for the modelling tools

- The ASTRA model is a System Dynamics model at the European scale focused on describing the linkages between the transport system, the economy and the environment. The relationships between the different systems in the model are manifold. For instance, the economic activity affects transport demand both because freight depends upon the amount of goods produced and traded and because higher employment rates correspond to higher personal mobility rates. On the reverse side, the level of consumptions and investments in the transport sector spread over the whole economy by means of an input/output mechanism. The effect on the environment (emissions) depends on the amount of traffic as well as on the technology development of the fleet.

Table 2.2 Overview of the ASTRA model

ASTRA System Dynamics Model

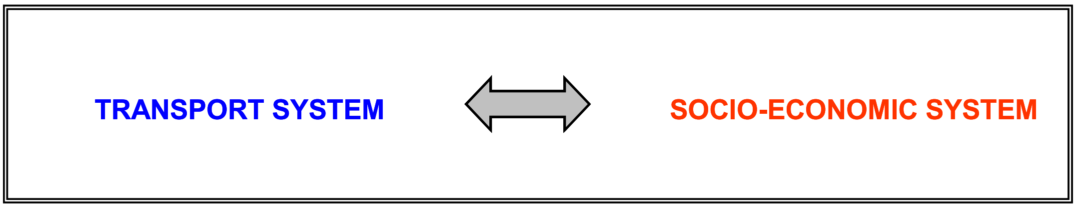


	KEY INPUTS	**MAIN OUTPUTS**
TRANSPORT SYSTEM	transport modes speed, transport cost, trip generation rates, volume-to-value ratios, load factors, vehicle occupancy factors	traffic performance, modal split, vehicle fleet size and composition
ENVIRONMENTAL SYSTEM	emission factors, unitary fuel consumptions	fuel consumption, emission levels
SOCIO-ECONOMIC SYSTEM	taxation, fertility, mortality	GDP, employment, investments, tax revenues

- SASI is a model of socio-economic development of 1,330 regions in Europe, subject to exogenous assumptions about the economic and demographic development of the European Union as a whole, transport infrastructure investments (in particular of the trans-European transport networks) and other transport policies. The *Regional GDP* submodel is the core of the SASI model. It forecasts Gross Domestic Product (GDP) per capita by six industrial sectors generated in each region as a function of endowment indicators and accessibility computed according to traditional location factors, such as availability of skilled labour and business services, capital stock (i.e. production facilities) and intraregional transport infrastructure as well as 'soft' location factors, such as indicators describing the spatial organisation of the region, i.e. its settlement structure and internal transport system, institutions of higher education and cultural facilities and quality of life.

Table 2.3 Overview of the SASI model

SASI Model

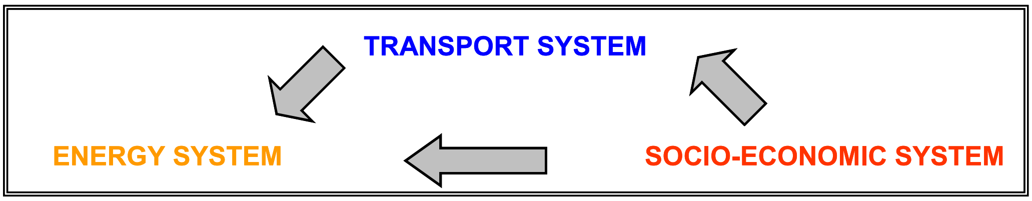


	KEY INPUTS	MAIN OUTPUTS
TRANSPORT SYSTEM	transport project, transport policies	regional accessibility
SOCIO-ECONOMIC SYSTEM	labour productivity, endowment, fertility, mortality, migration policies, transfer payments	accessibility, GDP, employment, population, labour force

- The POLES model deals with the worldwide energy market, simulating final energy demand by main sectors, the primary energy supply, the electricity and conventional energy and transformation system and new and renewable energy technologies. The simulation of the different energy balances allows for the calculation of import demand / export capacities by region. Production and trade flows are modelled on a bilateral trade basis, thus allowing for the identification of a large number of geographical specificities and the nature of different export routes. The comparison of import and export capacities and the changes in the Reserves/Production ratio for each market determines the variation of the prices for the subsequent periods.

Table 2.4 Overview of the POLES model

POLES Model

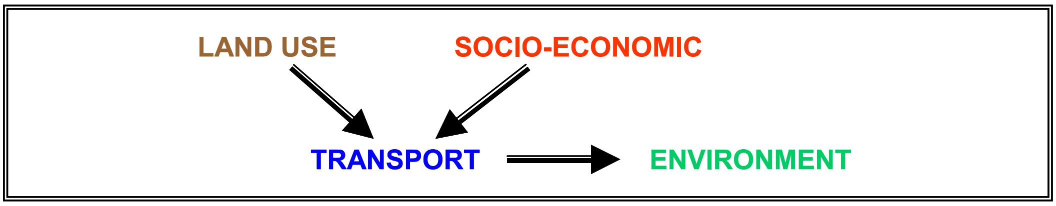


	KEY INPUTS	MAIN OUTPUTS
TRANSPORT SYSTEM	techno-economic characterisation, fuel efficiency, emission factors, car costs	car fleet size and composition, fuel consumption, emission levels
ENERGY SYSTEM	techno-economic characterisation	energy prices
SOCIO-ECONOMIC SYSTEM	GDP, population, fuel taxes, carbon taxes, subsidies for technology, emission limits	

- The IRIS model is used for the Brussels region as a tool used to define a global development strategy through the analysis of the relation between land use, transport, socio-economic data and environment topics. This model is used for the constitution of the travel master plan of the Brussels region. The Brussels model is a classical four steps model where each step is dealt with a specific sub-model. The generation and attraction sub-model provides the peak hours number of trips generated and attracted by each zone using as input the locations of households, jobs and commercial activities. The modal split sub-model is based on Logit algorithms. Private and public transport assignment stages are ruled by two different sub-models.

Table 2.5 Overview of the Brussels model

Brussels Model

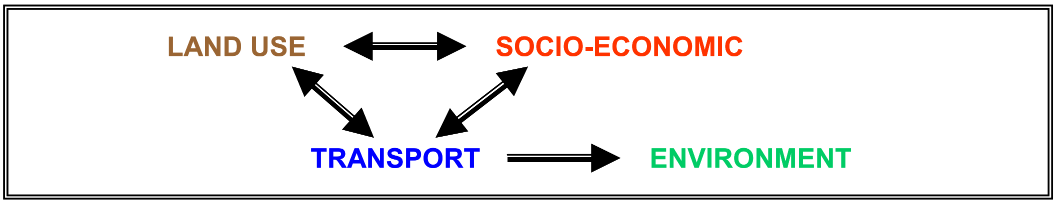


	KEY INPUTS	MAIN OUTPUTS
TRANSPORT	public transport services, road network, transport costs, tariffs, car ownership	passenger-km for the public transport, vehicle-km for the private vehicles
SOCIO-ECONOMIC	employment, population	
LAND USE	location of households, jobs and commercial activities	
ENVIRONMENT	emission functions, fuel consumption factors	Fuel consumption, CO2 emissions

- The Dortmund model was designed to study the impacts of global and local policies from the fields of industrial development, housing, public facilities, land use and transport. It has a modular structure and consists of six interlinked submodels, operating in a recursive fashion on a common spatio-temporal database. Global policies affect the economic or institutional environment of urban development in the whole region: e.g. changes in tax laws or subsidies, new or regulations governing land use or construction activity, parking fees or public transport fares. Local policies may be either regulatory or direct zone-specific investment projects: e.g. local land-use planning, new industrial locations or plant closures, local transport policies. For each simulation period, the model predicts, intraregional location decisions of industry, residential developers and households, the resulting migration and travel patterns, construction activity and land-use development and the impacts of public policies in the fields of industrial development, housing, public facilities and transport.

Table 2.6 Overview of the Dortmund model

Dortmund Model

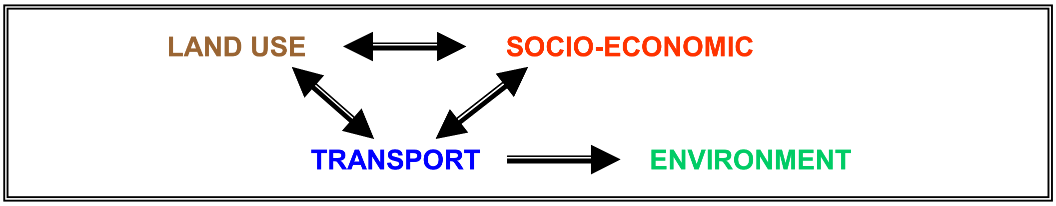


	KEY INPUTS	MAIN OUTPUTS
TRANSPORT	public transport lines and services, road network projects, fuel costs and consumption, public transport fares	accessibility, trip by purpose and mode trip length, travel time car ownership
SOCIO-ECONOMIC	total regional employment by sector, total regional immigration and outmigration	zonal population, zonal employment, intraregional migration industrial relocation
LAND USE	local land use planning, local public facilities	zonal housing, zonal industrial floorspace
ENVIRONMENT	emission functions	Fuel consumption, emissions by transport, land take

- The Edinburgh model is one application of the SPM model, a strategic, interactive land-use and transport interaction (LUTI) model. The model can be divided into two main sub-models: the land-use and the transport model. The model can deal with the transport and behavioural responses to several demand and supply-side instruments. The model assumes that land-use is not a constant but is rather part of a dynamic system that is influenced by transport infrastructure, this interaction process is modelled using time-lagged feedback loops between the transport and land-use sub-models over a period of 30 years. Accessibility in the year *n* as computed from the transport model is used as an input into the location models in the year *n+1*; workplace and residential location in the year *n*, output of the land use model, is used as attraction and potential in the transport model in the year *n+1*.

Table 2.7 Overview of the Edinburgh model

Edinburgh Model

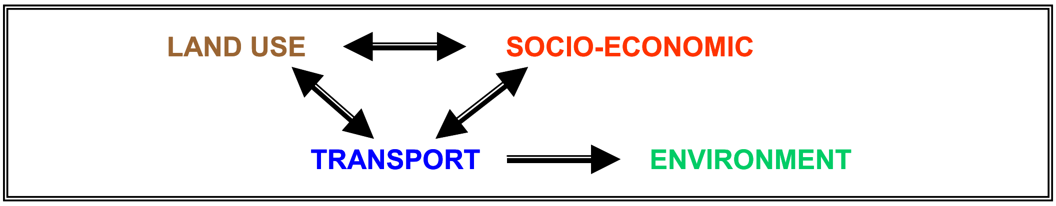


	KEY INPUTS	MAIN OUTPUTS
TRANSPORT	transport costs, distances, public transport frequencies, tolls, taxes, parking costs, commute trip rate, occupancy factors	traffic performance, modal split, load on link, average speed, level of congestion
SOCIO-ECONOMIC	average income, population, car-ownership, workplaces, employment, licence holding	
LAND USE	land use for residential, land use for commercial, land use for green space	residential location, workplace location
ENVIRONMENT	emission functions, fuel consumption factors	Fuel consumption , emissions level, total accidents cost

The Helsinki model is a land-use/transport model developed using the MEPLAN software. Two main modules can be recognised: a land use model and a transport model. An interface module provides the required connections between the two main modules in both directions. In the land model, the local economy is represented by an input-output matrix where the interacting factors include economics sectors, population groups and floorspace. The mobility of individuals is determined by the interaction between economic sectors and the population groups. The integration of land-use and transport in the model framework allows not only to compute endogenously the trips matrices but also to simulate feedbacks from the transport system to land use. More specifically, changes of locations may be induced by variations of transport costs and accessibility which are the effect of increasing congestion, new infrastructures, additional services and so on. Effects on land-use are lagged (i.e. changes on the transport side at the year *n* are reflected on land use only at time *n+t*) to take into account that re-location choices need some time to be put in practice.

Table 2.8 Overview of the Helsinki model

Helsinki Model

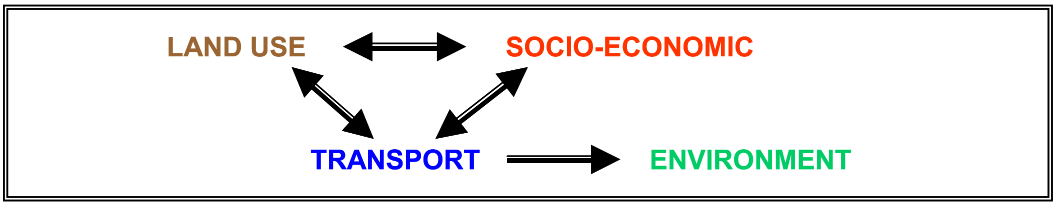


	KEY INPUTS	MAIN OUTPUTS
TRANSPORT	public transport services, road network, transport costs, tariffs, occupancy factors	traffic performance, modal split, load on link, average speed, level of congestion
SOCIO-ECONOMIC	employment, population	
LAND USE	floorspace use	floorspace price, zone attractiveness
ENVIRONMENT	emission functions, fuel consumption factors	Fuel consumption, emissions level,

- Also the South Tyrol model belongs to the group of land-use/transport models built with MEPLAN. The framework of the model is therefore very similar to that of the Helsinki model, with a land use model and a transport model connected by means of an interface. The same input-output approach is used in the land model to simulate the interaction between population, economic sectors and floorspace under the form of production/consumption relationships (e.g. in the model economic sectors 'consume' population to represent the usage of workforce, while population 'consume' floorspace to simulate housing demand. Such relationships take place between different zones (e.g. employees working in a given zone comes from many other zones) and, thanks to the interface, give rise to the mobility in the area that in the transport model is subjected to modal split and route choice. As in the Helsinki model feedbacks from the transport system to land use are simulated.

Table 2.9 Overview of the South Tyrol model

South Tyrol Model



	KEY INPUTS	MAIN OUTPUTS
TRANSPORT	public transport services, road network, transport costs, tariffs, occupancy factors	traffic performance, modal split, load on link, average speed, level of congestion
SOCIO-ECONOMIC	employment, population	
LAND USE	floorspace destination	floorspace price, zone attractiveness
ENVIRONMENT	emission functions, fuel consumption factors	Fuel consumption, emissions level,

From the description above, it is apparent that the models cover a range of different methodologies. Even if the ASTRA and the SASI model are both European models, they work with two different approaches. Based on a coarse geographical system, ASTRA is a system dynamics model where the input/output relationships between sectors play a major role to explain the linkages between transport, economy and environment. SASI is a recursive (i.e. looking for equilibrium) model, aimed at analysing the impacts of infrastructure and other major changes in the transport system to the local economies. Impacts are modelled by regional production functions in which spatially disaggregate accessibility indicators are included. Therefore, even though both models provide a response about how changes on the transport side affect the economy, their response is given from two well separate perspectives.

Also in the regional models, some differences can be noted. From the point of view of the methodology, in almost all models land use and transport interact in some way, even if not in the same way (the Helsinki and the South Tyrol model share the same software and are more similar, the Dortmund and the Edinburgh model are built with different relationships). Also the local contexts are different: the Brussels and Dortmund models are focused on very densely populated metropolitan areas with millions of inhabitants; the Helsinki and Edinburgh models cover wider regions with a major city centre where most of the population live; finally, the study area of the South Tyrol model is the whole province, sparsely populated and where the major city counts no more than 100.000 inhabitants.

So, each different model used for simulating the scenarios provides a different way of looking at the impacts of the policies; specific mechanisms that play a major role in one tool could be secondary in another one and therefore lead to different effects. Thus, the proper features of the tools should be taken into account when comparing the outcomes of the simulation runs. From a different perspective, if the responses obtained from different models go in the same direction, this could be interpreted as robustness of the results.

2.2 The STEPs scenarios

Eight main different modelling scenarios have been defined in STEPs; seven other additional modelling scenarios have been also identified. These scenarios are a development of the initial six scenarios established in Workpackage 3.

The six scenarios defined in Workpackage 3 resulted from crossing two diverse policy strategies in two contexts of future energy supply until the year 2030. From the point of view of *energy availability*, two groups of scenarios have been identified:

- Scenarios ‘A’, based on a generally accepted energy supply forecast, which means that oil price is assumed to increase 2% per year on average. In the following, these scenarios will be named **‘Low oil price growth scenarios’** or just **‘Scenarios A’**;
- Scenarios ‘B’ is based on the assumption of energy, scarcity i.e. oil price is meant to increase 7% per year on average. In the following, these scenarios will be named **‘High oil price growth scenarios’** or just **‘Scenarios B’**.

At the same time, two contrasting *policy strategies* have been considered:

- Policy strategy ‘1’, concentrating on investments in technologies (i.e. improving energy efficiency, supporting innovative vehicles). In the following, these scenarios will be named **‘Technology investments scenarios’** or just **‘Scenarios 1’**;
- Policy strategy ‘2’, focussed on demand regulation (i.e. reducing the need of travel, reducing trip lengths, shifting demand on public modes, etc.). In the following, these scenarios will be named **‘Demand regulation scenarios’** or just **‘Scenarios 2’**.

These two strategies have been put next to **Business as Usual** alternatives (labelled as **'Scenarios 0'**), where only a limited number of policy measures (coherently to the current transport and energy policy approach) are assumed. The final result was a matrix of six alternative scenarios (see table 2.10)[6].

Table 2.10 STEPs Scenarios as defined in Workpackage 3

	Business as usual	**Technology investments**	**Demand regulation**
Low oil price growth	A0	A1	A2
High oil price growth	B0	B1	B2

In a later stage, this set of six scenarios has been enlarged from three separate perspectives.

Isolate energy price impact. As specified above, the 'Business as usual' scenarios defined in Workpackage 3 contain some policy measures beside the assumptions concerning the development of the energy price. Such measures represent the expected 'policy environment' for the future years and therefore their inclusion in a 'Business as usual' scenario is justified; however, from a modelling point of view, it is important that the effect of the development of energy price can be isolated. For that reason, a set of scenarios where only the assumption concerning the oil price growth is considered has been defined. These scenarios have been labelled **'Scenarios –1'** and in the following they will be named **'No-policy scenarios'**.

Simulating more 'pessimistic' assumptions about fuel price. The assumptions concerning the development of energy price do not enter directly in all the modelling tools in terms of *fuel price* development. Instead, the assumptions relate to the *oil price* development and, as such, are a direct input only for the POLES model[7]. The POLES model simulates the reaction of worldwide demand and supply to oil price and produce forecasts of fuel price; this fuel price is the actual input for the other modelling tools. As explained in the following chapters, the mechanisms modelled in POLES leads to an adjustment of demand such that fuel price increases much slower than the 7% p.a. assumed for oil in the high oil price growth scenarios (scenarios 'B'). This means that the difference in terms of energy price between scenarios 'A' and scenarios 'B' is not as large as the different assumptions concerning oil price would suggest. In scenarios 'A' where a low oil price development is assumed, the growth rate is 2% p.a. over the next 30 years, while in the high oil price growth case the rate is 7% p.a. Instead, pure fuel price grows on average of 1% p.a. in scenarios 'A' and 4% in scenarios 'B'. With the objective of allowing for the simulation of a

6 Details on the scenarios developed in Workpackage 3 can be found in the STEPs Deliverable D3.1, 'Framework of the scenarios & description of the themes'.

7 Actually, also the ASTRA model works with the direct assumptions concerning oil price as input for its economic module.

larger fuel price difference, to test an 'extreme' case, a new group of scenarios has been defined in a later stage. In such group of scenarios, pure fuel price grows at 7% per year. These scenarios have been labelled as **Scenarios 'C'** and in the following they are named as **'Extreme fuel price growth scenarios'**.

Simulating an integrated policy approach. Demand regulation and investments in technology are simulated as alternative approaches in scenarios '1' and scenarios '2' respectively. However, especially when a fast growth of energy price is assumed, both types of policy measures could be applied. Therefore, a further set of scenarios have been defined to allow for testing a policy approach where both investments in technology and demand regulation are put into practice. These scenarios have been labelled as **'Scenarios 3'** and are referred in the following as **'Integrated policy scenarios'**.

Table 2.11 summarises the whole set of scenarios, which includes 15 different elements, i.e. the original set of scenarios defined in Workpackage 3 is more than doubled.

Table 2.11 Full set of STEPs scenarios

	No policies	**Business as usual**	**Demand Regulation**	**Technology investments**	**Integrated policies**
Low oil price growth	A-1	A0	A1	A2	A3
High oil price growth	B-1	B0	B1	B2	B3
Extreme fuel price growth	C-1	C0	C1	C2	C3

	Main STEPs modelling scenarios		Additional modelling scenarios

Within the time and the resources available in the project, implementing, testing and reporting 15 different scenarios was a challenging task, especially for some models. For that reason, it has been decided to identify a sub-set of *main scenarios* to be simulated by each modelling tool. The remaining scenarios have been considered additional scenarios, whose simulation could be carried out on a voluntary basis. This has led to the 'Extreme fuel price growth scenarios' (Scenarios 'C') and 'Integrated policy scenarios' (Scenarios '3') (coloured yellow) to be considered as additional scenarios. The larger part of the modelling application has been maintained on the six scenarios defined in Workpackage 3, with the addition of the 'No-policy scenarios' A-1 and B-1, in order to identify the effect of a higher oil price (coloured blue).

In the end, the 'Extreme fuel price growth scenarios' and the 'Integrated policy scenarios' have been simulated in the SASI European model and in the Dortmund regional model as the structure of these two models allows for implementing and simulating several scenarios quite easily once the underlying framework of input is defined. In the other STEPs models, implementing and simulating an additional scenario is a more complex task and so only the eight main scenarios have been simulated.

The quantification of the different scenarios (i.e. the value assumed for each key variable) has been completed in Workpackage 3, as yearly variations in relation to the base year values. Table 2.12 provides a summary of the quantitative assumptions for each scenario group. As it can be readily seen from the table, the Business as usual scenarios include several interventions, especially in terms of pricing and taxing of car and road freight modes. As explained above, rather than a neutral projection of the current policy approach of Member States and European Commission, the BAU scenario already includes pro-active measures aimed at the reduction of energy consumption. The above consideration should be taken into account when analysing the results of the simulations.

Table 2.12 Quantitative assumptions for the policy strategies

Measure		Indicator	A0/B0	A1/B1	A2/B2
			Annual change (%)		
Socio-economic	Pure Fuel price	Gasoline	2% / 7%		
		Diesel	2% / 7%		
	Car sharing etc.	Car ownership	+1%	As A0	-0.6%
	Fuel tax	Gasoline	+0.7%	As A0	+4.7%
		Diesel	+1.5%	as A0	+4.7%
		Kerosene (% of gasoline tax, from 2012)	50%	as A0	200%
	Travel cost due to tax increases	Car/lorry cost per km	+0.5%	+0.5%	+3%
		Air cost per km	-0.5%	-0.5%	+3%
	Telework	Work trips saved	0%	as A0	+0.3%
Spatial	Residential	Central	+	as A0	++
		Inner urban	++	as A0	+++
		Outer urban	+++	as A0	0
	Services	Central	0/+	as A0	+
		Inner urban	+	as A0	++
		Outer urban	++	as A0	0
	Industrial	Central	0	as A0	0
		Inner urban	+	as A0	+++
		Outer urban	+++	as A0	0/+

Measure		Indicator	A0/B0	A1/B1	A2/B2
			Annual change (%)		
Travel	European rail	European rail speed	+0.8%	+2.0%	as A0
	Regional rail	Regional rail speed	+0.4%	+1.7%	as A0
	Public transport	Local public transport speed	+0.3%	+1.1%	as A0
	Traffic calming	Average speed reduction for cars	-0.4 or -1.5% every 5 years	as A0	-1.0% or -4% every 5 years
	Road pricing	Average cost of car km	+2.0%	as A0	+6.0%
	Public transport cost	Bus cost	+0.8%	as A0	-1.7%
		Train cost	+0.8%	as A0	-1.7%
Freight	Traffic calming	Average speed reduction for trucks	-0.4 or -1.5% every 5 years	as A0	-1.0% or -4% every 5 years
	Road pricing	Average cost of road ton-km	+2.0%	as A0	+6.0%
	City logistics	Freight average distance	-0.2%	-0.5%	as A0
		Freight load factor (short distance)	+0.8%	+2.4%	as A0
	Rail freight	Rail freight speed	+0.7%	+2.0%	as A0
		New freight rail network cost	-0.6%	-1.5%	as A0
Energy	Energy efficiency for cars and lorries	Gasoline fuel consumption per car	-0.5%	-2.0%	as A0
		Diesel fuel consumption per car	-1.0%	-3.0%	as A0
	Alternative vehicles	Emissions per km	-50% every 9 year (new EURO) or -8.1%/year	-50% every 5 year (new EURO) or -16%/year	as A0
		Car fleet	<u>Share:</u> Conventional: 72% Hybrids: 15% CNG: 10% Electric: 1% Hydrogen: 2% <u>Annual increase</u>: Conventional: -1% Hybrids: +12,5% CNG: +10% Electric +3% Hydrogen + 3%	<u>Share:</u> Conventional:55% Hybrids: 20% CNG: 15% Electric: 5% Hydrogen: 5% <u>Annual increase</u>: Conventional: -2.1% Hybrids: +13,5% CNG: +12% Electric +7% Hydrogen + 7.8%	as A0
	Energy use rail	Train fuel consumption rate [l/(vhc*km)] (diesel trains), Electric Consumption Factors [kWh/km]	-0.8%	-5.0	as A0

Measure		Indicator	A0/B0	A1/B1	A2/B2
			Annual change (%)		
	Energy use ship	Ship diesel consumption [kg/km]	-0.4%	-1.6%	as A0

2.3 Models simulation strategy

The STEPs scenarios have been implemented in the modelling tools according to their specific features and capabilities. As stated in the proposal, Workpackage 4 of the STEPs project was aimed at using existing tools to simulate a set of scenarios. Existing tools means that, excluding some limited adaptation and re-calibration, the models have been used using their original structure and parameters without a dedicated work for checking and homogenising definitions, common variables, etc. Furthermore, the modelling tools have not been linked in a tight way and have worked as independent models.

One important consequence of the specificity of each tool is that none of the several modelling tools used is capable of simulating all measures included in the scenarios. Some of the scenario variables were not present ‘as such’ in the models and therefore the implementation of the measures has been based on *proxy* variables. Table 2.13 reports a summary of which scenario variables could be simulated in each model, either directly or indirectly, and which ones were outside the tools domain.

Table 2.13 Models simulation capability

Measure		Indicator	ASTRA	POLES	SASI	Brussels	Dortmund	Edinburgh	Helsinki	South Tyrol
Socio-economic	Oil Price Development	Pure Fuel price	yes	yes	indirect	yes	indirect	yes	indirect	indirect
	Car sharing etc.	Car ownership	indirect	indirect	no	yes	yes	yes	indirect	no
	Fuel tax	Fuel tax	yes	yes	yes	yes	yes	yes	yes	yes
	Travel cost due to tax increases	Car/lorry cost per km	indirect	indirect	yes	indirect	yes	indirect	indirect	indirect
		Air cost per km	indirect	no	yes	no	no	no	no	no
	Telework	Work trips saved	yes	no	no	yes	yes	yes	yes	yes
Spatial	Residential		no	no	no	yes	yes	yes	yes	yes
	Services		no	no	no	yes	yes	yes	yes	yes

	Measure	Indicator	ASTRA	POLES	SASI	Brussels	Dortmund	Edinburgh	Helsinki	South Tyrol
	Industrial		no	no	no	yes	yes	yes	yes	yes
Travel	European rail	European rail speed	yes	no	yes	no	no	no	no	no
	Regional rail	Regional rail speed	yes	no	yes	yes	Yes	no	Yes	Yes
	Public transport	Local public transport speed	yes	no	no	yes	Yes	yes	Yes	Yes
	Traffic calming	Average speed reduction for cars	yes	no	no	yes	Yes	yes	Yes	Yes
	Road pricing	Average cost of car km	yes	indirect	yes	yes	Yes	yes	Yes	Yes
	Public transport cost	Bus cost	yes	indirect	No	yes	Yes	Yes	Yes	Yes
		Train cost	yes	indirect	no	yes	Yes	Yes	Yes	Yes
Freight	Traffic calming	Average speed reduction for trucks	yes	no	no	yes	No	No	Yes	Yes
	Road pricing	Average cost of road ton-km	yes	indirect	yes	yes	No	No	Yes	Yes
	City logistics	Freight average distance	yes	no	no	No	No	No	Yes	Yes
		Freight load factor (short distance)	yes	no	no	No	No	No	Yes	Yes
	Rail freight	Rail freight speed	yes	no	yes	No	No	No	No	No
		New freight rail network cost	indirect	no	yes	No	No	No	No	No
Energy	Energy efficiency for cars and lorries		yes	yes	yes	Yes	Yes	yes	Yes	no
	Alternative vehicles	Emissions per km	yes	yes	no	Yes	Yes	yes	Yes	Yes
		Car fleet	yes	yes	indirect	yes	indirect	yes	indirect	indirect
	Energy use rail	Train fuel consumption rate, Electric Consumption Factors	yes	no	yes	No	Yes	no	no	no
	Energy use ship	Ship diesel consumption [kg/km]	yes	no	yes	no	No	no	no	no

So, each model has implemented a 'customised' version of the scenarios. However, from the details reported in the following chapters 4 and 5 on how each model has implemented the scenario assumptions, it will be clear that the main features of each scenario are represented in each model. Although each tool has been applied as an independent model, there are at least four conditions that ensure results can be compared at least in broad terms.

This is explained below.

1. First, whenever possible, the same measure has been implemented in the same way and this is true for key variables like fuel taxes, public transport performance or vehicle energy efficiency.

2. Second, although significant differences exist between the European models, as their focus is different, they are broadly comparable in terms of the basic common trends and assumptions and therefore the policy measures affect the same evolution of the economic, transport and energy systems through time. This aspect is addressed in more details in paragraph 2.3.1 below.

3. Third, even if models have worked as independent tools, a linkage was actually activated through an iterative procedure that made use of the POLES and ASTRA models to forecast the effect on *fuel prices* of the assumptions concerning *oil price,* given the development of transport demand. Forecasts obtained with this procedure have represented an input for all other tools. More details are provided in paragraph 2.3.2.

4. Finally, to guarantee consistency between the European models and the local models, exogenous information such as energy price or fleet development adopted by local models has been drawn from European models forecasts.

2.3.1 Base common trends of European models

The three European models have different features and deal with a different set of variables, but they all simulate the economic and demographic trends for the EU countries and such trends play a role in the outcomes of the simulations. Therefore, even if the models have worked as independent tools, in order to guarantee comparability, it is useful that these trends are similar across the models.

Figure 2.1 and Figure 2.2 show how the population and the GDP are forecast to develop until the year 2030 in the EU 25 plus Romania and Bulgaria according to the ASTRA, POLES and SASI models. The forecasts in the figures are drawn from their baseline, calibrated in the LOTSE project (Schade et al., 2004) for ASTRA and in the WETO project for POLES, while the SASI data concerns the STEPs No-policy A-1 scenario.

From the figures, it can be seen that, even if not equal, the trends are comparable. As far as population is concerned, the models largely agree that EU15 population is generally stable while several countries of East Europe should lose population in the next years, even if the

SASI model projections are somewhat more 'extreme' (the scale of graph tends to emphasise the differences, but, taking Poland as instance, the discrepancy between the SASI and the ASTRA projection is 0.5% p.a., i.e. a difference not higher than 8% of total population at year 2020). The SASI model presents negative projections also for some EU15 countries, where POLES and especially ASTRA forecast a positive development. Germany and Greece are the two main cases of such differences.

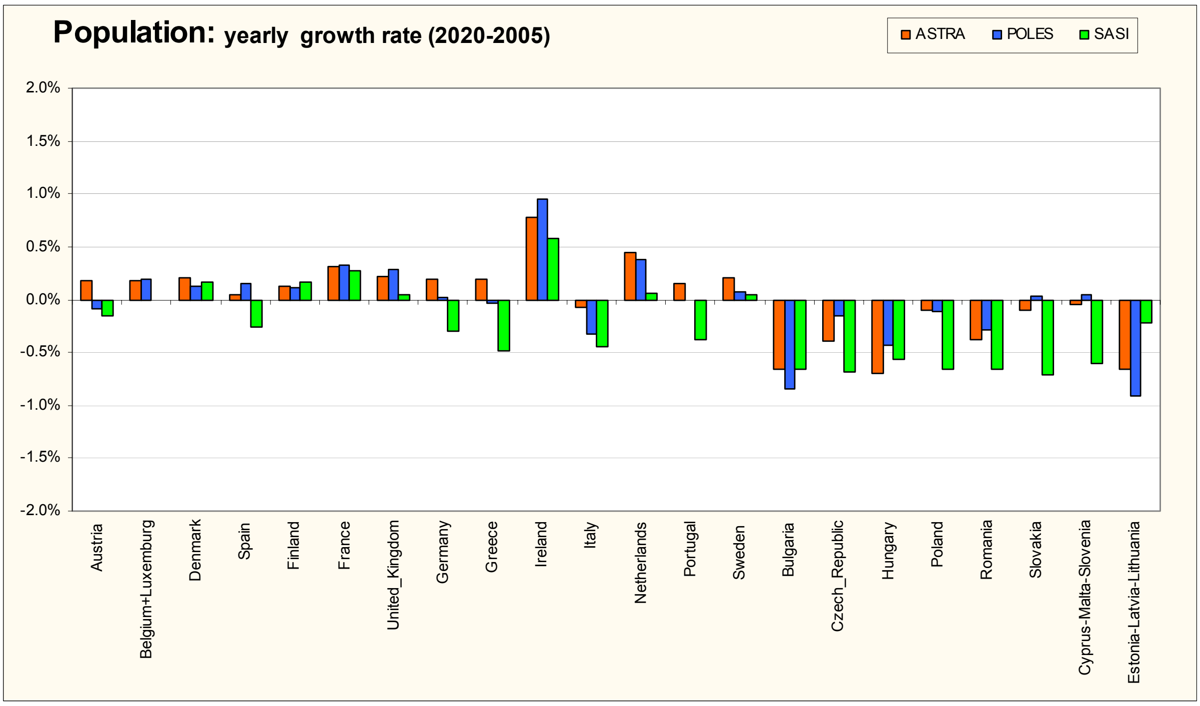


Figure 2.1 Comparison between European models Population basic trend

Also with reference to GDP, growth rates are not the same, but there is a good degree of concordance across countries. Especially, all the three models forecast higher average growth rates for the Eastern European countries, even if SASI, coherently to its assumption on total population, comes out with lower growth rates in such countries than ASTRA and POLES. In any case, all three models forecast that the average growth of GDP in EU15 countries will be generally lower than 2% p.a., while in New EU countries the development rate is about 3% p.a.

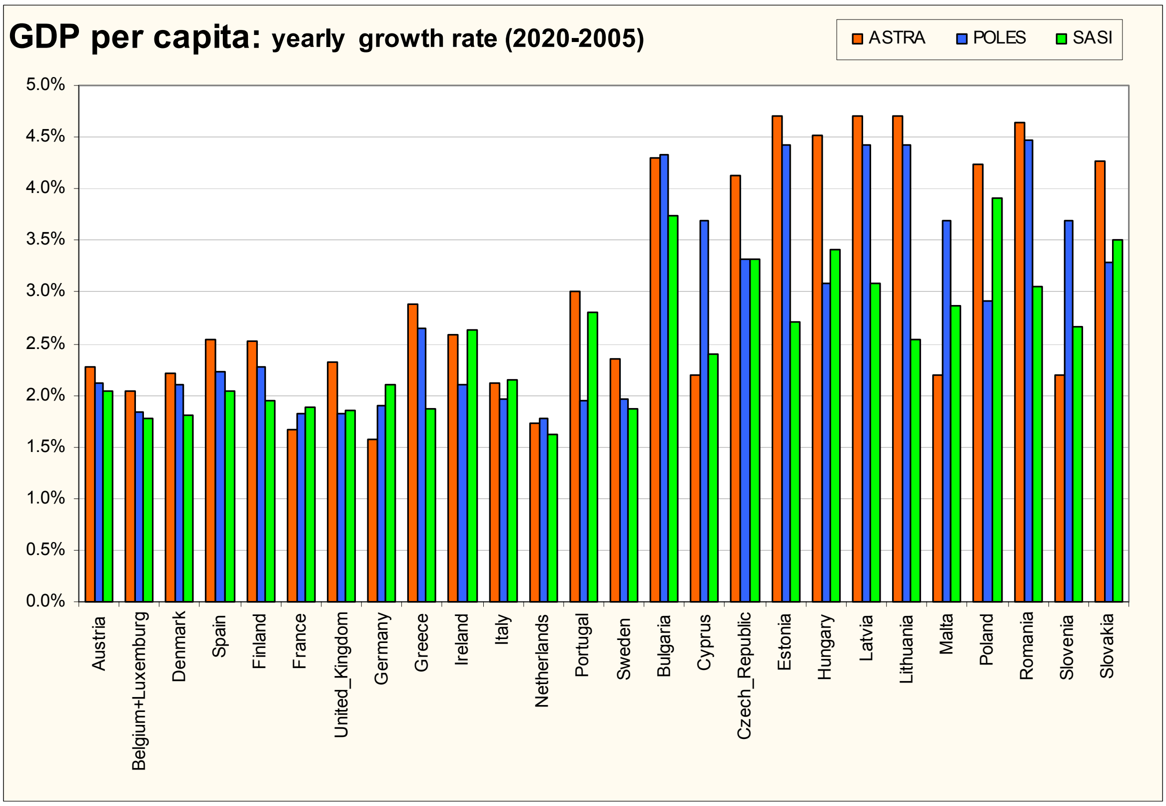


Figure 2.2 Comparison between European models GDP basic trend

2.3.2 ASTRA-POLES feed-back and data exchange between models

Scenarios are clearly separated in two groups according to the assumption concerning the development of oil price (Scenarios A and Scenarios B). However, for all models simulating the energy price in the transport sector, the relevant variable is not the price of oil, but the resource price (i.e. net of taxes) of gasoline, diesel and kerosene[8].

The definition of the scenarios was based on oil price as this is the primary variable, which drives the cost of all fossil fuels. However, even if there is a clear correlation between oil price and fuels price, it would not be correct to assume that the hypothesis concerning the former could be applied as such to the latter. Actually, historical trends show that fuel price is generally less volatile than oil price. For instance, the crude oil price has grown by about 120% in the last 6 years (from an average of 16.5 $/Barrel in 1999 to an average of 37.5 $/Barrel in 2004), while gasoline price in the same period has grown significantly less (e.g. of about 35% in Italy, of about 40% in Germany, etc.).

It was the energy market POLES model which took care of the simulation of the fuel price development as a consequence of the oil price hypothesis assumed in the scenarios. And since one crucial variable affecting the development of fuel price is transport demand, this

8 Other fuels like Compressed Natural Gas or Liquefied Petroleum Gas are not modelled in STEPs as they have a minor share in the vehicle fleets.

was provided to POLES form the ASTRA model. Transport demand affects price but also the reverse is true, so there is a feed-back relation to take into account. For that reason, the POLES and ASTRA models have worked interactively in a feed-back process.

Taking transport cost, as generalised costs, and transport demand, as vehicles-kms, from the ASTRA model, POLES has computed the fleet evolution and fuel price development. In turn, the fuel (resource) price forecast by POLES has been used in ASTRA to revise the transport demand forecast, which is again fed into POLES. The loop *transport demand – fuel price impact – impact on transport demand – impact on fuel price* between the two models has requested two iterations (Figure 2.3) before reaching the equilibrium; in fact, from the third iteration on, results did not show any significant changes. So, the fuel price and vehicle fleet development produced in the second iteration (by the POLES model) have been made available for the other models as input for the scenarios.

Figure 2.4 summarises which variables are exchanged and how the STEPs models are linked to each other. In addition to fuel resource price and vehicle fleet from POLES, also fuel taxes by country from ASTRA and average emission factors are tranferred to the local and regional models. The diagram illustrates how the internal coherence of the scenarios has been strengthened by means of the endogenously computed variables exchanged between the different models (actually from ASTRA-POLES to other models). In some cases these variables have replaced direct assumptions defined in Workpackage 3.

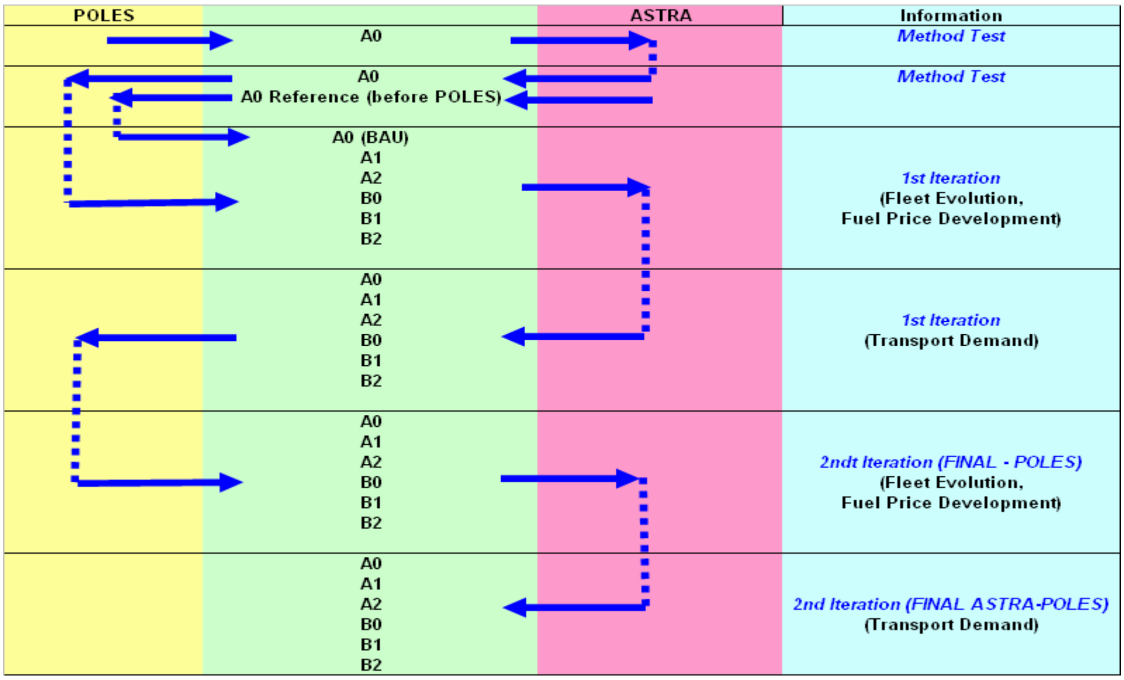


Figure 2.3 The POLES – ASTRA iteration

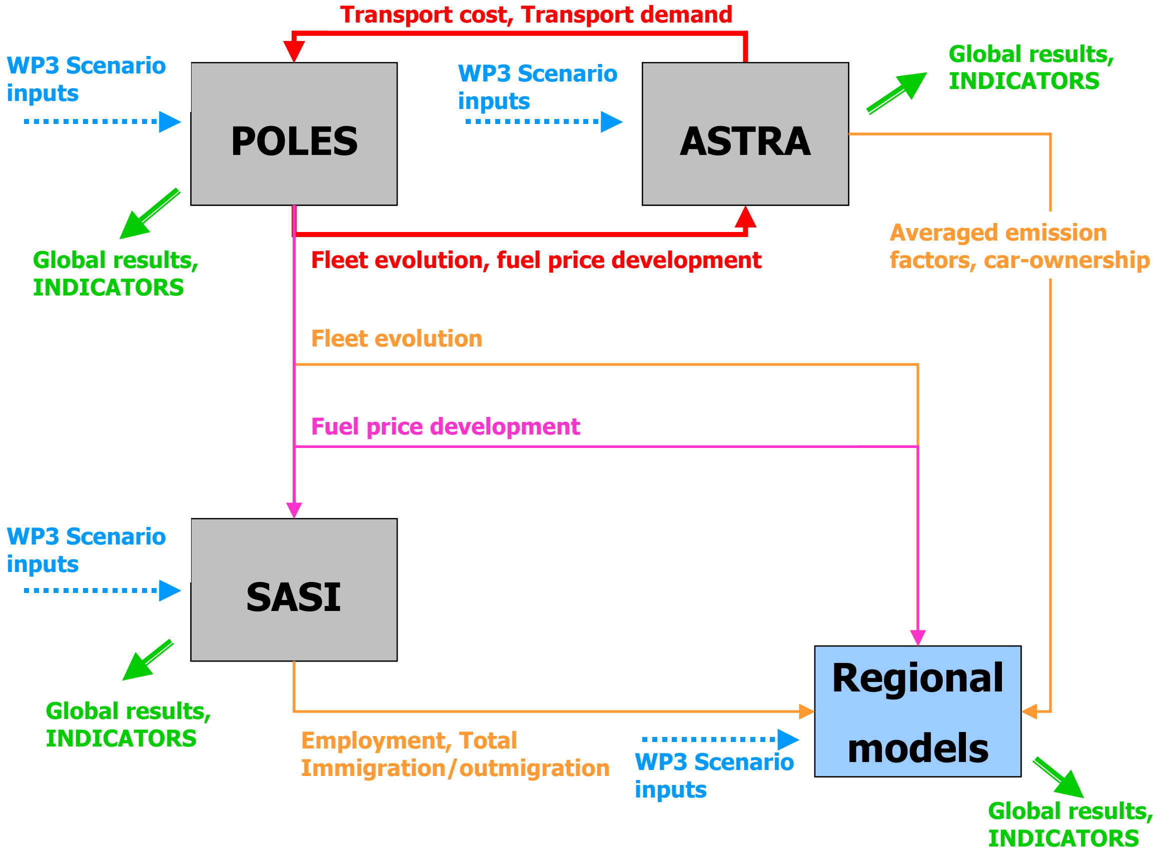


Figure 2.4 Data exchange between models in scenarios simulation

Chapter 3 Summary of scenarios simulation results

In this chapter the *main outcomes* of the simulation of the STEPs scenarios are presented. Detailed results for each model are described in the following chapters 4 and 5, concerning European models and local models respectively. Here the attempt is to provide an overall picture using results from all models. As explained in paragraph 3.2.1, there are methodological reasons to believe that results of the models can be compared to define a concise description of the impacts of the scenarios. At the same time, the differences existing in the models, as well as in the strategies uses to implement the scenarios, suggest to compare the outcomes between models only in broad terms. Therefore, in this chapter only a few numbers are reported and impacts are reported and discussed in terms of their intensity and direction.

The results will be discussed with reference to several aspects: transport demand, energy consumption, greenhouse and polluting emissions, economic development, local accessibility, etc. The discussion below is articulated into four main parts:

- In section 3.1, the analysis of the forecasted future trends is reported in the no-policy scenario under the low oil price growth assumption (scenario A-1) and in the business-as-usual scenario still under the low oil price growth assumption (scenario A0);

- the effects of higher oil/fuel price, i.e. the results of the no-policy scenario under the high oil price growth assumption (scenario B-1) and in the business-as-usual scenario still under the high oil price growth assumption (scenario B0) are discussed in section 3.2;

- the impacts of the policy measures, i.e. the results of the scenarios A1, A2, B1 and B2 are reported in section 3.3;

- section 3.4 deals with the final conclusions.

3.1 Future trends assuming low oil price growth

In the A-1 scenario, where only the lower growth rate of oil price is modelled, transport demand is clearly growing both for passengers and for freight. Such a trend of growing demand for the future years is common to Europe-wide models as well as to regional models. Even if population in the EU25 is forecasted as stable or even decreasing in the future years, the modelling results suggest that the mobility of people will continue to grow in terms of passengers-km until 2030. Higher motorisation rates (the number of cars per 1000 inhabitants is forecast to be 25% higher in 2030 than nowadays) and higher average personal income can explain a slightly larger number of trips; at the same time, average trip length distances are also increasing. With reference to freight transport, the number of tonnes-km is forecast to grow faster than the economic growth, thus continuing the past trend observed in the last 30 years[9]. As far as the economic development is concerned, forecasts range from an average GDP growth rate of 1.8% p.a. (SASI forecasts) to an average rate of 2.7% p.a. (ASTRA forecasts).

The picture is not too different in the business-as-usual scenario (A0). Although policies aimed at increasing costs and times for road modes (and conversely favouring rail modes) are already implemented in this scenario, their effect on the overall mobility level is minor: both passenger and freight transport demand continue their growth until the year 2030.

Cars and trucks are currently the dominant transport modes and their role is confirmed or even enhanced in the future, according to the No-policy scenario. On the freight side, also sea shipping maintains a significant role. As far as passenger transport is concerned, car share is stable or even increasing although on long distance trips the role of air transport is rapidly growing.

[9] See for instance EU Energy and Transport in figures 2004 page 3.1.3.

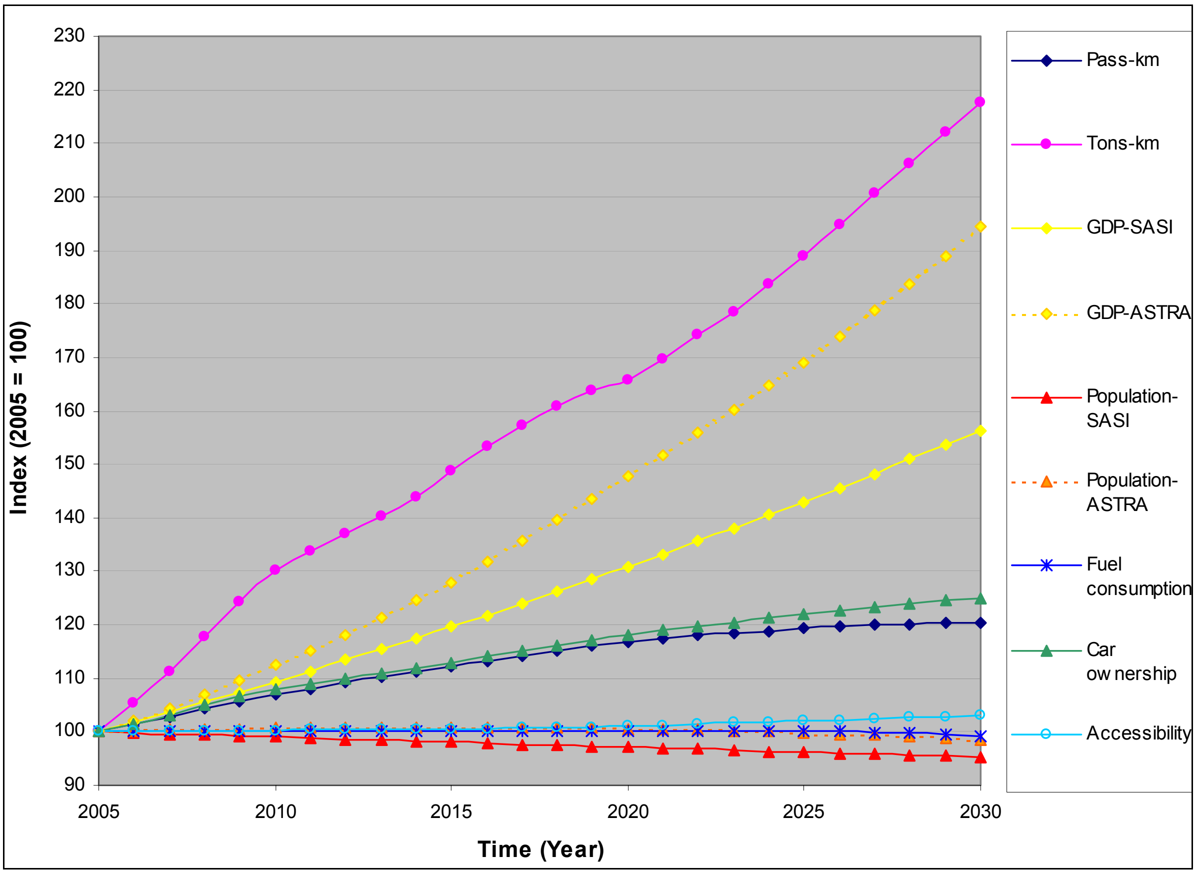


Figure 3.1 Main trends for EU countries in the no-policy scenario

In the A0 scenario, car and road freight clearly continue to be the main modes even though their shares are slightly reduced. The growth of the overall mobility does not trigger a proportional increment of the energy consumption in the transport sector. Total fuel consumption in the A0 scenario is substantially unchanged over the simulation period. This effect is due to the evolution of the vehicle fleet: in fact it is assumed that innovative vehicles (electric, fuel cells, etc.) will amount to about 10% of the fleet at 2030 in the A0 scenario. A greater efficiency of the vehicles explains why more or less the same amount of fuel is used even if demand is increasing. Additionally, renewable energy sources assume a greater importance even if only the energy consumed in the transport sectors is considered.

Improved efficiency of road vehicles is clearly visible also when considering the environmental effects (see table 3.1). Polluting emissions are sharply decreasing already in the no-policy scenario (A-1), with the only (though relevant) exception of the greenhouse emissions (CO_2). Actually, for technical reasons, the gain in terms of reducing unitary emissions of pollutants that can be obtained in the newest conventional vehicles (EURO IV, EURO V, etc.) does not have a correspondence on the greenhouse gases side. However, as far as elements like CO or PM are concerned, the reduction of the emissions is huge at the extent that the absolute value of emission in the future year will be significantly lower despite the traffic growth.

Table 3.1 Change of total emissions in the no-policy scenario under the low oil price growth assumption 2005 - 2030 and innovative fleet share at 2030

Model	CO_2 emissions	CO emissions	NO_x emissions	PM emissions	VOC emissions	% innovative vehicles in the fleet
European models						
ASTRA	↑	≈	↓	n.a.	↑	↑
Local models						
Brussels[1]	↑	↑	↑	n.a.	↑	≈
Dortmund	≈	↓	↓	↓	↑	↑
Edinburgh[2]	≈	n.a.	↓	↓	n.a.	↑
Helsinki[1]	↑	↓	↓	↓	n.a.	↑
South Tyrol[1]	↑	↓	↓	↓	↓	↑

↑	Increment with respect to 2005
↓	Decrement with respect to 2005
≈	Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.
2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

The measures simulated in the A0 scenario do not add much to the base trend of the A-1 scenario, even if direct greenhouse emissions are reduced in the final years of the simulation period. It seems this is not the case when well-to-wheel emissions are considered, as it happens in the Edinburgh model.

On the economic side, the impact of the Business as Usual policy measures (especially pricing and taxing of road modes) is to slightly reduce the growth of GDP and employment, but the base trend of the No-policy scenario is not significantly changed.

According to the model simulations, the average European accessibility for passengers and freight is increasing in the future years according to the No-policy scenario because of the underlying assumptions on further European integration. This growing trend is consistent with the dynamics of the past years, while the Business as Usual scenario gives rise to a break in the trend, slightly reducing average accessibility (especially for freight) as a consequence of higher cost of road transport (see figure 3.2).

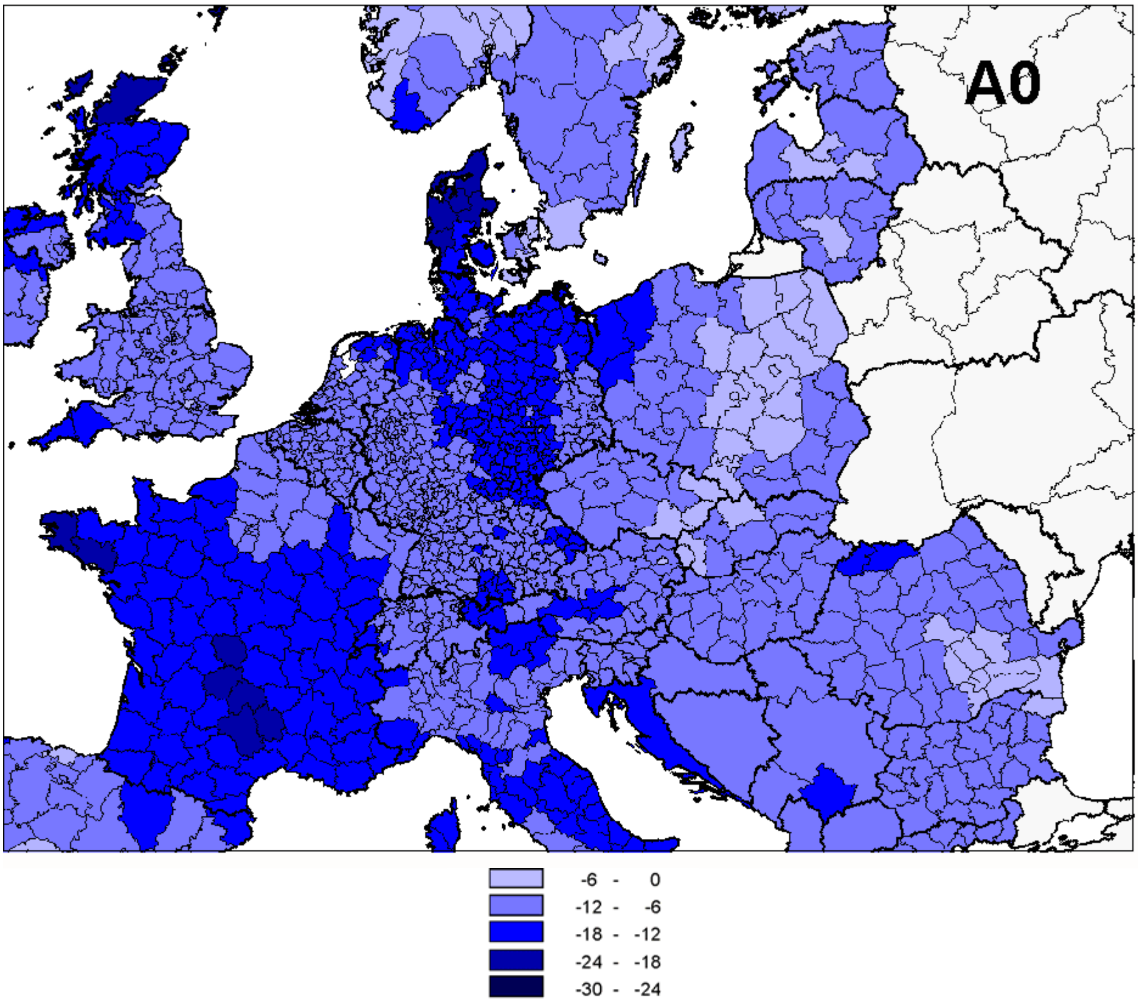


Figure 3.2 Accessibility road/rail/air travel, Scenario A0 with respect to Scenario A-1 2031 (SASI model results)

3.2 Effect of higher energy prices

Of special interest is the impact of the higher assumptions concerning the evolution of energy price, that is results from scenarios B-1 and B0, where such an assumption is added to the no-policy or Business as Usual case respectively.

As already mentioned, even if the assumption about oil price is a 7% growth rate p.a., the demand/supply mechanism in the fossil fuel market simulated within the POLES model leads to a slower growth of gasoline and diesel prices, which is on average about 4% p.a.
In fact, the main consequence of a faster growth of oil price seems to be a strong pressure for improving efficiency and using alternative sources of energy. On the transport demand side, the impact is also visible (although not so dramatic) and consists partially of a reduction of total mobility and partially of a shift to non-road modes. Passenger demand

seems more elastic than freight demand and the faster growth of fuel price significantly affects car ownership as well (see table 3.2).

Table 3.2 Change of fleet size 2005 – 2030 and share of innovative vehicles: comparison between A-1 and B-1 scenarios

Model	Vehicle fleet		% innovative vehicles in the fleet	
	A-1	B-1	A-1	B-1
European models				
ASTRA	↑	↓	↑	↑
Local models				
Brussels[1]	↑	≈	≈	≈
Dortmund	↑	↑	↑	↑
Edinburgh	↑	↑	↑	↑
Helsinki[1]	n.a.	n.a.	↑	↑
South Tyrol[1]	n.a.	n.a.	↑	↑

(green)	Increment change with respect to A-1	↑	Increment with respect to 2005
(yellow)	Not significant change with respect to A-1	↓	Decrement with respect to 2005
(red)	Decrement with respect to A-1	≈	Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.

On the vehicle fleet side, one can see the most significant impacts of the higher assumption on fuel price growth. Fleet in the year 2030 is shrunk with respect to the no-policy or Business as Usual base trend and its size is reduced even if compared to the present day. In addition, the internal composition of the fleet is significantly changed, with a higher share of cars – and especially large cars – substituted with innovative cars.

With a lower motorisation rate and higher costs for travelling, total passenger demand is still growing but at a low rate and especially the performance of cars is limited and falls below the base year (2005) value at the end of the simulation period. Instead, freight demand is more rigid and the higher fuel price is unable to reduce significantly the growth of passengers-km as well as to cut the mode share of road freight.

This rigidity can be partially explained with the limited effect that a faster dynamic of the oil price has on the economic growth. According to the modelling simulations, GDP is not so low in the ‘high oil price growth’ scenarios than in the ‘Low oil price growth’ ones and also employment is only slightly reduced. Also, the accessibility of regions, and so their opportunity of development, is not damaged dramatically looking at the outcome of the simulations.

In brief, modelling simulations suggest that the European Economy is able to put into practice strategies to improve efficiency and that the economic system as a whole can cope with more expensive energy (see table 3.3).

Table 3.3 Change of GDP and Employment 2005-2030: comparison between A-1 and B-1 scenarios

Model	**GDP**		**Employment**	
	A-1	**B-1**	**A-1**	**B-1**
ASTRA	↑	↑	↑	↑
SASI	↑	↑	↑	≈

(green)	Increment change with respect to A-1
(yellow)	Not significant change with respect to A-1
(red)	Decrement with respect to A-1

↑	Increment with respect to 2005
↓	Decrement with respect to 2005
≈	Near constant with respect to 2005

Table 3.4 Change of accessibility and cohesion 2005-2030: comparison between A-1 and B-1 scenarios

Model	**Passenger Accessibility**		**Relative Cohesion**	
	A-1	**B-1**	**A-1**	**B-1**
SASI	↑	↓	≈	↓

(green)	Increment change with respect to A-1
(yellow)	Not significant change with respect to A-1
(red)	Decrement with respect to A-1

↑	Increment with respect to 2005
↓	Decrement with respect to 2005
≈	Near constant with respect to 2005

Table 3.5 Change of Passengers-km and tonnes-km 2005-2030: comparison between A-1 and B-1 scenarios

Model	**passengers-km**		**tonnes-km**	
	A-1	**B-1**	**A-1**	**B-1**
European models				
ASTRA	↑	↑	↑	↑
Local models				
Brussels[1]	n.a.	n.a.	n.a.	n.a.
Dortmund	↑	↑	n.a.	n.a.
Edinburgh	↑	↑	n.a.	n.a.
Helsinki[1]	↑	↑	n.a.	n.a.
South Tyrol[1]	↑	↑	↑	↑

Increment change with respect to A-1 (green): ASTRA tonnes-km B-1
Not significant change with respect to A-1 (yellow): Edinburgh passengers-km B-1; South Tyrol tonnes-km B-1
Decrement with respect to A-1 (red): ASTRA, Dortmund, Helsinki, South Tyrol passengers-km B-1

↑ Increment with respect to 2005
↓ Decrement with respect to 2005
≈ Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.

There is no need to say that fuel consumption decreases significantly as consequence of its higher price. At the year 2030, fuel consumption is reduced of about 25% with respect to the scenarios featuring low oil price growth. At the same time, renewable sources are further fostered with respect to the A-1 scenario.

On the environmental side the impact of a higher energy price is positive, even though is the base trend already working in the 'Low oil price growth scenario which explains the majority of the gains. Instead, CO_2 emissions are significantly reduced below the A-1 level even if not necessarily under the current level.

Table 3.6 Change of emissions 2005-2030: comparison between A-1 and B-1 scenarios

Model	**CO2**		**CO**		**NOx**		**PM**		**VOC**	
	A-1	**B-1**	**A-1**	**B-1**	**A-1**	**B-1**	**A-1**	**B-1**	**A-1**	**B-1**
European models										
ASTRA	↑	↑	↓	↓	↓	↓	n.a.	n.a.	↑	↑
Local models										
Brussels[1]	↑	↓	↑	↓	↑	↓	n.a.	n.a.	↑	↓
Dortmund	↓	↓	↓	↓	↓	↓	↓	↓	↑	↓
Edinburgh[2]	↓	↓	n.a.	n.a.	↓	↓	↓	↓	n.a.	n.a.
Helsinki[1]	↑	↑	↓	↓	↓	↓	↓	↓	n.a.	n.a.
South Tyrol[1]	↑	↑	↓	↓	↓	↓	↓	↓	↓	↓

(green)	Increment change with respect to A-1	↑	Increment with respect to 2005
(yellow)	Not significant change with respect to A-1	↓	Decrement with respect to 2005
(red)	Decrement with respect to A-1	≈	Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.
2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

3.3 The impacts of the two policy strategies

As explained above, two diverse policy strategies have been simulated, one pivoted around technology investments (scenarios 1) and the other aimed at transport demand regulation (scenarios 2). The expected impact of both strategies is especially to help saving energy and reducing harmful transport emissions, but a full assessment of their effects has to take into account also other dimensions like the effect on the economy and the accessibility.

First, both strategies do not affect dramatically the size of demand, as total passengers-km and tonnes-km are increasing in all scenarios. Not surprisingly, demand regulation measures have a stronger impact and slow down the dynamic of transport demand (see tables 3.7 and 3.8). This trend is visible even if mobility is not reduced below the base year level (also under the high oil price growth assumption) and, as far as freight is concerned, the growth rate of tonnes-km is still higher than GDP growth rate.

Table 3.7 European models: Change of Passengers-km and tonnes-km 2005-2030: comparison between demand regulation and technology investments scenarios

Model	**A-1**	**A1**	**A2**	**B-1**	**B1**	**B2**
Passengers						
ASTRA	↑	↑	↑	↑	↑	↑
Freight						
ASTRA	↑	↑	↑	↑	↑	↑

(green)	Increment change with respect to A-1	↑	Increment with respect to 2005
(yellow)	Not significant change with respect to A-1	↓	Decrement with respect to 2005
(red)	Decrement with respect to A-1	≈	Near constant with respect to 2005

Table 3.8 Local models: Change of Passengers-km and tonnes-km 2005-2030: comparison between demand regulation and technology investments scenarios

Model	**A-1**	**A1**	**A2**	**B-1**	**B1**	**B2**
Passengers						
Brussels[1]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Dortmund	↑	↓	↓	↑	↓	↓
Edinburgh	↑	↑	↑	↑	↑	↑
Helsinki[1]	↑	↑	↑	↑	↑	↑
South Tyrol[1]	↑	↑	↑	↑	↑	↑

(green)	Increment change with respect to A-1	↑	Increment with respect to 2005
(yellow)	Not significant change with respect to A-1	↓	Decrement with respect to 2005
(red)	Decrement with respect to A-1	≈	Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.

A specific circumstance affects this result: the demand regulation measures provoke a modal shift towards rail and ship and such modes have higher average distances than road for most of the O/D pairs. In fact, modes like rail and shipping often need feeder modes from true origin to starting terminal and from arrival terminal to final destination. Furthermore, sea shipping routes can be much longer than land routes. Therefore, total distance travelled is often actually higher and this effect should not be underestimated: shifting goods from road to other modes means increasing the total amount of tonnes-km. These aspects are considered in the ASTRA model[10] and thus when scenarios are effective in terms of modal shift, a larger number of tonnes-km results.

[10] Although, given the coarse geographical detail in ASTRA, the increment of trip length could be somewhat overestimated.

The rigidity of freight and passenger demand with respect to the policy strategies is in agreement with the limited effects on the economic growth of all scenarios. On the one side, the simulations suggest that the technology investments scenarios (scenarios 1) are neutral for the economic development as they slightly reduce accessibility. However, at the same time they can have a positive effect due to the additional investments, the acceleration of the renewal of the fleet and therefore a positive development of intermediate and final consumptions. On the other side, demand regulation scenarios have a double negative effects. Firstly, they penalise the road transport sector and thus have a negative impact on the whole economy as predicted through the input/output mechanism: secondly they reduce accessibility of regions and then hinder their development. However, even if the reduction of GDP growth (and, correspondingly, of employment) is significant relative to the no-policy scenarios, economy is sharply growing in absolute terms; even in the scenario B2, when the demand regulation measures are associated to the high oil price growth assumption.

In brief, there are different impacts on the economy, but the final result does not bring about a break of the base trend. Consequently, the economic determinants of freight demand (and, although less directly, of passenger demand) do not change much and this explains why the outcome of the scenarios shows adjustments on the demand side, but not large variations (see table 3.9).

Table 3.9 Change of GDP and Employment 2005-2030: comparison between demand regulation and technology investments scenarios

Model	A-1	A1	A2	B-1	B1	B2
GDP						
ASTRA	↑	↑ (green)	↑ (red)	↑ (red)	↑ (green)	↑ (red)
SASI	↑	↑ (yellow)	↑ (red)	↑ (red)	↑ (red)	↑ (red)
Employment						
ASTRA	↑	↑ (green)	↑ (red)	↑ (red)	↑ (green)	↑ (red)
SASI	↑	↑ (yellow)	≈ (red)	≈ (red)	≈ (red)	↓ (red)

(green)	Increment change with respect to A-1	↑	Increment with respect to 2005
(yellow)	Not significant change with respect to A-1	↓	Decrement with respect to 2005
(red)	Decrement with respect to A-1	≈	Near constant with respect to 2005

On the environmental side, demand regulation measures prove to be more effective than technology investments (see tables 3.10 and 3.11). However, if compared to the no-policy trend, where polluting emissions are already reduced due to the fleet renewal, the additional gain is not always large. From a European perspective, the strategy of limiting demand and shifting on non-road modes is able to invert the trend of greenhouse emissions. If associated to the high oil price growth assumption, direct CO_2 emissions could be reduced of 30-50% with respect to the no-policy scenario and also well-to-wheel CO_2 emissions could be cut significantly. For pollutants, demand regulation strategy generates reductions that, especially at the local level, are not so large if compared to the effect of the technology investments and/or the only effect of higher oil price growth.

Table 3.10 Change of emissions 2005-2030: comparison between demand regulation and technology investments scenarios under the low oil price growth assumption

Model	CO2		CO		NOx		PM		VOC	
	A1	**A2**	**A1**	**A2**	**A1**	**A2**	**A1**	**A2**	**A1**	**A2**
European models										
ASTRA	↓	↓	↓	↓	↓	↓	n.a.	n.a.	≈	↓
Local models										
Brussels[1]	≈	↓	↓	↓	↓	↓	n.a.	n.a.	↓	↓
Dortmund	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Edinburgh[2]	↓	↓	n.a.	n.a.	↓	↓	↓	↓	n.a.	n.a.
Helsinki[1]	↑	↑	↓	↓	↓	↓	↓	↓	n.a.	n.a.
South Tyrol[1]	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓

Low Increment change with respect to A-1
High Increment change with respect to A-1
Not significant change with respect to A-1
Low Decrement with respect to A-1
High Decrement with respect to A-1

↑ Increment with respect to 2005
↓ Decrement with respect to 2005
≈ Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.
2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

The effectiveness of technology investments for reducing harmful emissions is lower. In some cases differences are small; in other cases they are significant. In rough terms, the reason is that the advantages in terms of lower unitary emissions are not as high as the reduction of the emitting units obtained with the demand regulation. However, the strategy of using technology has more positive impacts on the total energy usage and development of renewable sources. When looking at fuel consumption the regulation of demand still seems more effective.

Given the direct linkage between the quantity of demand (especially road demand) and externalities like accidents, noise and congestion, the conclusion is clear that the strategy of controlling demand performs better also on these respects.

Table 3.11 Change of emissions 2005-2030: comparison between demand regulation and technology investments scenarios under the high oil price growth assumption

Model	CO2		CO		NOx		PM		VOC	
	B1	B2	B1	B2	B1	B2	B1	B2	B1	B2
European models										
ASTRA	↓	↓	↓	↓	↓	↓	n.a.	n.a.	↓	↓
Local models										
Brussels[1]	↓	↓	↓	↓	↓	↓	n.a.	n.a.	↓	↓
Dortmund	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Edinburgh	↓	↓	n.a.	n.a.	↓	↓	↓	↓	n.a.	n.a.
Helsinki[1]	↑	↑	↓	↓	↓	↓	↓	↓	n.a.	n.a.
South Tyrol[1]	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓

Low Increment change with respect to A-1
High Increment change with respect to A-1
Not significant change with respect to A-1
Low Decrement with respect to A-1
High Decrement with respect to A-1

↑	Increment with respect to 2005
↓	Decrement with respect to 2005
≈	Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.
2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

On the accessibility side (table 3.12), both demand regulation and technology investments provoke negative effects as transport costs are increased. The negative impact is almost negligible for passengers in the technology investments scenarios, while is quite significant for freight especially in the demand regulation scenarios. As almost all European regions depends heavily on road modes for freight transport, this result is coherent to the expectations. Instead, for passengers, the picture is more mixed and the policy measures aimed at developing technology can have also some positive effects especially on peripheral regions of EU (especially New EU10 countries).

In terms of cohesion within EU25, measured as convergence of GDP, there is clear progress if an absolute indicator is used. This is because the impact of scenarios on the GDP of richer regions is higher and so differences between richer and poorer regions is reduced. More interesting is the analysis of relative cohesion (i.e. in terms of relative variations of GDP). Relative cohesion is lower in the demand regulation scenarios, independently from the assumptions relative to oil price. Instead, in the technology investments scenarios, the relative cohesion is higher, especially if the low oil price growth hypothesis is adopted. Therefore, from the simulations, it seems that investing on technologies has a better impact on poorer regions than the demand regulation, other things being equal.

Table 3.12 Change of accessibilty and cohesion 2005-2030: comparison between demand regulation and technology investments scenarios

	A1	**A2**	**B1**	**B2**
Passenger Accessibility				
SASI	≈	↓	↓	↓
Relative Cohesion (GDP)				
SASI	↑	↓	↑	↓

Cell colours in the table above (relative to A-1):
- A1: Passenger Accessibility SASI – Not significant change; Relative Cohesion SASI – High Increment
- A2: Passenger Accessibility SASI – Low Decrement; Relative Cohesion SASI – High Decrement
- B1: Passenger Accessibility SASI – High Decrement; Relative Cohesion SASI – Low Increment
- B2: Passenger Accessibility SASI – High Decrement; Relative Cohesion SASI – High Decrement

(light green)	Low Increment change with respect to A-1
(dark green)	High Increment change with respect to A-1
(yellow)	Not significant change with respect to A-1
(light orange)	Low Decrement with respect to A-1
(red)	High Decrement with respect to A-1

↑	Increment with respect to 2005
↓	Decrement with respect to 2005
≈	Near constant with respect to 2005

3.4 Conclusions

The following tables summarise the impacts of the policy scenarios compared to the A-1 scenario, using some variables that can provide a broad idea about the environment, the energy system, the economy and the mobility: emissions, energy consumptions, the average travel time per trip, accessibility and economic cohesion.

Table 3.13 and 3.14 show the impacts of the high oil price growth assumption. Apparently, in comparison to the low oil price growth assumption, positive and neutral effects are dominant: pollution diminishes (even if CO_2 is increasing with respect to year 2005) as well as energy consumption. Average time per trip is stable as well as GDP (even though a slight decrement is forecast) and relative cohesion. Instead negative effects can be found on accessibility.

In brief, according to the modelling simulations, a faster growth of fuel price could not be a too bad perspective, assuming that the modelled reactions in terms of improved efficiency are actually put into practice.

Table 3.13 European models: Summary of Scenario B-1 results with respect to A-1 at year 2030

Model	CO2 emissions	NOX emissions	Energy consumption	% innovative vehicles	GDP	Accessibility	Relative Cohesion (GDP)
ASTRA	↑	↓	↑	↑	↑	n.a.	n.a.
SASI	n.a.	n.a.	n.a.	n.a.	↑	↓	↓

Cell colours: ASTRA — CO2 emissions, NOX emissions and Energy consumption red; % innovative vehicles green; GDP yellow. SASI — GDP yellow; Accessibility red; Relative Cohesion (GDP) yellow.

Green	Increment change with respect to A-1	↑	Increment with respect to 2005
Yellow	Not significant change with respect to A-1	↓	Decrement with respect to 2005
Red	Decrement with respect to A-1	≈	Near constant with respect to 2005

Table 3.14 Local models: Summary of Scenario B-1 results with respect to A-1 at year 2030

Model	CO2 emissions	NOX emissions	Energy consumption	Av. Time per trip	Accessibility
Brussels[1]	↓	↓	↓	n.a.	n.a.
Dortmund	↓	↓	↓	≈	↓
Edinburgh[2]	↓	↓	↓	↑	↓
Helsinki[1]	↑	↓	n.a.	≈	n.a.
South Tyrol[1]	↑	↓	n.a.	↓	↑

Cell colours: CO2 emissions red in every row. NOX emissions and Energy consumption red for Brussels, Dortmund and Edinburgh; NOX emissions yellow for Helsinki and South Tyrol. Av. Time per trip yellow for Dortmund, Edinburgh, Helsinki and South Tyrol. Accessibility yellow for Dortmund, Edinburgh and South Tyrol. Cells marked n.a. are uncoloured.

Green	Increment change with respect to A-1	↑	Increment with respect to 2005
Yellow	Not significant change with respect to A-1	↓	Decrement with respect to 2005
Red	Decrement with respect to A-1	≈	Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.

2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

From Table 3.15 and table 3.16 it can be seen that the technology investments scenario under the low oil price growth assumption is able to realise improvements for almost all the variables considered with some local exception. Progress is generally made also with respect to year 2005, although CO_2 emissions are generally increasing and accessibility levels are diminishing.

Table 3.17 and table 3.18 show that (still under the assumption that oil price will grow slowly) the demand regulation scenario improves most of the variables as well. Progresses concern mainly the same variables that are positively affected by the technology investments scenario; with the relevant exception of GDP (which is somewhat reduced in the demand management scenario). So, in terms of the directions of the impacts, the two policy strategies are comparable. However, as explained in the previous paragraphs, the size of the impacts of the two scenarios is not the same and quantitative aspects should be taken into account as well to compare the two policy strategies.

Finally, from table 3.19 to table 3.22 the summary impacts of the two policies is presented, technology investments and demand regulation respectively, under the high oil price growth hypothesis. The two tables are not significantly different from the previous ones, which is a confirmation of the limited role of the energy price to explain the results of the scenarios. However, even this limited effect is able to emphasise the negative impact of the demand regulation strategy on the economy.

Both policy measures are therefore effective for reducing energy consumption as well as greenhouse and pollutant emissions without a very negative impact on the economic growth. However, in particular demand regulation policies significantly reduce accessibility, i.e. impose constraint to mobility, especially to passengers' private mobility: modal shift towards public modes is favoured, trip lengths are reduced, etc. Although this can be seen as a benefit from a collective point of view, these changes in travel behaviour are not voluntary but forced responses, which might imply a loss of quality of life.

In brief, the price paid for the success on the environmental side can be substantial in terms of money and quality of life; however, discussing ways to alleviate the hardships in these two dimensions are beyond the scope of this project.

Table 3.15 European models: Summary of Scenario A1 results with respect to A-1 at 2030

Model	CO2 emissions	NOX emissions	Energy consumption	% innovative vehicles	GDP	Accessibility	Relative Cohesion (GDP)
ASTRA	↓ (red)	↓ (red)	↓ (red)	↑ (green)	↑ (yellow)	n.a.	n.a.
SASI	n.a.	n.a.	n.a.	n.a.	↑ (yellow)	↓ (red)	↑ (green)

(green)	Increment change with respect to A-1
(yellow)	Not significant change with respect to A-1
(red)	Decrement with respect to A-1
↑	Increment with respect to 2005
↓	Decrement with respect to 2005
≈	Near constant with respect to 2005

Table 3.16 Local models: Summary of Scenario A1 results with respect to A-1 at 2030

Model	CO2 emissions	NOX emissions	Energy consumption	Av. Time per trip	Accessibility
Brussels[1]	≈	↓	≈	n.a.	n.a.
Dortmund	↓	↓	↓	↑	↓
Edinburgh[2]	↓	↓	↓	↑	↓
Helsinki[1]	↑	↓	n.a.	↓	n.a.
South Tyrol[1]	↑	↓	n.a.	≈	↑

Green	Increment change with respect to A-1	↑	Increment with respect to 2005
Yellow	Not significant change with respect to A-1	↓	Decrement with respect to 2005
Red	Decrement with respect to A-1	≈	Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.
2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

Table 3.17 European models: Summary of Scenario A2 results with respect to A-1 at 2030

Model	CO2 emissions	NOX emissions	Energy consumption	% innovative vehicles	GDP	Accessibility	Relative Cohesion (GDP)
ASTRA	↓	↓	↓	≈	↑	n.a.	n.a.
SASI	n.a.	n.a.	n.a.	n.a.	↑	↓	↓

Green	Increment change with respect to A-1	↑	Increment with respect to 2005
Yellow	Not significant change with respect to A-1	↓	Decrement with respect to 2005
Red	Decrement with respect to A-1	≈	Near constant with respect to 2005

Table 3.18 Local models: Summary of Scenario A2 results with respect to A-1 at 2030

Model	CO2 emissions	NOX emissions	Energy consumption	Av. Time per trip	Accessibility
Brussels[1]	↓	↓	↓	n.a.	n.a.
Dortmund	↓	↓	↓	↑	↓
Edinburgh[2]	↓	↓	↓	≈	↑
Helsinki[1]	↑	↓	n.a.	≈	n.a.
South Tyrol[1]	↑	↓	n.a.	≈	↑

Green	Increment change with respect to A-1	↑	Increment with respect to 2005
Yellow	Not significant change with respect to A-1	↓	Decrement with respect to 2005
Red	Decrement with respect to A-1	≈	Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.
2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

Table 3.19 European models: Summary of Scenario B1 results with respect to A-1 at 2030

Model	CO2 emissions	NOX emissions	Energy consumption	% innovative vehicles	GDP	Accessibility	Relative Cohesion (GDP)
ASTRA	↓	↓	↓	↑	↑	n.a.	n.a.
SASI	n.a.	n.a.	n.a.	n.a.	↑	↓	↑

Green	Increment change with respect to A-1	↑	Increment with respect to 2005
Yellow	Not significant change with respect to A-1	↓	Decrement with respect to 2005
Red	Decrement with respect to A-1	≈	Near constant with respect to 2005

Table 3.20 Local models: Summary of Scenario B1 results with respect to A-1 at 2030

Model	CO2 emissions	NOX emissions	Energy consumption	Av. Time per trip	Accessibility
Brussels[1]	↓	↓	↓	n.a.	n.a.
Dortmund	↓	↓	↓	↑	↓
Edinburgh[2]	↓	↓	↓	↑	↓
Helsinki[1]	↑	↓	n.a.	↓	n.a.
South Tyrol[1]	↓	↓	n.a.	≈	↑

Green	Increment change with respect to A-1	↑	Increment with respect to 2005
Yellow	Not significant change with respect to A-1	↓	Decrement with respect to 2005
Red	Decrement with respect to A-1	≈	Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.
2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

Table 3.21 European models: Summary of Scenario B2 results with respect to A-1 at 2030

Model	CO2 emissions	NOX emissions	Energy consumption	% innovative vehicles	GDP	Accessibility	Relative Cohesion (GDP)
ASTRA	↓	↓	↓	↑	↑	n.a.	n.a.
SASI	n.a.	n.a.	n.a.	n.a.	↑	↓	↓

Green	Increment change with respect to A-1	↑	Increment with respect to 2005
Yellow	Not significant change with respect to A-1	↓	Decrement with respect to 2005
Red	Decrement with respect to A-1	≈	Near constant with respect to 2005

Table 3.22 Local models: Summary of Scenario B2 results with respect to A-1 at 2030

Model	CO2 emissions	NOX emissions	Energy consumption	Av. Time per trip	Accessibility
Brussels[1]	↓	↓	↓	n.a.	n.a.
Dortmund	↓	↓	↓	↑	↓
Edinburgh[2]	↓	↓	↓	≈	↑
Helsinki[1]	↑	↓	n.a.	≈	n.a.
South Tyrol[1]	↓	↓	n.a.	↑	↑

Green	Increment change with respect to A-1	↑	Increment with respect to 2005
Yellow	Not significant change with respect to A-1	↓	Decrement with respect to 2005
Red	Decrement with respect to A-1	≈	Near constant with respect to 2005

1 Data of Brussels, Helsinki and South Tyrol models concerns year 2020.

2 CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions

Chapter 4 Results of the European models

4.1 Introduction

In this chapter the results of the three European models use for the simulation of the STEPs scenarios – POLES, ASTRA and SASI – are presented in detail. As explained previously, each model has specific capabilities and therefore the presented results differ, at least partially. Notwithstanding, projections concerning the same variables from different models are also reported. In such cases, the differences between models should be taken into account for interpreting discrepancies, especially on the size of the changes forecasted. Indeed, given the specific nature of each model, variables can be simulated in more or less detail and from different points of view. Therefore, although in general it can be expected that the direction of the changes are the same, the magnitude of the forecasts can well be different.

In some cases, when the theories underlying the modelling of the behaviour of some variables are completely different and/or variables are defined in different ways, also forecasts different in sign can be expected and justified. For instance, SASI and ASTRA simulate the linkage between the transport system and the economy from two different perspectives: the former on the basis of the concept of accessibility as condition for economic development, the latter in terms of input/output relationships between the transport sector and the rest of the economy. In such a cases, similar results are a clue that a specific effect can be expected as result of different mechanisms, while dissimilar results might suggest that counterbalancing effects are in place.

4.2 The ASTRA model results

4.2.1 The ASTRA model

The ASTRA model is a System Dynamics model at the European scale focused on describing the linkages between transport, economy and environment. The ASTRA model covers the EU25 member states plus Bulgaria, Norway, Romania and Switzerland.

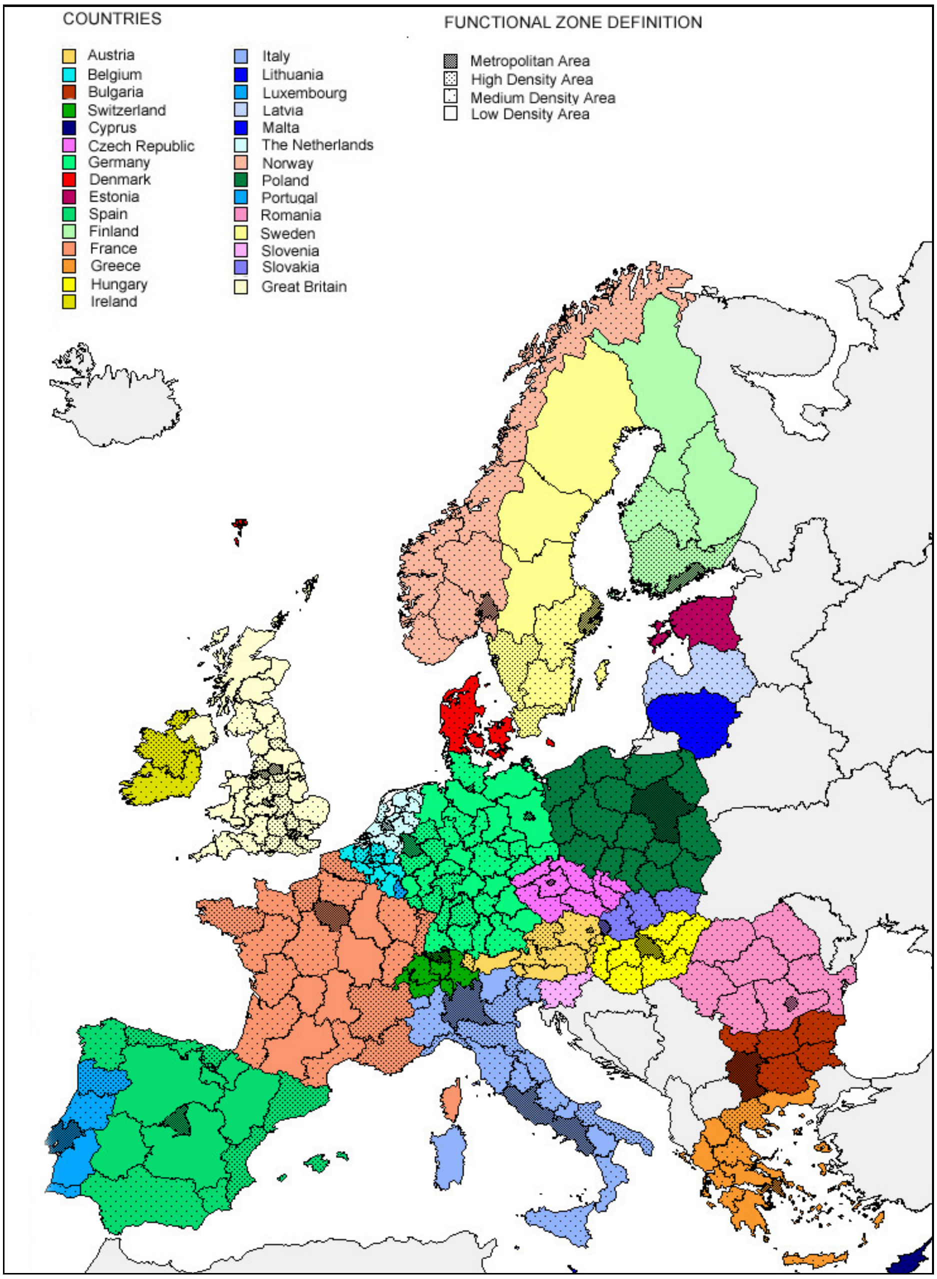


Figure 4.2.1 The ASTRA zoning system

The ASTRA model consists of eight main modules:

- Population Module (POP),
- Macro-economic Module (MAC),
- Regional Economic Module (REM),
- Foreign Trade Module (FOT),
- Transport Module (TRA),
- Environment Module (ENV),
- Vehicle Fleet Module (VFT) and
- Welfare Measurement Module (WEM).

As depicted in Figure 4.2.2, several interrelationships exist between the eight ASTRA modules so that they form a single integrated framework. In this way, when changes happen in one module, its effects are echoed throughout the whole model. For a more detailed description of the ASTRA model, the reader is referred to deliverable D4.1 of the STEPs project.

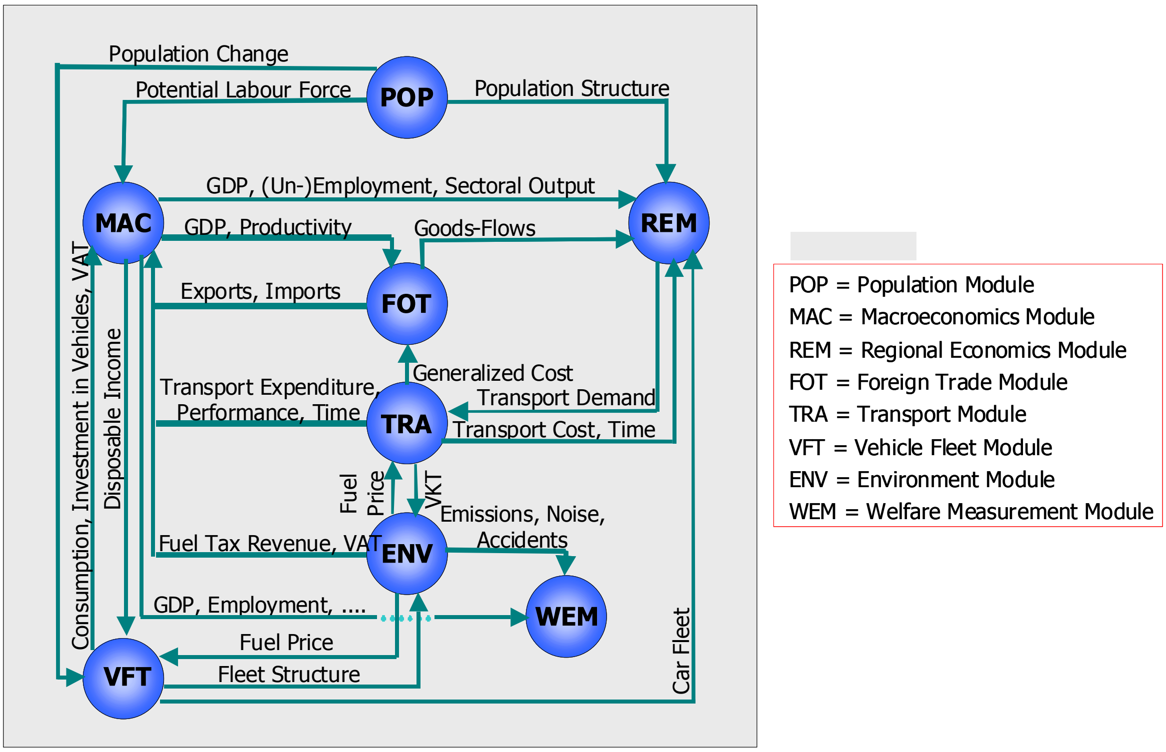


Figure 4.2.2 The structure of the ASTRA model

4.2.2 Implementation of the scenarios in the ASTRA model

To implement the eight STEPs scenarios in the ASTRA model it has been necessary to change or integrate some of the D3 values in order to fit into the model structure and to exploit the integration with other modelling tools.

Indeed, the ASTRA model has been used to simulate the STEPs scenarios in co-ordination with the POLES model, exchanging input and output between the models as explained in paragraph 2.3.2. ASTRA has implemented output data from POLES concerning:

- pure fuel cost for gasoline and diesel in the future years (the growth rates obtained from POLES have been implemented by country);
- the car fleet composition and the number of new registrations (this data was implemented directly in the Vehicle Fleet Module).

For fuel taxes, the assumed scenarios trend has been applied to the base values of fuel taxes (excises) for each country; the same yearly growth rate has been introduced for all the countries. VAT rates were not part of the scenarios and have not been changed.

Table 4.2.1 Pure fuel price and fuel taxes by country in ASTRA at 2005 (Euro/litre)

	Pure fuel price		**Fuel Tax (excluded VAT)**	
Country	***Gasoline***	***Diesel***	***Gasoline***	***Diesel***
EU15				
Austria	0.412	0.464	0.426	0.298
Belgium&Luxembourg	0.393	0.518	0.462	0.314
Denmark	0.493	0.521	0.382	0.333
Spain	0.433	0.424	0.610	0.384
Finland	0.508	0.518	0.546	0.399
France	0.458	0.430	0.364	0.264
Great Britain	0.305	0.305	0.573	0.410
Germany	0.470	0.462	0.520	0.298
Greece	0.463	0.420	0.601	0.601
Ireland	0.403	0.420	0.630	0.372
Italy	0.436	0.411	0.522	0.330
The Netherland	0.510	0.483	0.575	0.313
Portugal	0.577	0.418	0.317	0.220
Sweden	0.451	0.572	0.469	0.280

	Pure fuel price		Fuel Tax (excluded VAT)	
New EU Member States				
Cyprus	0.345	0.264	0.503	0.264
Czech Republic	0.335	0.357	0.352	0.253
Estonia	0.141	0.076	0.272	0.214
Hungary	0.353	0.386	0.376	0.314
Latvia	0.141	0.076	0.307	0.232
Lithuania	0.141	0.076	0.363	0.196
Malta	0.345	0.264	0.503	0.394
Poland	0.357	0.319	0.403	0.258
Slovenia	0.345	0.264	0.375	0.253
Slovakia	0.322	0.318	0.339	0.261

TEN infrastructures have been introduced in the model as part of the A1/B1 scenarios indirectly, as ASTRA does not have an explicit network. Thus, the effect of the TEN infrastructures has been considered in the simulations through average speed improvement on the relevant transport connections and activating the corresponding additional investments in the macroeconomic module.

Road pricing has been implemented in the ASTRA model in two different ways, one for passengers and the other for freight. For passenger cars (buses and coaches have been excluded from the pricing), the charge has been applied for all the trips with destination in a metropolitan area (according to the concept of cordon charge). For road freight modes, the additional cost per ton-km has been placed also for inter-urban trips (which is in accordance to the revision of road freight charging recently applied in several EU countries – e.g. Eurovignette).

Emission factors of cars have been reduced according to the assumptions defined in WP 3 with reference to the introduction of new technologies; reduction rates have been applied to the base data present in the model, which are distinguished by car category and emission standard. As well, fuel consumption trends assumed in WP 3 have been applied to the base values of the ASTRA model.

The development of car sharing has been modelled by reducing the number of new registered car per year received from POLES according to the rate of development of car sharing defined in WP 3. Land use policies could not be simulated in ASTRA, given the coarse geographical detail of the model.

Table 4.2.2 summarises how the scenarios assumptions have been translated into inputs for the ASTRA model.

Table 4.2.2 ASTRA Model: Scenario definition

	Measure	Indicator	A0/B0	A1/B1	A2/B2
			Annual change (%)		
Socio-economic	Pure Fuel price	Gasoline	POLES projection	POLES projection	POLES projection
		Diesel	POLES projection	POLES projection	POLES projection
	Car sharing etc.	Car fleet	POLES Car fleet	As A0	POLES car fleet minus .6%/year
	Fuel tax	Gasoline	+0.7%	As A0	+4.7%
		Diesel	+1.5%	as A0	+4.7%
		Kerosene (% of gasoline tax, from 2012)	50%	as A0	200%
	Travel cost due to tax increases	Car/lorry cost per km Air cost per km	Calculated endogenously by the model	Calculated endogenously by the model	Calculated endogenously by the model
	Telework	Work trips saved	0%	as A0	+0.3% (a)
Spatial	Residential	Central	+	as A0	++
		Inner urban	++	as A0	+++
		Outer urban	+++	as A0	0
	Services	Central	0/+	as A0	+
		Inner urban	+	as A0	++
		Outer urban	++	as A0	0
	Industrial	Central	0	as A0	0
		Inner urban	+	as A0	+++
		Outer urban	+++	as A0	0/+
Travel	European rail	European rail time	-0.8%	-2.0%	as A0
	Regional rail	Regional rail time	-0.4%	-1.7%	as A0
	Public transport	Bus time	-0.3%	-1.1%	as A0
	Traffic calming	Road time in MPA	+0.4	as A0	+1.0%
	Road pricing	Car cost for OD directed to MPA	+2.0%	as A0	+6.0%

Measure		Indicator	A0/B0	A1/B1	A2/B2
			Annual change (%)		
	Public transport cost	Bus cost per km	+0.8%	as A0	-1.7%
		Train cost per km	+0.8%	as A0	-1.7%
Freight	Traffic calming	Road time in MPA	+0.4	as A0	+1.0%
	Road pricing	€ per ton-km	+2.0%	as A0	+6.0%
	City logistics	Local average distance	-0.2%	-0.5%	as A0
		Local load factor	+0.8%	+2.4%	as A0
	Rail freight	Rail freight time	-0.7%	-2.0%	as A0
Energy	Energy efficiency for cars and lorries	Gasoline per km	-0.5%	-2.0%	as A0
		Diesel per km	-1.0%	-3.0%	as A0
	Alternative vehicles	Emissions per km	-50% every 9 year (new EURO)	- emissions -50% every 5 year (new EURO)	as A0
		Car fleet (d)	POLES car fleet	POLES car fleet	POLES car fleet
	Energy use rail	Energy per km	-0.8%	-5.0	as A0
	Energy use ship	Energy per km	-0.4%	-1.6%	as A0

Exogenous input (D3

Endogenous calculation

Not used in ASTRA Model

Input from POLES model

4.2.3 Main results from the ASTRA model

Main results from the ASTRA model are presented and commented below for three main areas: economy, transport demand and environment. Additional results are presented in a separate paragraph.

Economy

Figure 4.2.3 and Figure 4.2.4 show the development of GDP and Employment in the EU25 until the year 2030, according to the ASTRA forecasts for the eight STEPs scenarios. GDP is growing in all scenarios but at different paces. In A0 scenario, the average yearly growth rate is 2.5%, slightly lower than the growth rate in no-policy scenarios, where GDP increase by 2.6 to 2.7% per year (respectively in B-1 and A-1 scenarios). In the technology investments scenarios the growth rate is higher (2.8%) and this is true either if a low increase of oil price is assumed (A1) and or a higher increase is applied (B1). The effect of oil price on GDP is therefore almost negligible, and this is the case also when the business as usual scenario is run under high oil price growth assumption (B0 scenario). In modelling terms, this can be explained in terms of improved efficiency stimulated by the higher price of energy. In the demand regulation scenarios, the GDP growth is lowered to a 1.9% per year (A2) or 2.0% (B2). The reason for a reduced GPD growth in the model is that the overall economic activity is affected by the diminished demand derived from transport: consumption of fuel, vehicles, transport services, investments in transport means, infrastructures, etc. Here the effect of a higher oil price is slightly positive, as B2 performs better than A2. This effect depends again on the improved efficiency, which, in this scenario, allows the economy to react better to the diminished demand.

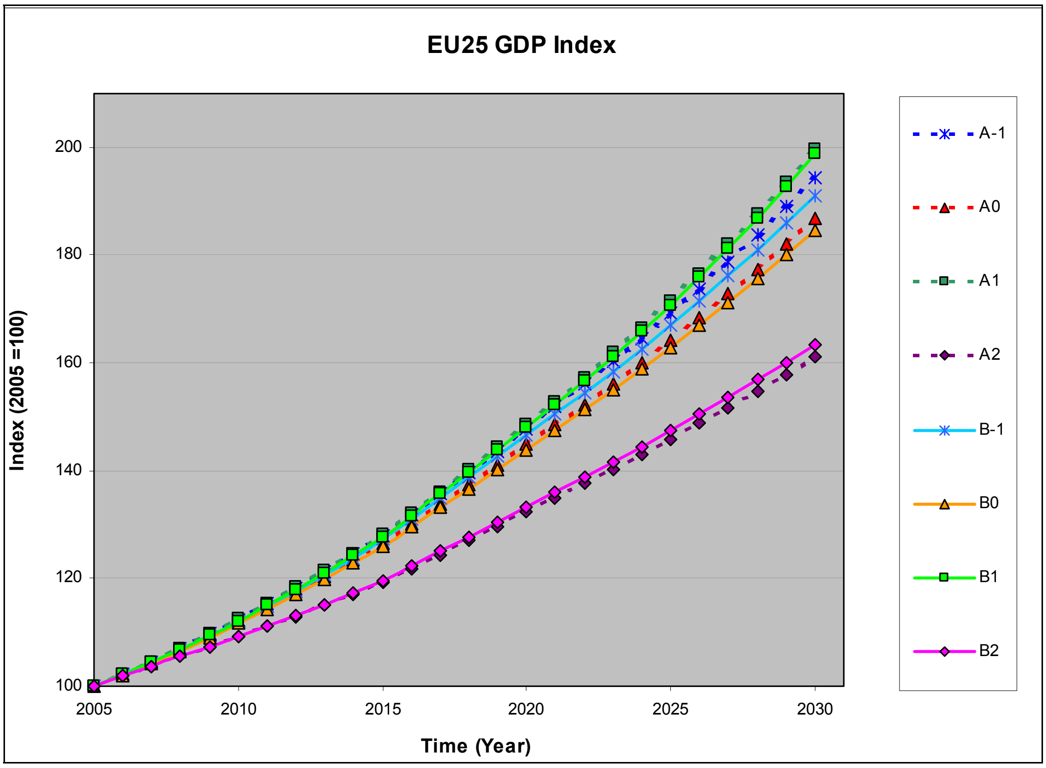


Figure 4.2.3 GDP index development for EU25 (2005 = 100)

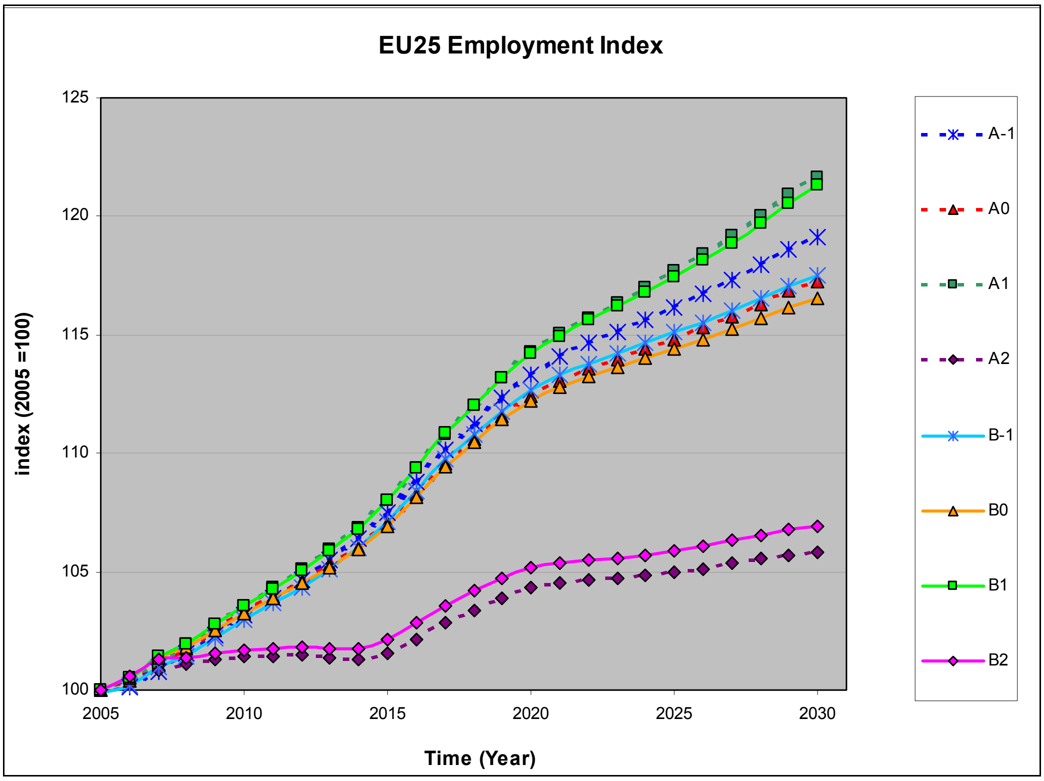


Figure 4.2.4 Employment index development for EU25 (2005 = 100)

In terms of employment, the hierarchy among scenarios proposed by the GDP index development is confirmed. The impact of reduced demand on employment is significant as transport is quite a labour-intensive sector and therefore both direct effects (lower transport demand) and indirect effects (reduced economic activity) play a negative role on employment.

The effects on the EU15 and new EU Member States (NMS) are similar but not identical. While the trends illustrated in the previous graphs for the EU25 are dominated by the results obtained from the EU15, Figure 4.2.5 and Figure 4.2.6 show the same data for the NMS.

- The effect of the demand regulation scenarios on the employment is much stronger for EU15 countries than for New Member States (NMS). The development of employment in the model follows primarily from the overall growth of the economy (GDP). As the growth rates of GDP for the NMS is significantly higher than for EU15 (around 4.0% per year), the impact of reduced demand in the transport sector is less important in the former than in the latter.

- The scenarios B, where oil price develops faster, do not show for the NMS a significant difference from the scenarios A and the minor difference existing has a different sign with respect to EU15, i.e. GDP and employment presents a slightly lower growth rate when oil price increases faster. This difference is due to the dissimilar importance of sectors in each country and therefore to the different effects that spread over the whole economy through the Input-Output mechanism modelled in ASTRA.

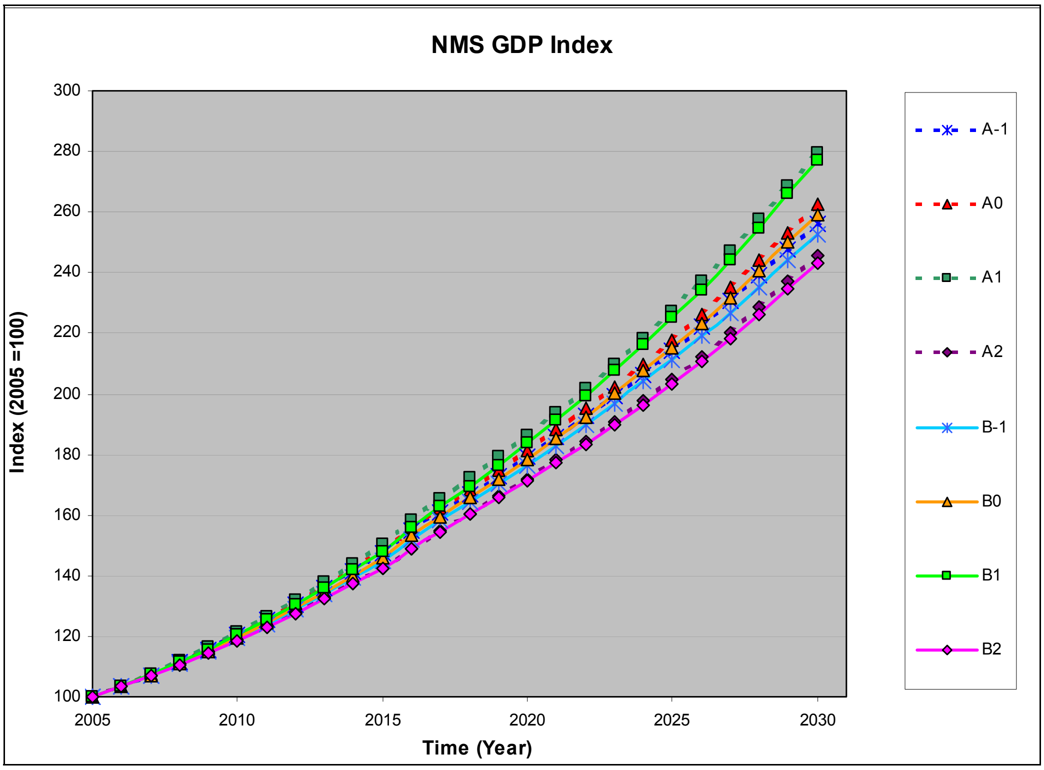


Figure 4.2.5 GDP index development for the New Member States (2005 = 100)

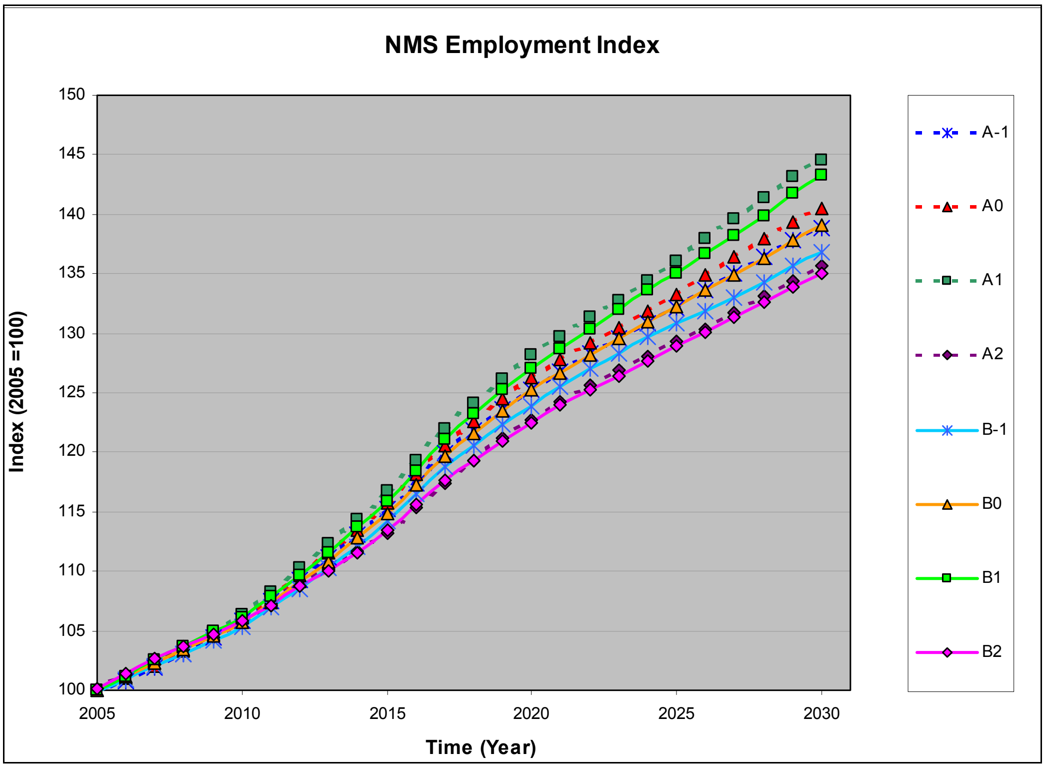


Figure 4.2.6 Employment index development for the New Member States (2005 = 100)

Transport demand

Figure 4.2.7 and Figure 4.2.8 show how passenger and transport demand will develop in EU25 until the year 2030 in the STEPs scenarios according to the ASTRA model forecasts. Total passenger demand is increasing in all scenarios. In the A0 scenario the average yearly growth rate is 0.9% which is higher than the growth rates in the No-Policy (A-1 and B-1) scenarios (0.6-0.7% per year). Therefore, the implementation of the business as usual policies brings about a slight growth of passenger traffic performance. This is caused by the modal shift towards non-road modes with higher average trip length.

In all other scenarios the growth rate is lower than in the A0 scenario, with the exception of the A1 scenario, where the total passengers-km increase a little bit more. This result in the A1 scenario has two main explanations. The main one is that in this scenario the motorisation (car ownership) is slightly higher, due to the slight increase of disposable income (see the economic section). A higher motorisation rate gives rise to more trips and therefore to more traffic. The second explanation of the increase of passengers-km in scenario A1 is that some demand is shifted to rail. As said before, for this mode average trip lengths are a bit higher for most of the long-distance O/D pairs and so this affect the total statistics. Set aside A1 scenario, in all other cases the demand growth is lowered with respect to A0 and A-1 scenarios. This is obviously the case especially for the demand regulation scenarios A2 and B2, which are exactly focused on such an aim. In the high oil price growth scenarios (B-1 to B2), passengers-km increase at a lower rate than in the correspondent scenarios A and this is reasonable, as higher prices of transport lead to a reduced demand.

Focusing attention on car (Figure 4.2.8), it can be noticed that in all scenarios transport demand at 2030 is not higher than in 2005 or generally lower, except for the A0 and A-1 scenarios where we observe a positive yearly growth rate of 0.1%. This result is consistent with the scenarios input, as in all scenarios modes alternative to private car improve in some way while car price is always increasing. Of course, when a faster growth of fuel price is associated to the other measures, the effect is emphasised: in scenario B2 car demand in EU25 is stable until 2012 and then declines with an average reduction of 0.8% per year until 2030.

According to the ASTRA results, freight transport demand is not as much reactive to policies as passenger demand. Total tonnes-km sharply increase in all scenarios. In the A0 scenario, the average growth rate is 3.4% per year, a little bit more than in the A-1 scenario, where freight demand increases by 3.2% per year. Anyway this rate is higher than the GDP growth rate (see the economic section): according to ASTRA it seems that decoupling will not be there in the next future.

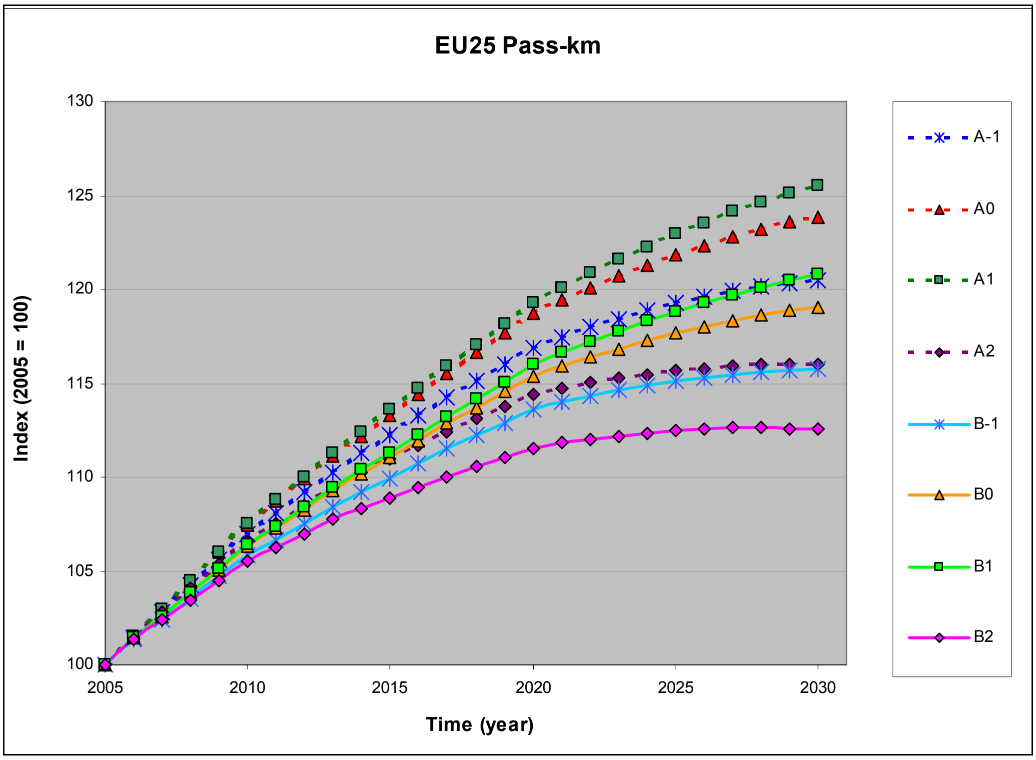


Figure 4.2.7 Pass-km index development for EU25 (2005 = 100)

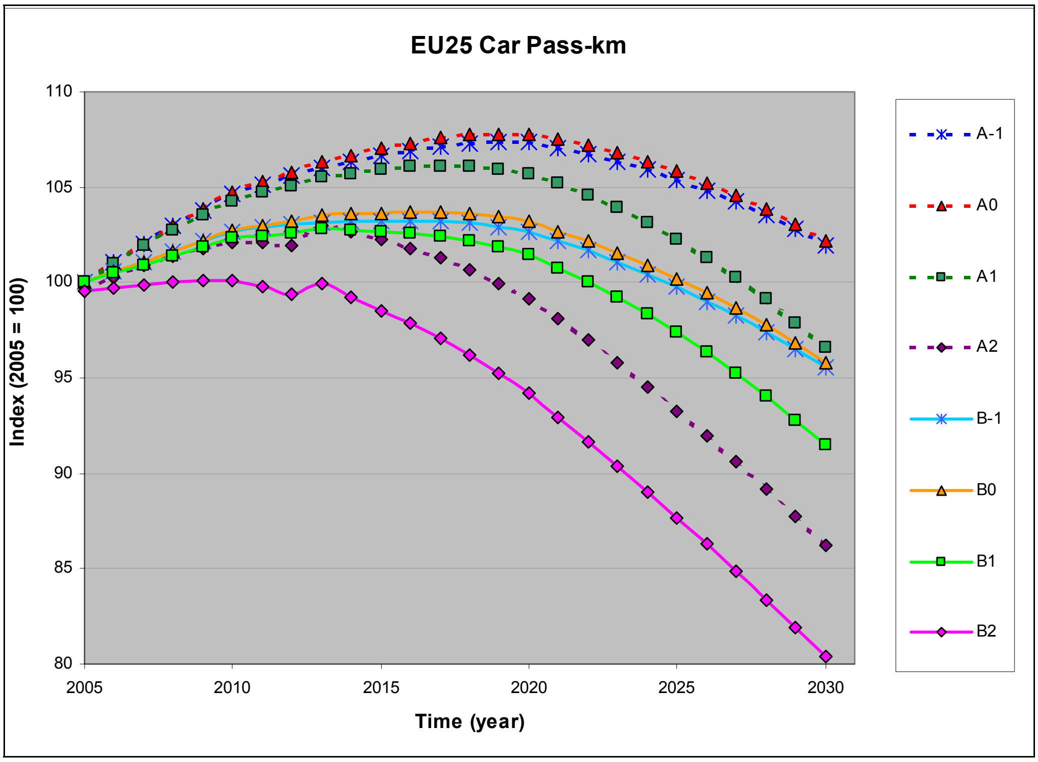


Figure 4.2.8 Car Pass-km index development for EU25 (2005 = 100)

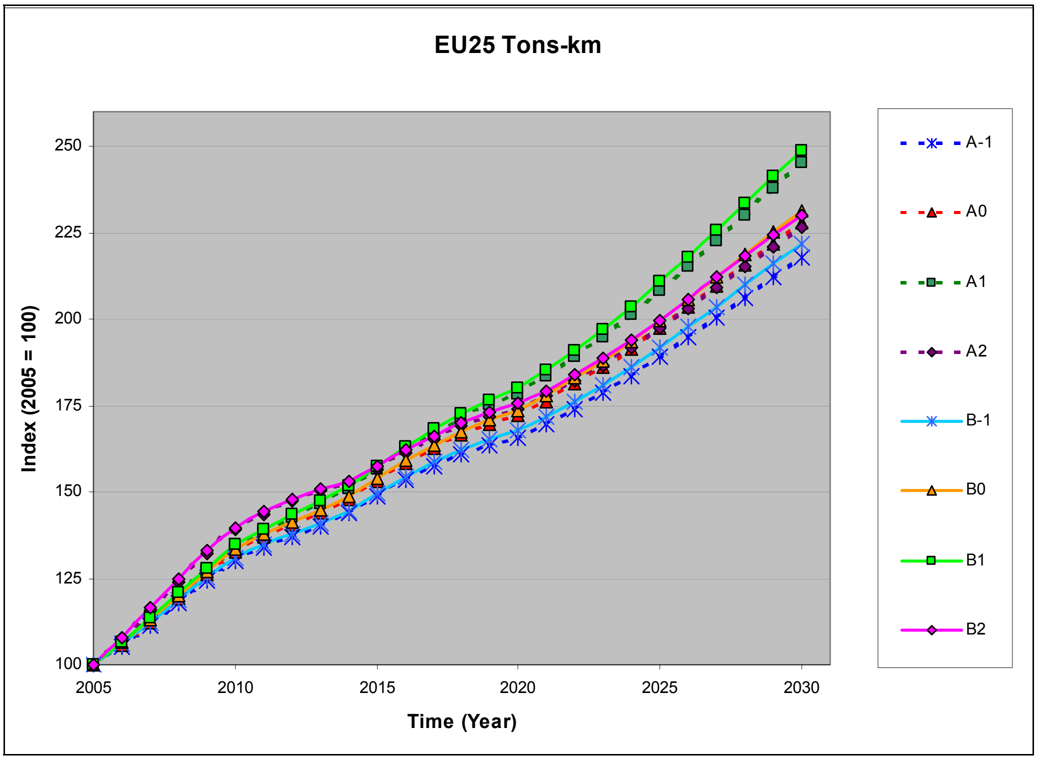


Figure 4.2.9 Tons-km index development for EU25 (2005 = 100)

In the policy scenarios, total tonnes-km are even more than in the A0 scenario (Figure 4.2.9), however this effect is largely caused by the modal shift: more than for passengers modes, for a given O/D pair the average trip length of non-road modes is often larger than road trip length. Actually, both rail and sea shipping need that goods are moved to and from terminals and the routes linking the terminals are generally longer than the road route. So the total distance for the consignment is generally higher when travelling by rail or sea shipping: when a given amount of tonnes is shifted to rail and ship tonnes-km are automatically increased. This effect is especially visible in the technology investments scenarios because in the demand regulation scenarios there are polices that induce a reduction of average consignment length and this effect offsets the impact of modal shift.

Figure 4.2.10 to Figure 4.2.15 report the forecasted trend of passenger and freight demand in EU15 and NMS. The same considerations expressed above for EU25 apply also for EU15 and NMS separately, even if the growth rates are different. Especially, it can be noted that passenger demand in NMS is forecast to grow less than in EU15 (0.3% per year in A0 scenario instead of 0.9%): this is due to the decrement of population in the NMS according to the available projections (-0.3% p.a. from 2000 until 2020 according to the ASTRA population model), which overbalance the effect of the wealth growth.

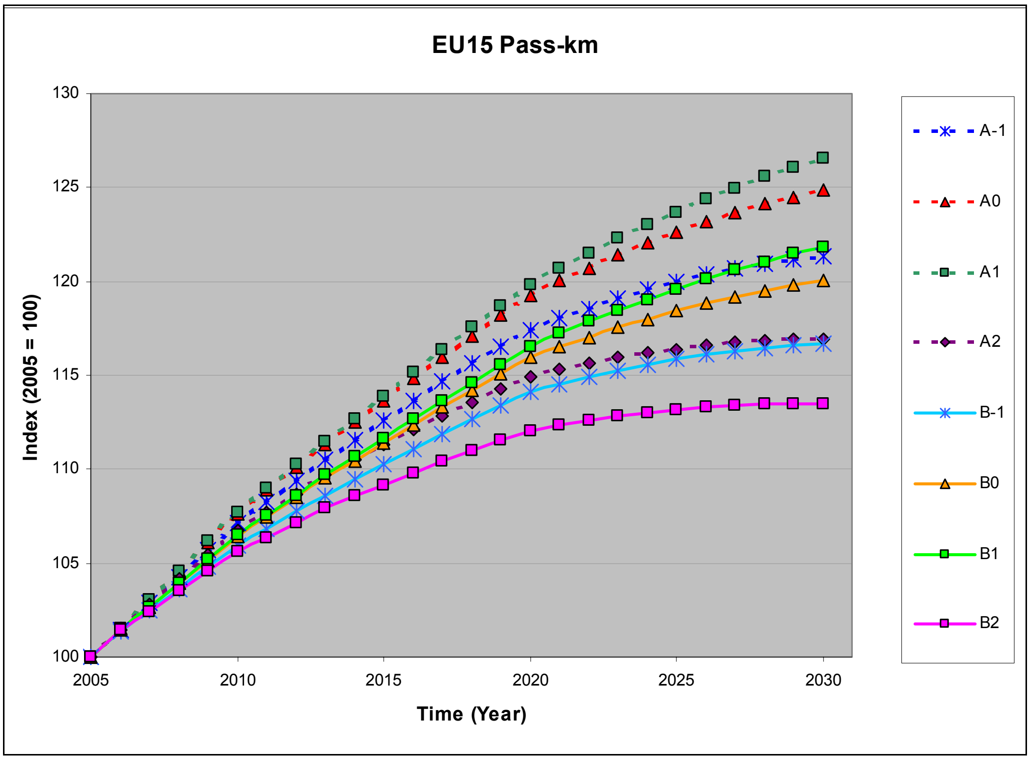


Figure 4.2.10 Pass-km index development for EU15 (2005 = 100)

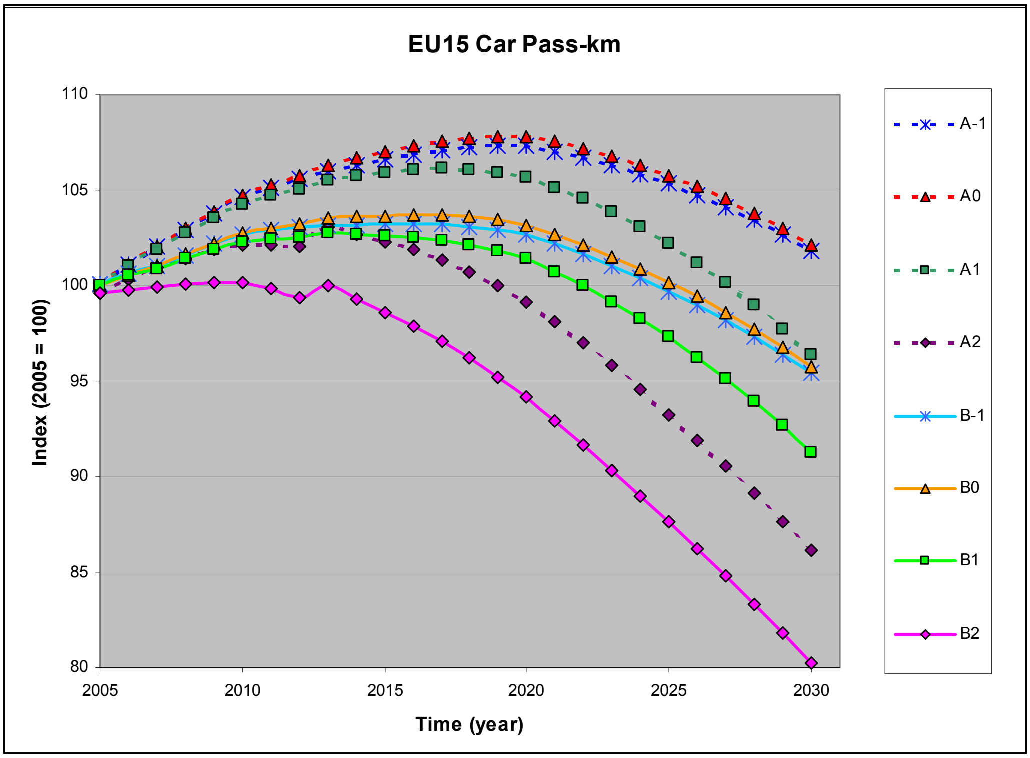


Figure 4.2.11 Car Pass-km index development for EU15 (2005 = 100)

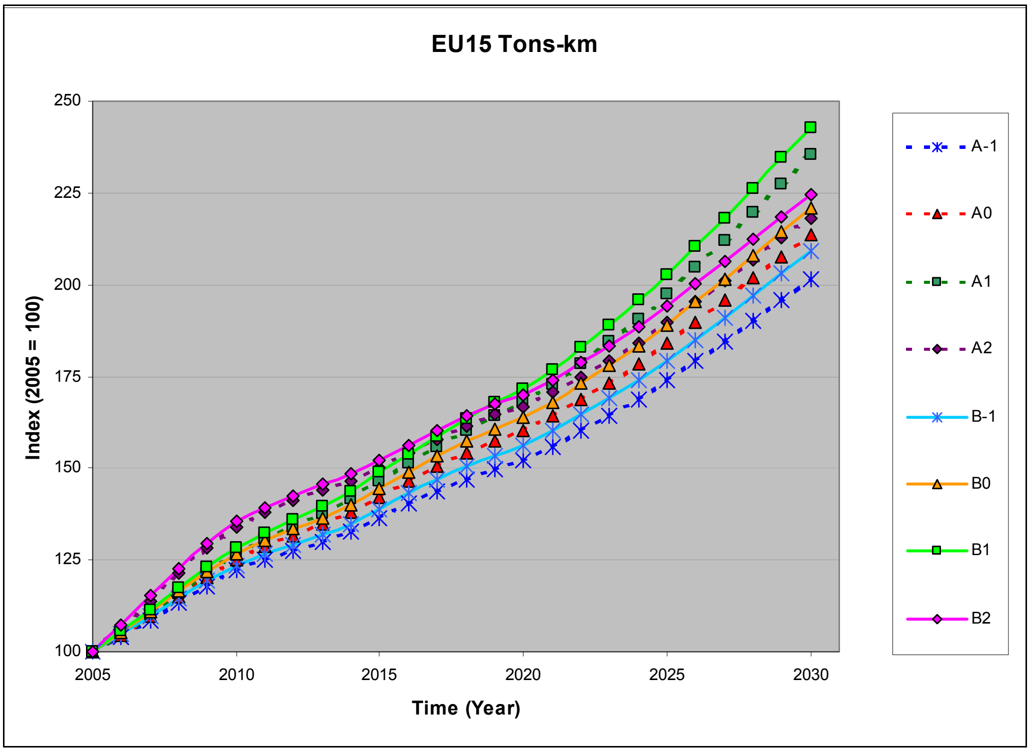


Figure 4.2.12 Tons-km index development for EU15 (2005 = 100)

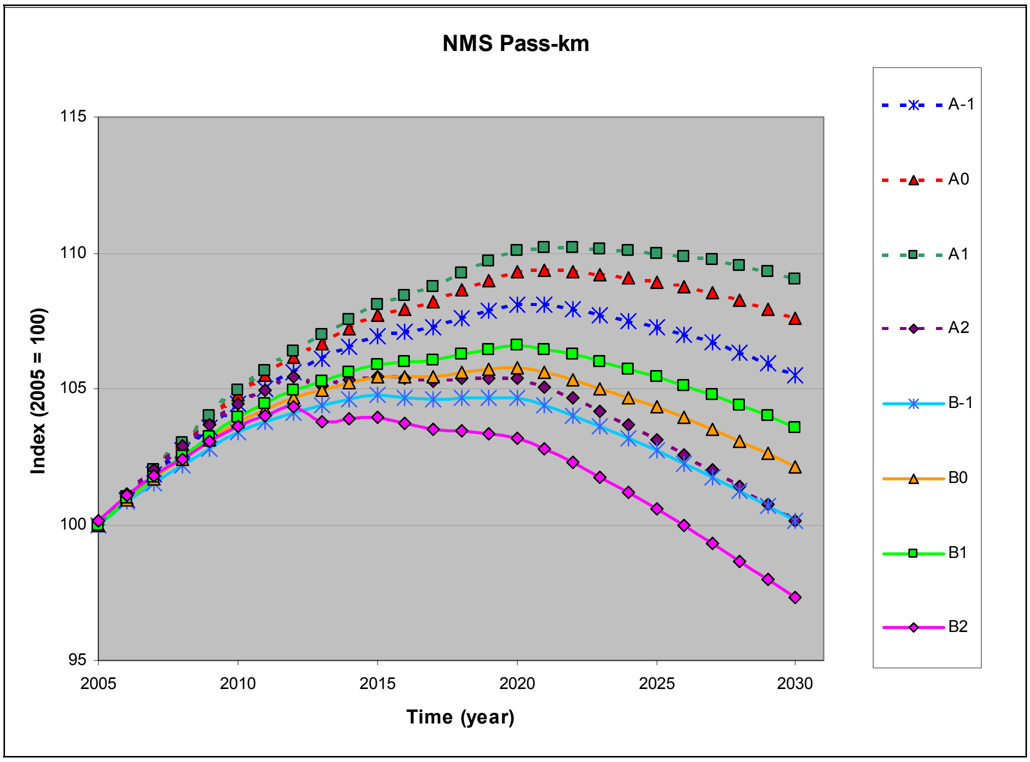


Figure 4.2.13 Pass-km index development for NewEU10 (2005 = 100)

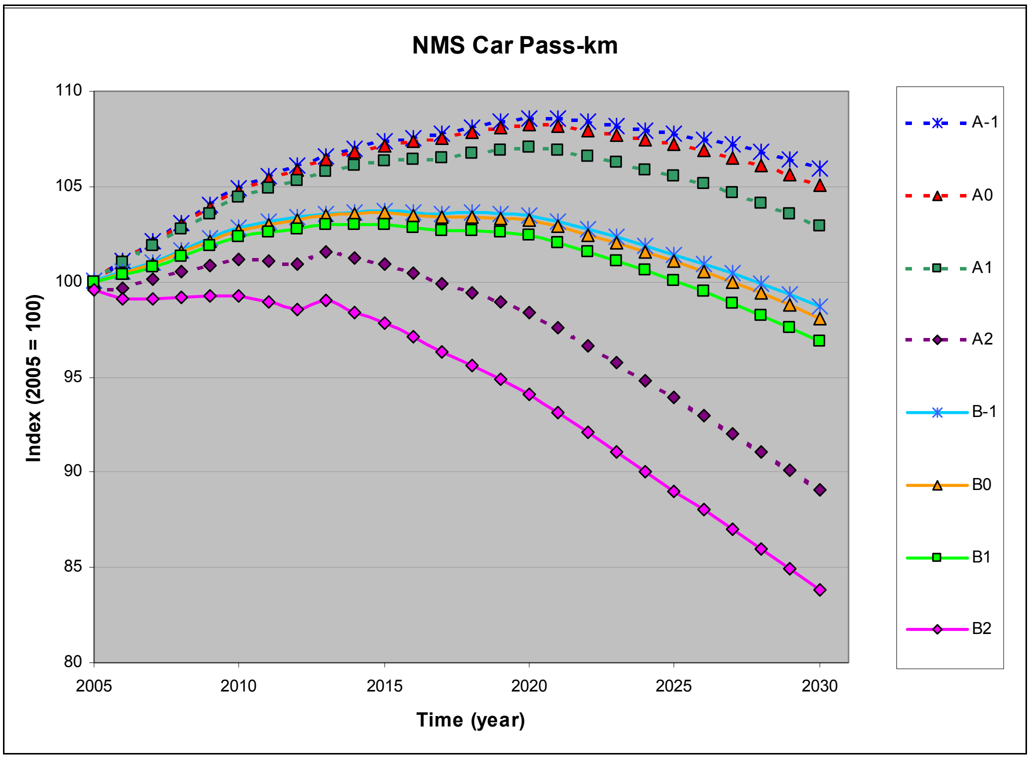


Figure 4.2.14 Car Pass-km index development for NewEU10 (2005 = 100)

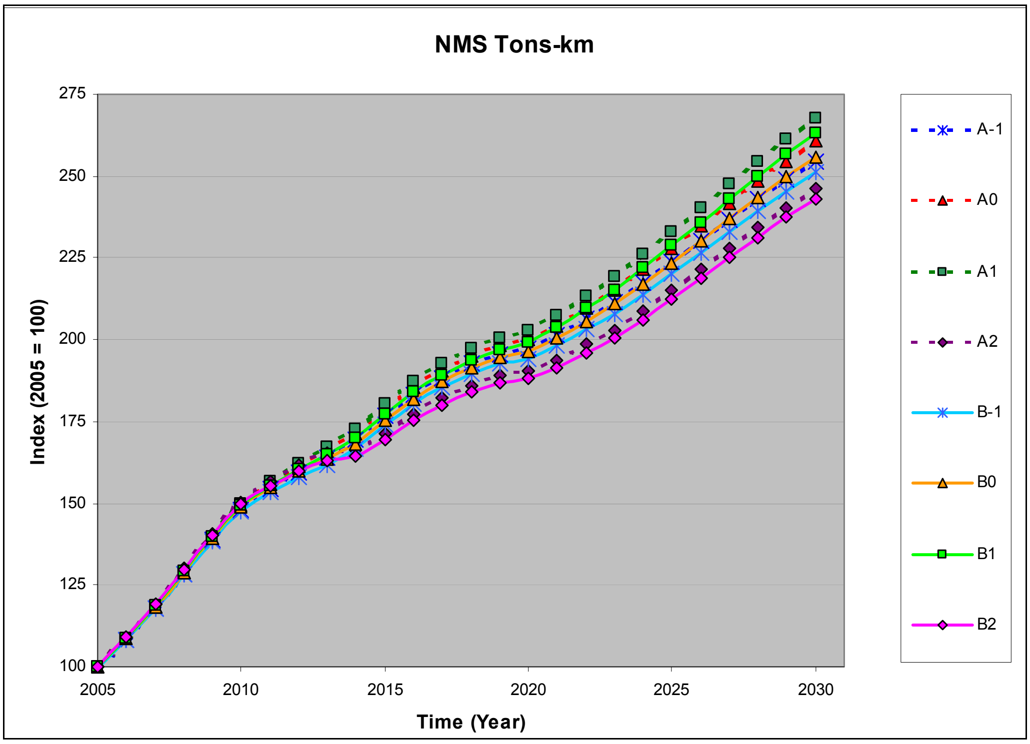


Figure 4.2.15 Tons-km index development for NewEU10 (2005 = 100)

Freight mode shares

Table 4.2.3 and the following graphs show mode shares of freight modes in the different scenarios. Road freight share is forecast to fall from about 55% in 2005 to 48% in the A0 scenario. This result goes upstream with respect to the No-Policy scenarios, where an increase of the road share (up to 59%) is expected. So, while on the passenger side just the trend of the fuel price is expected to produce a reduction of road private demand, on the freight side the attractiveness of road is not dampened down as effect of more expensive fuels. Even in the B-1 scenario, where the fuel price growth faster, at the year 2030 road freight has a higher mode share than in 2005. Actually, an impact of the fuel price dynamics can be observed as just at the beginning of the simulation period, when a price shock is simulated, the road freight share increases slightly in both A-1 and B-1 scenarios and only lately it goes beyond the base year level. However, when policy measures are added, road freight mode share is finally reduced. The effect is especially visible in the demand regulation scenarios (A2/B2), where the shift from road to other modes is stronger than in other scenarios.

Table 4.2.3 ASTRA model: Modal shares of freight modes at 2030 in the STEPs scenarios

Geo	Mode	2005	2030							
			A-1	A0	A1	A2	B-1	B0	B1	B2
EU25	Road	55%	59%	48%	44%	39%	57%	46%	43%	39%
	Rail+IWW	17%	14%	21%	26%	27%	15%	23%	27%	27%
	Ship	28%	27%	31%	30%	34%	28%	31%	30%	34%
	Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
EU15	Road	56%	61%	48%	43%	37%	58%	45%	41%	37%
	Rail+IWW	14%	11%	18%	24%	24%	12%	20%	25%	24%
	Ship	30%	28%	34%	33%	39%	29%	35%	34%	39%
	Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
New EU10	Road	47%	50%	40%	37%	26%	46%	37%	35%	25%
	Rail+IWW	34%	37%	46%	48%	59%	40%	49%	51%	61%
	Ship	19%	14%	14%	14%	15%	14%	14%	14%	15%
	Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Others	Road	38%	39%	34%	33%	24%	38%	32%	31%	22%
	Rail+IWW	8%	8%	11%	13%	22%	9%	13%	15%	23%
	Ship	54%	52%	54%	55%	55%	53%	54%	54%	54%
	Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

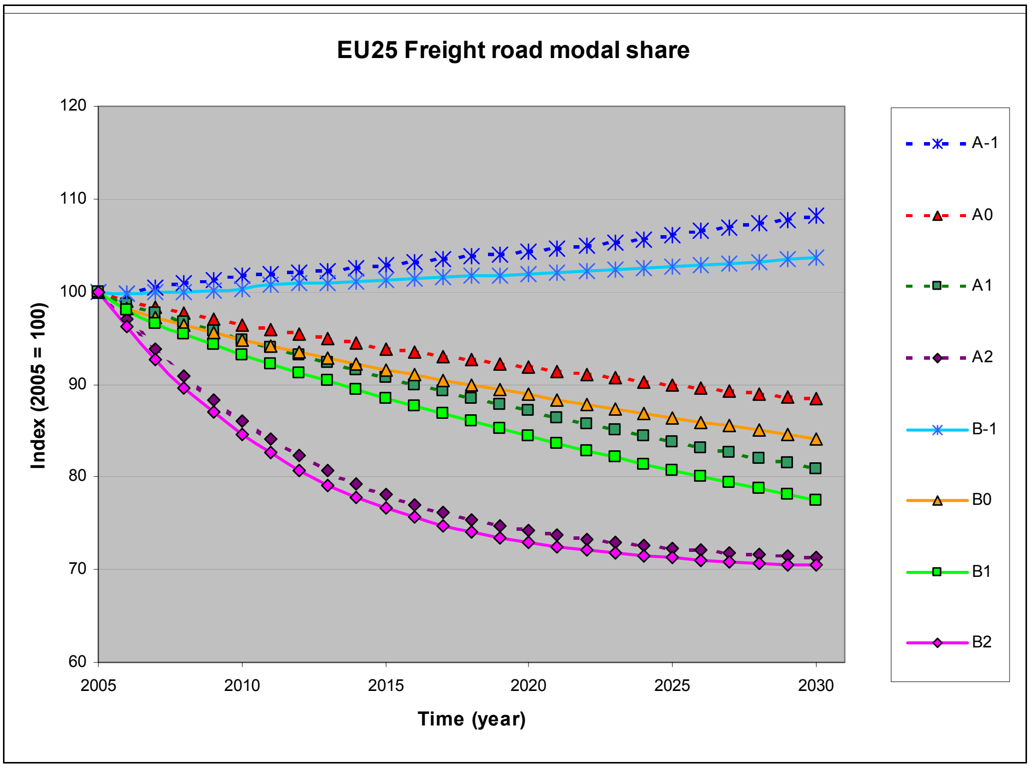


Figure 4.2.16 Freight road modal share index development for EU25 (2005 = 100)

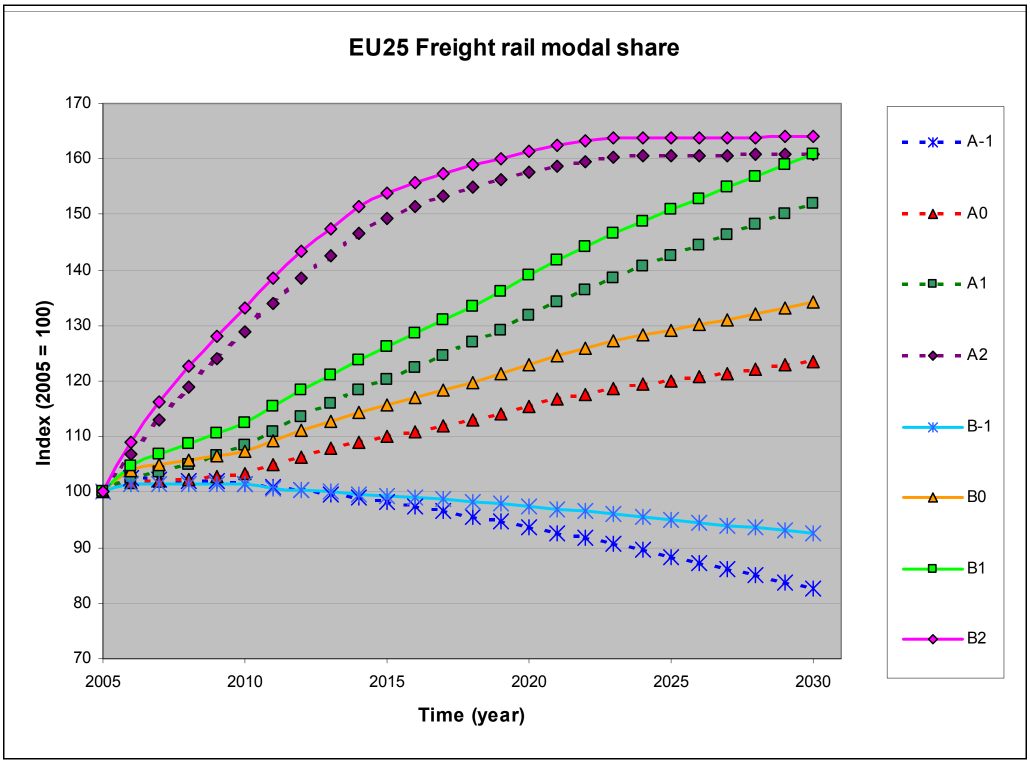


Figure 4.2.17 Freight rail modal share index development for EU25 (2005 = 100)

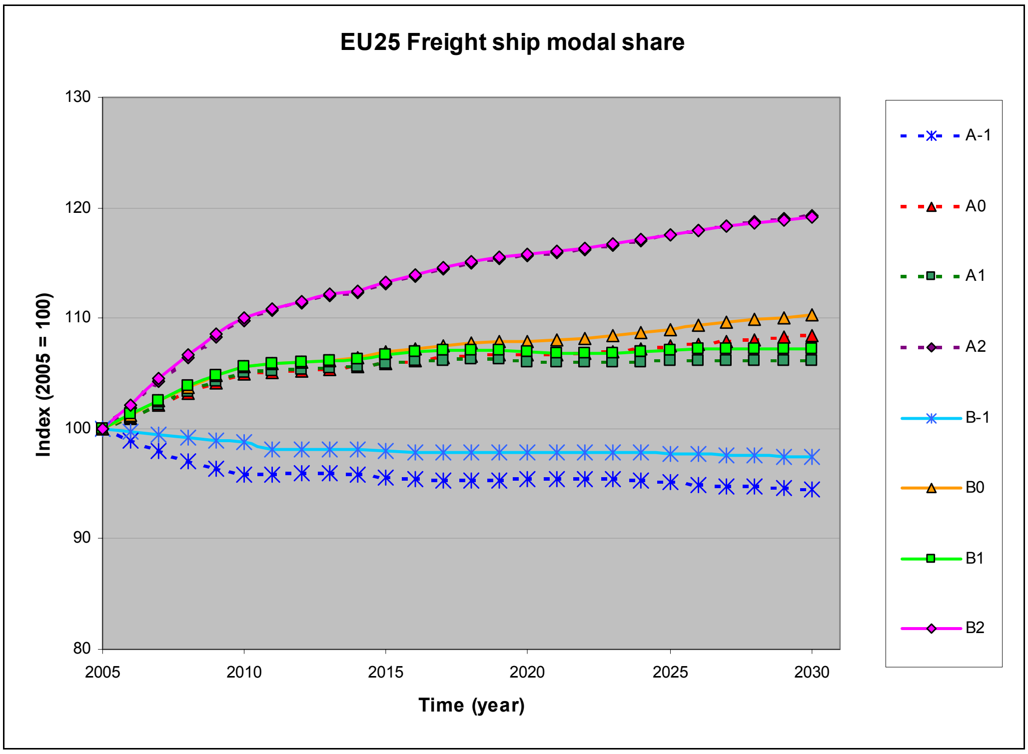


Figure 4.2.18 Freight ship modal share index development for EU25 (2005 = 100)

Environment

Main results provided by ASTRA on the environmental side concern transport emissions. The following figures show that emissions are generally declining in all policy scenarios, the A0 scenario inclusive, although in the policy scenarios 1 and 2 the reduction is sharper. The only exception is the case of CO_2 emissions, for which an increase is foreseen in the No-Policy scenarios. The growth is larger in the A-1 scenario (0.7% per year) than in the B-1 scenario (0.4% per year) and this suggests that pure contribution of oil price to the greenhouse emissions dynamics although not strong enough to reverse the growing trend, is able to almost halving the growth rate.

In the A0 scenario, transport emissions are reduced especially because of the renewal of car fleet. Cleaner vehicles with significantly lower unitary emissions off-set the increment of demand and, even more, give rise to lower total emissions. If fuel price increases faster, like in the B0 scenario, the total transport demand is lower (see transport section) and, in turn, also emissions are reduced.

Policies implemented in scenarios A and B contribute to a more intensive reduction of emissions. On this respect, demand regulation scenarios (A2 and B2) are more effective than technology investments scenarios (A1 and B1). In modelling terms this happens because the two kind of policies work mainly on two separate leverages: in the technology investments scenarios average unitary emissions are further reduced due to the introduction of innovative technologies in the vehicle fleet, whereas in the demand regulation scenarios average unitary emissions are not reduced but are applied to a lower amount of demand. In brief, the reduction of demand is comparatively higher than the reduction of unitary emissions and this explains why the total effect is larger in the demand regulation scenarios. Additionally, such scenarios also obtain to shift more demand from car and road freight to other modes, in this way adding a further contribution of the reduction of emissions.

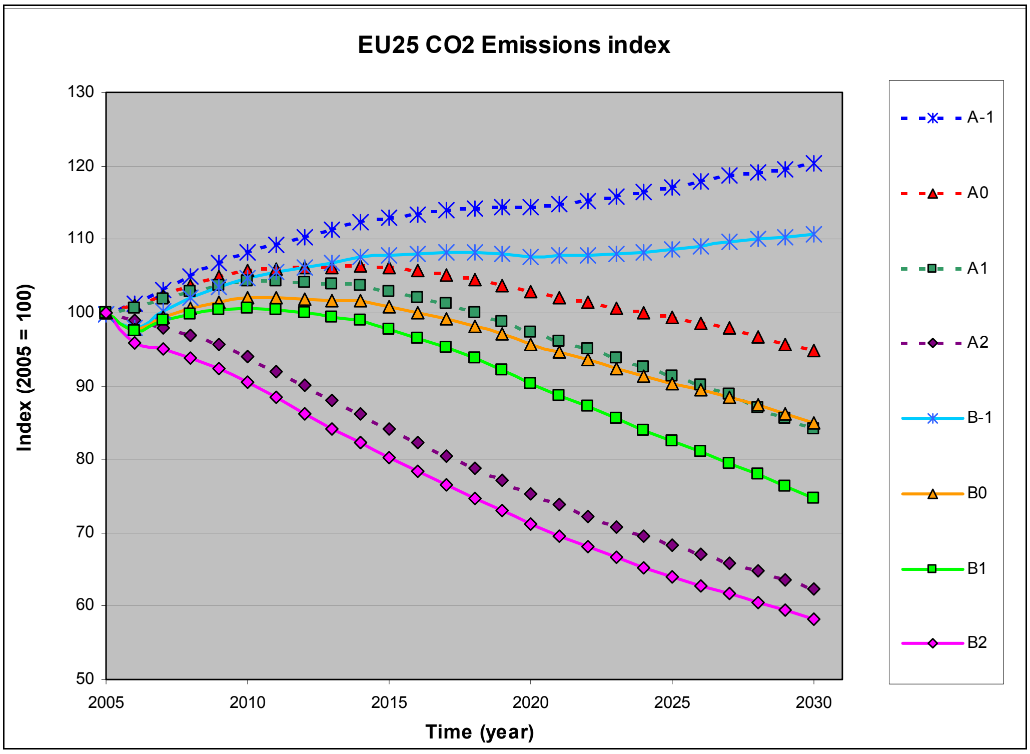


Figure 4.2.19 Emissions of CO_2 for EU25 in the STEPs scenarios

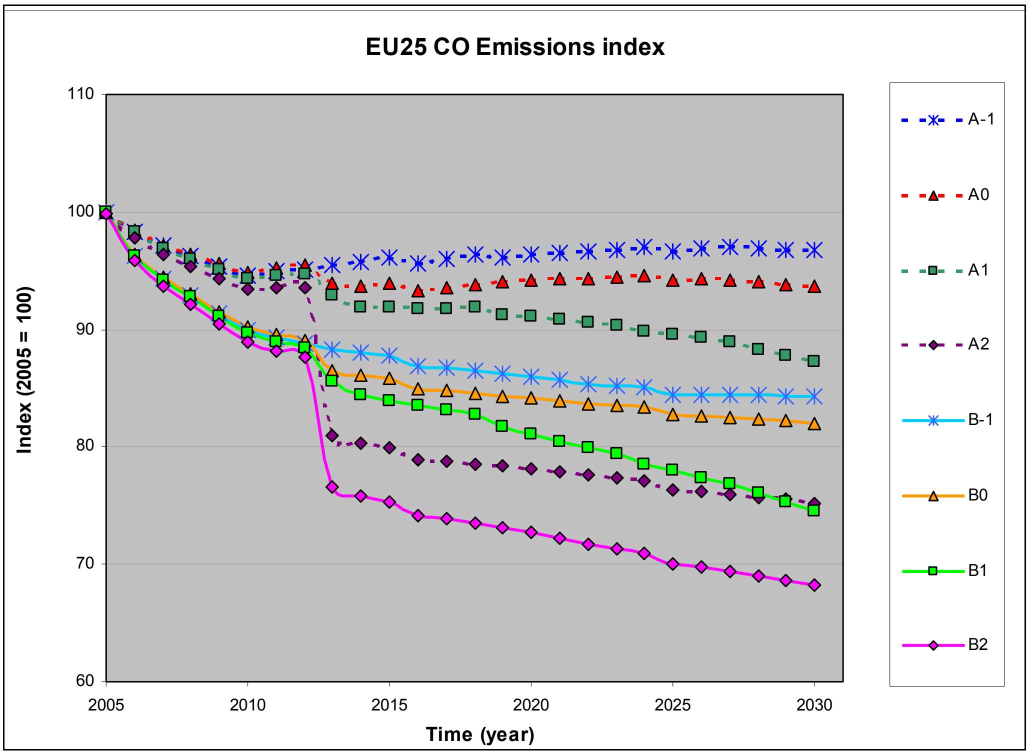


Figure 4.2.20 Emissions of CO for EU25 in the STEPs scenarios

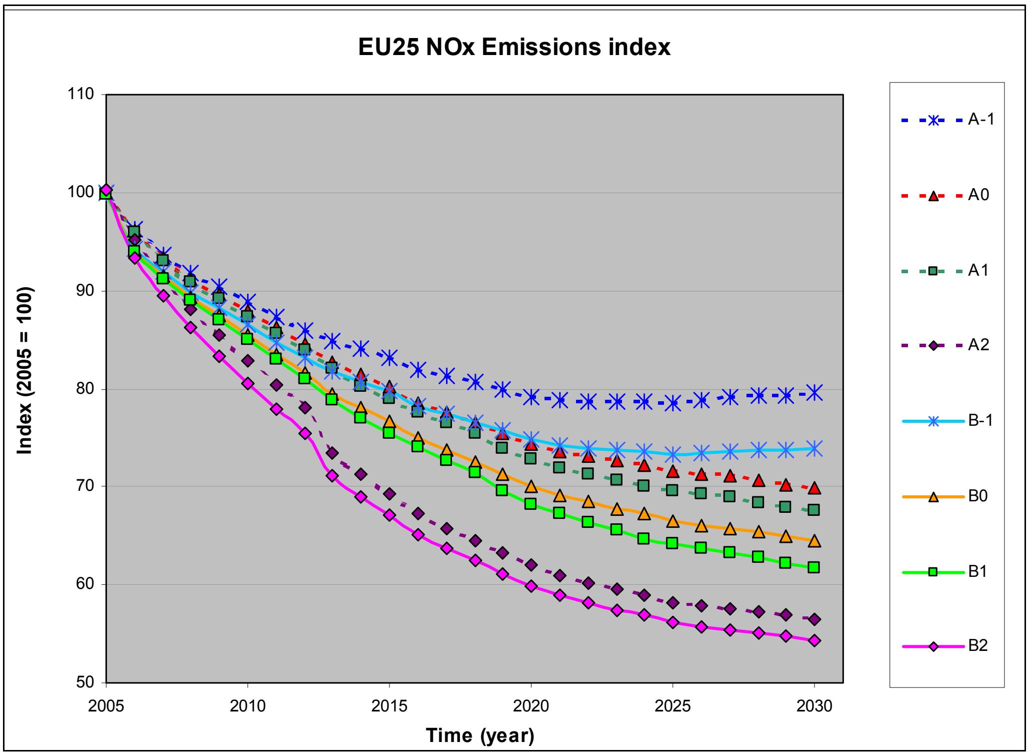


Figure 4.2.21 Emissions of NO_X for EU25 in the STEPs scenarios

4.2.4 Additional results from the ASTRA model

Figure 4.2.22 is focused on variations of employment in specific sectors where the impact of the scenarios are expected to be more significant. The graph represents the size of the employment changes at year 2030 with respect to the A0 scenario[11].

The most negative effect (in comparison to this case) on the employment takes place in the vehicles production sector, where in the B2 scenario the number of employed persons at the year 2030 is 17% lower than in the A0 scenario. The demand regulation scenarios (A2 and B2) are associated to negative impacts on the employment side for all the transport and energy related sectors, with the only exception of air/maritime transport services sectors. Instead, technology investments scenarios (A1 and B1) give rise to positive effects for the employment in the transport and energy sectors. If the high oil price growth assumption is applied (scenarios B), the effects on the employment side are generally worsened.

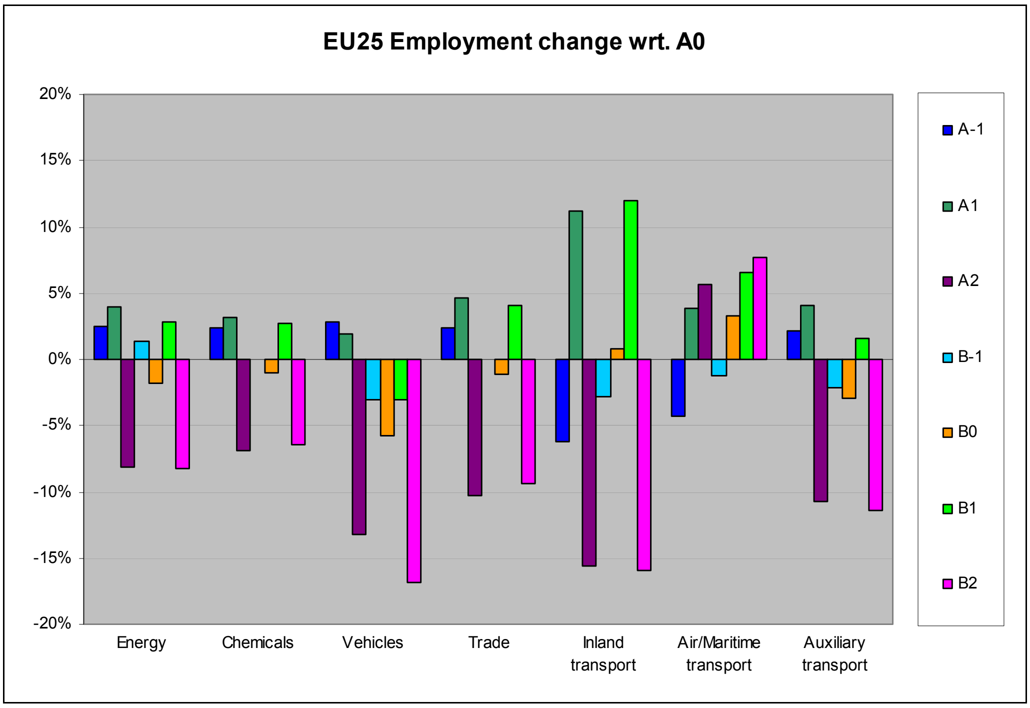


Figure 4.2.22 Variation of employment in EU25 at 2030 with respect to A0 scenario

Figure 4.2.23 is similar to Figure 4.2.22 but concerns consumption. Consumption include demand from households, industries and public sectors. This second graph shows that, in most cases, the impacts on consumptions are in line with the effects on employment: demand regulation scenarios (A2 and B2) have negative impacts for all sectors with the exception of air and maritime transport, while technology investments scenarios present better results. It should be remembered that consumption is measured in monetary terms

[11] As reported above, total employment is increasing in all scenarios and, in general, in all sectors. Thus negative values in the graph do not mean that employment will be lower than in the base year but that it will be growing less than in the A0 scenario.

and a price effect is present. For instance, the consumption of Air/Maritime transport services is lower in scenarios A1 and B1 than in the A0, but this does not mean necessarily that a lower ‘amount’ of services is purchased: if the unitary price of such services is reduced (and this is the case for scenarios examined) the monetary consumption will be lower, unless the price elasticity is higher than one.

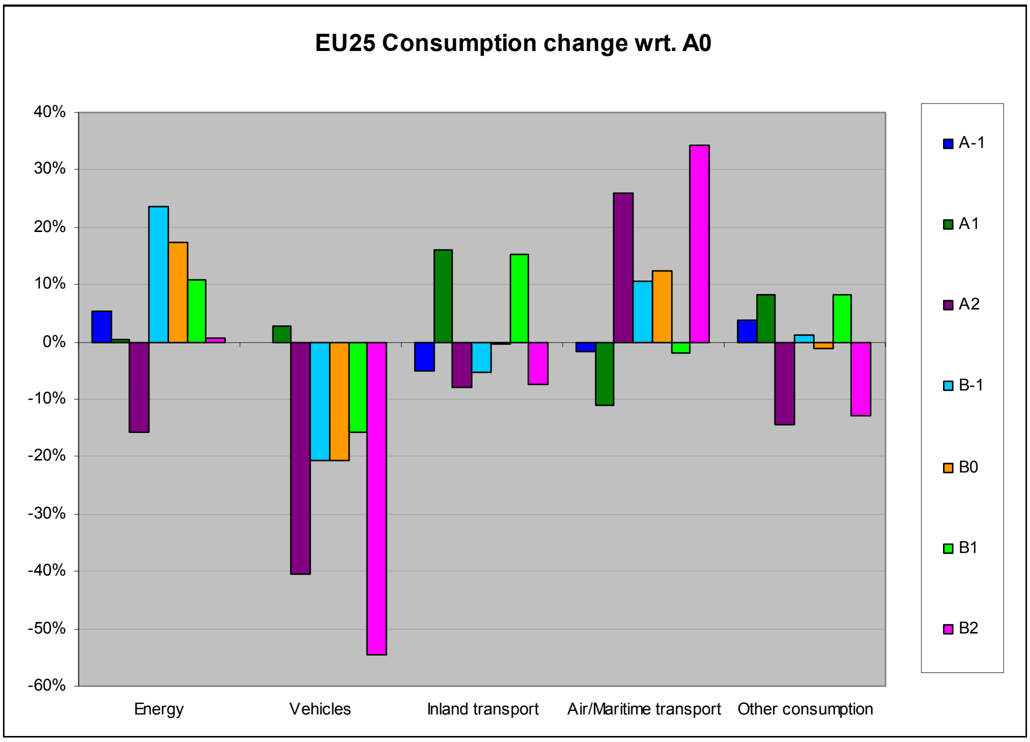


Figure 4.2.23 Variation of consumption in EU25 at 2030 with respect to A0 scenario

The changes of energy consumption show the price effect mixed to a demand effect. In the technology investments scenarios (A1 and B1), the price effect is prevalent and the higher cost of oil gives rise to an increase of energy consumption. The same happens in scenario B0, where the growth of the oil price is more significant and, without the action of specific policies, energy demand reveals a price elasticity lower than one (oil price and fuel price grow much more than the 17%, this means that oil and fuel price demand is reduced by the higher prices, but less than proportionally). In scenario A2, the policies simulated cause a further reduction of demand and the net effect is a lower amount of energy demand in monetary terms. In scenario B2, policy measures are the same as in scenario A2, but oil and fuel prices grow much more and thus off-set the effect on the demand side.

4.3 The POLES model results

4.3.1 The POLES model

The POLES energy model structure follows a hierarchical system of interconnected modules at three level of analysis: i) international energy markets; ii) regional energy balances and iii) national energy demand, new technologies, electricity production, primary energy production systems and CO_2 emissions per sector.

The dynamics of the model corresponds to a recursive process where energy demand and supply in each national/regional module respond with different lag structures to international prices variations in the preceding periods. In each module, behavioural equations take into account the combination of price effects and of techno-economic constraints, time lags or trends.

While the simulation of the different energy balances allows for the calculation of import demand and export capacities by region, the horizontal integration is ensured in the energy markets module, the main inputs of which are import demand and export capacities of the different regions. Only one world market is considered for the oil market (the 'one great pool' concept), while three regional markets (America, Europe, Asia) are identified for coal, in order to take into account for different cost, market and technical structures. Natural gas production and trade flows are modelled on a bilateral trade basis, thus allowing for the identification of a large number of geographical specificities and the nature of different export routes. The comparison of import and export capacities and the changes in the Reserves/Production ratio for each market determines of the variation of the prices for the subsequent periods.

The IPTS transport technologies module of POLES is used to describe the dynamics of the passenger car market and the introduction of new technologies in the sector. The model simulates the way that consumer choices concerning passenger cars are influenced by changes in car and fuel prices, technological development and general socio-economic trends.

Transport demand in the model is also affected by the fluctuations of fuel prices, GDP growth, the general trends of increased transport intensity, and the changes in the costs for each market segment. Combining the projected demand, the breakdown of the car park in technologies, and the expected efficiency for each technology in each generation, the model provides an outlook for fuel consumption and CO_2 emissions for each country, as well as for each of the market segments covered.

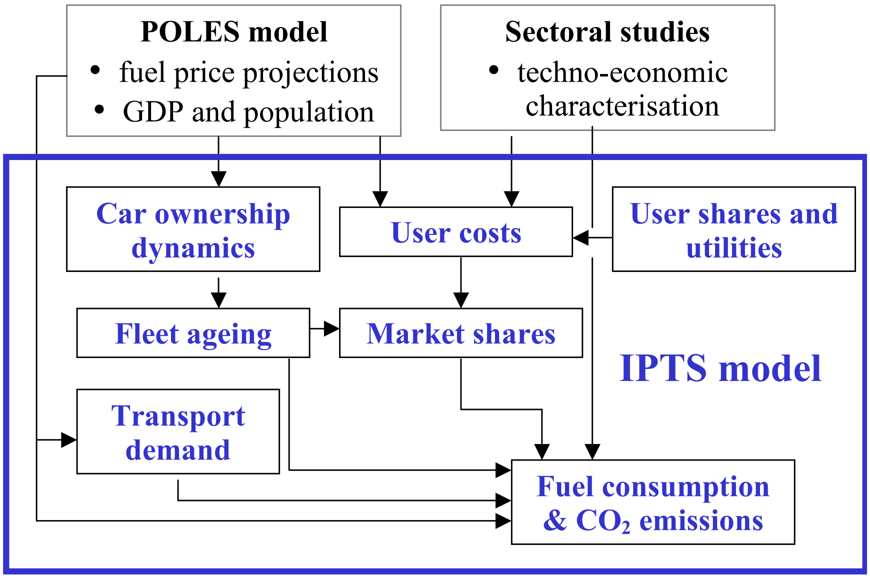


Figure 4.3.1 IPTS transport technology module of POLES

4.3.2 Implementation of the scenarios in the POLES model

Scenarios values for POLES model could be summarized in Table 4.3.1. POLES is an energy model which deals with energy supply and demand market and it's able to forecast the energy prices variations as well as the fuel prices changes. Considering this capacity as an advantage, several modifications have been applied to the scenarios values especially those related to the oil and fuel price changes.

Furthermore, the 7% yearly growth of oil price value planned to be applied for the high oil price growth scenarios is as well abandoned. The initial objective of applying this growth percentage is to simulate an exogenous shock as a proxy for the reduced energy supplies. However, transportation and other sectors would be willing to buy petrol only up to certain price level. In higher levels, there will be a shift to other technologies and fuels or there will be some behavioural changes, e.q. drive less or burn less oil for heating or industry. POLES model optimises the energy markets by finding a price-demand equilibrium based on the available energy supply every year. The real price growth after the equilibrium is then lower than the shock planned. Instead of using 7% yearly growth in the high oil price growth scenarios, POLES applies 30% growth in the year 2006 and 4% yearly growth for the rest of the observed period. These values are obtained by the internal simulation of market equilibrium against oil price shock in POLES model. Overall modifications of scenarios value could be seen in Table 4.3.2.

Table 4.3.1 Scenarios values for POLES

		Business as usual	Technology investments	Demand regulation
		Scenario A0	**Scenario A1**	**Scenario A2**
Low oil price growth scenarios Gas and oil prices grow by 2% per year, or 50% until 2030.	Fuel taxes:	gasoline+0.7%/year diesel +1.5%/year	As Scenario A0	gasoline+4.7%/year diesel +4.7%/year
	Efficiency:	Car diesel -1%/year Car gasoline –0.5%/year	Car diesel -3%/year Car gasoline –2%/year	As Scenario A0
		Scenario B0	**Scenario B1**	**Scenario B2**
High oil price growth scenarios Gas and oil prices grow by 7% per year, or 300% until 2030.	Fuel taxes:	as Scenario A0	as Scenario A1	as Scenario A2
	Efficiency:	as Scenario A0	as Scenario A1	as Scenario A2

Gas and oil prices growths from scenarios A and B, as well as growths from the application of taxes in demand regulation scenarios, are used directly in POLES as multipliers to the oil price of the A0 scenario. The difference of oil price in each scenario in comparison with the oil price of A0 scenario are then used as a variable which is taken into account when the model calculates new cars registration, fleet size, fleet share, mileage and the fuel consumption. The fuel consumption change; fuel consumption in each scenario compared to the A0 scenario fuel consumption, is in its turn taken into account in calculating the difference of the oil price, the fuel and the gasoline price in the following year. An example of oil price differences for Austria is presented in Figure 4.3.2. The B2 scenario has the strongest oil price development. It is due to the high oil price growth assumption (30% raise in 2006 and 4% yearly increase until 2030) and the yearly 4.7% tax in the demand regulation assumption.

Scenarios A-1 and B-1 are not significantly different from scenarios A0 and B0 from the point of view of the POLES model as the difference between the two pairs consist of the policy measures that are not modelled in POLES. Therefore, such two scenarios have not been implemented in the models.

Table 4.3.2 POLES adaptation of scenarios' values

		Business as usual	Technology/infrastructure	Demand regulation
		Scenario A0	**Scenario A1**	**Scenario A2**
Optimistic scenario Gas and oil prices grow by 1% per year, or 25% until 2030. (POLES' BAU)	Fuel taxes:	POLES' BAU	As Scenario A0	gasoline+4.7%/year diesel +4.7%/year
	Efficiency:	POLES' BAU	Car diesel -3%/year Car gasoline –2%/year	As Scenario A0
		Scenario B0	**Scenario B1**	**Scenario B2**
Worst-case scenario Gas and oil prices grow by 30% in 2006 followed by 4% per year (POLES output)	Fuel taxes:	as Scenario A0	as Scenario A1	as Scenario A2
	Efficiency:	as Scenario A0	as Scenario A1	as Scenario A2

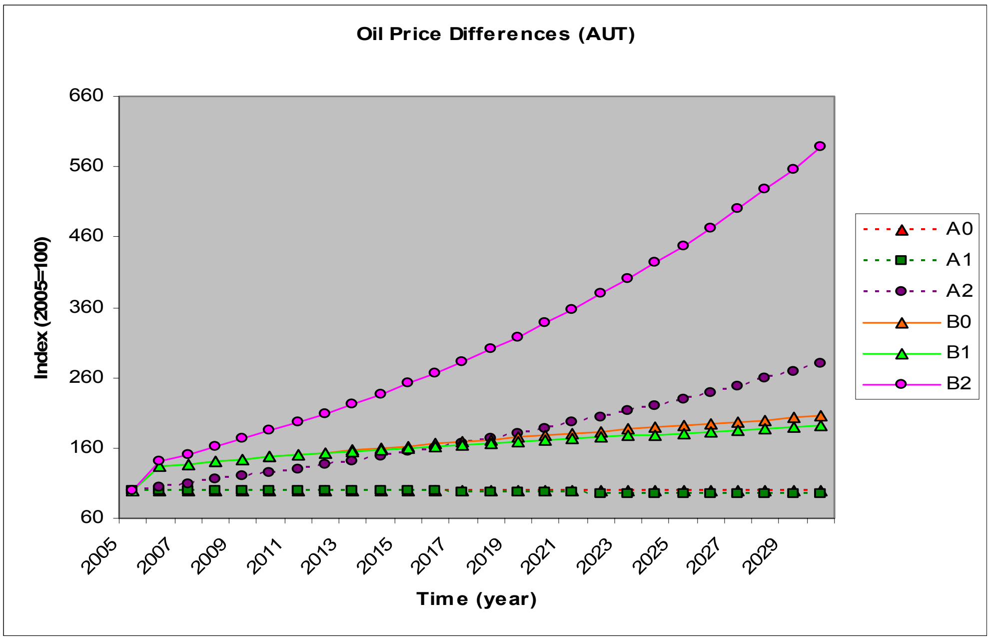


Figure 4.3.2 *Oil price differences (case: Austria)*

4.3.3 Main results from the POLES model

Economy: fuels consumption and fuels prices

Fuel consumption (Figure 4.3.3) decreases in all the scenarios as the difference in the oil price develops faster with respect to the A0 scenario. Energy shortage represented in the high oil price growth scenarios (B scenarios) lowers down fuel consumption more significantly than the low oil price growth scenarios (A scenarios). Within both types of scenarios, it can be seen that the demand regulation, represented by 4.7% yearly tax on fuel price, is more effective in decreasing fuel consumption than technology investments. Furthermore, the scenarios impacts on fuel consumption in EU15 are generally stronger that those in New Member States.

POLES provides gasoline and diesel prices to the ASTRA. Excluding all taxes, resource fuels prices are shown in the next two figures with reference to EU25. It can be noted that when fuel taxes are excluded, resource cost of fuel in business as usual alternatives and demand regulation scenarios are very similar. Instead, figures above clearly show the gap in the fuels prices between the high and the low oil price growth scenarios. Within each type of scenarios, it can be seen that technology investments recorded in the A1 and B1 scenarios restraint slightly the growth of fuels prices. This is due to the less fuel demand and fuel consumption which then generate slightly lower price. One interesting point is that fuels prices develop slightly faster within the new member states. This should due to the less sensitive fuel consumption in the new member states towards the policy and technological measures applied by the scenarios. In average absolute values, fuels prices in EU15 are still higher than those in NMS (Table 4.3.3 and Table 4.3.4).

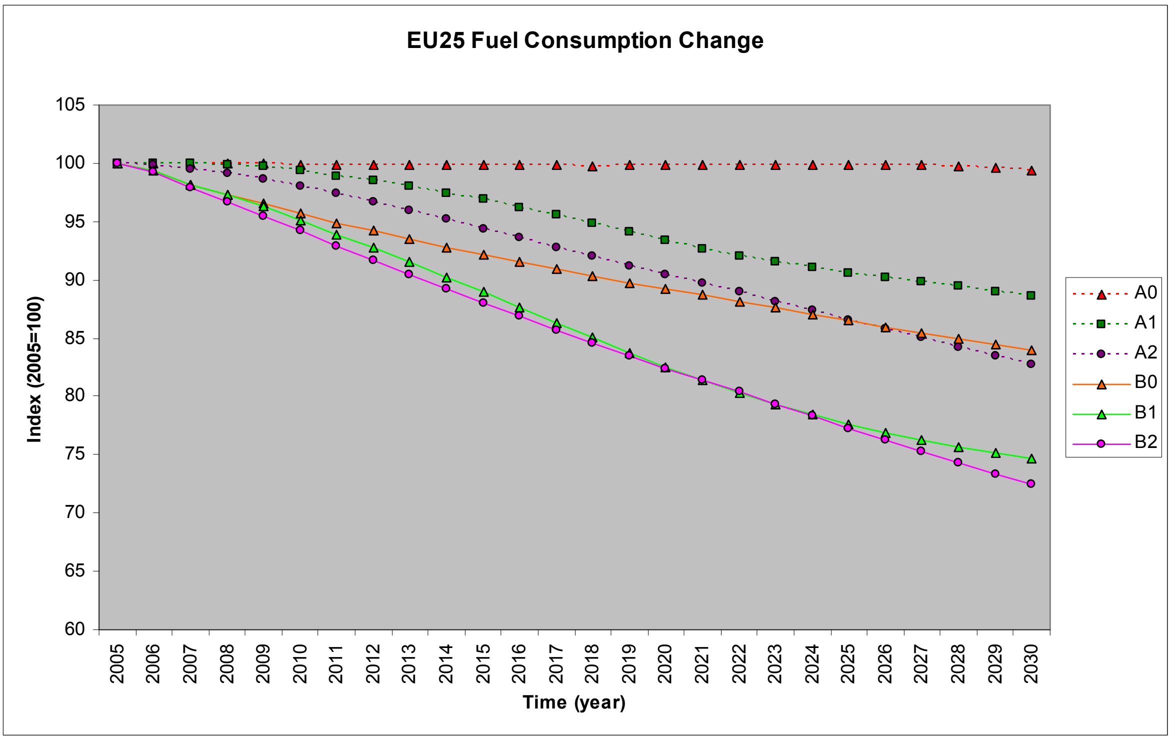


Figure 4.3.3 Average Fuel Consumption Change for EU 25 (2005=100)

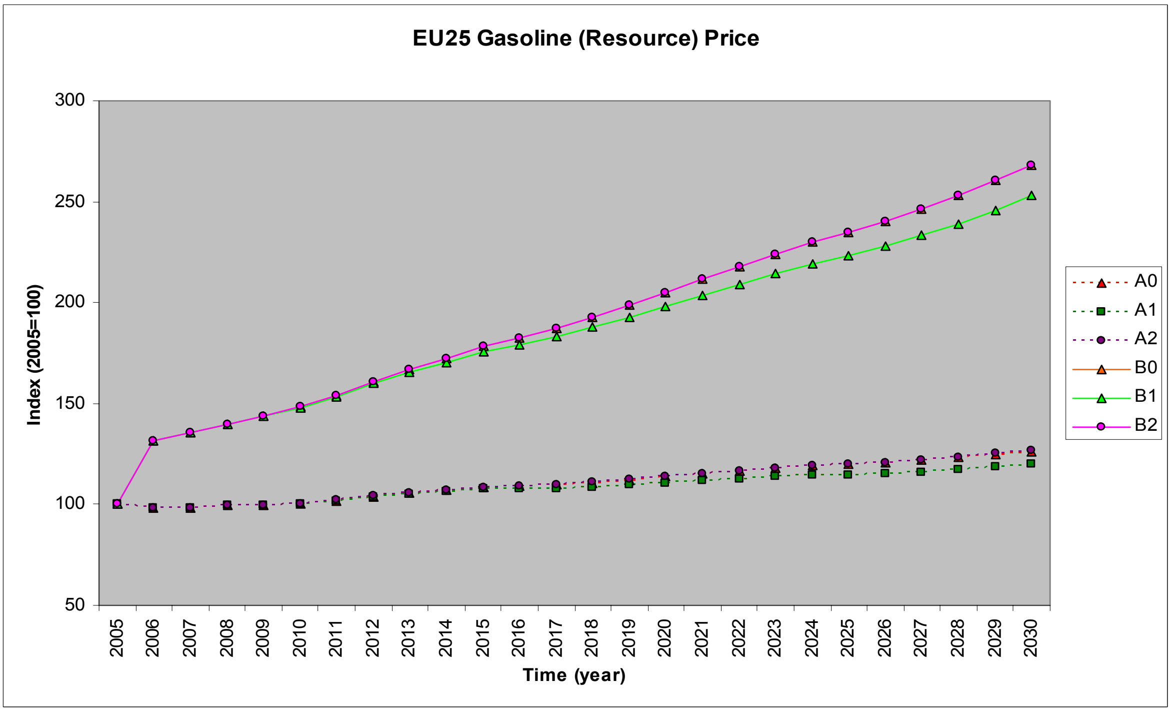


Figure 4.3.4 Average gasoline (resource) price for EU 25 (2005=100)

Table 4.3.3 POLES model: Average gasoline (resource) price (euros/litre)

	2005	2010	2015	2020	2025	2030
			EU 15			
A0	0,434	0,435	0,469	0,491	0,517	0,543
A1	0,434	0,435	0,464	0,477	0,493	0,515
A2	0,434	0,436	0,470	0,492	0,518	0,546
B0	0,434	0,643	0,771	0,886	1,014	1,153
B1	0,434	0,641	0,759	0,854	0,959	1,084
B2	0,434	0,643	0,771	0,886	1,014	1,153
			NMS			
A0	0,330	0,334	0,363	0,382	0,405	0,430
A1	0,328	0,331	0,359	0,375	0,393	0,415
A2	0,328	0,332	0,362	0,381	0,404	0,430
B0	0,328	0,489	0,592	0,685	0,794	0,917
B1	0,328	0,488	0,587	0,673	0,773	0,885
B2	0,328	0,489	0,592	0,685	0,794	0,916

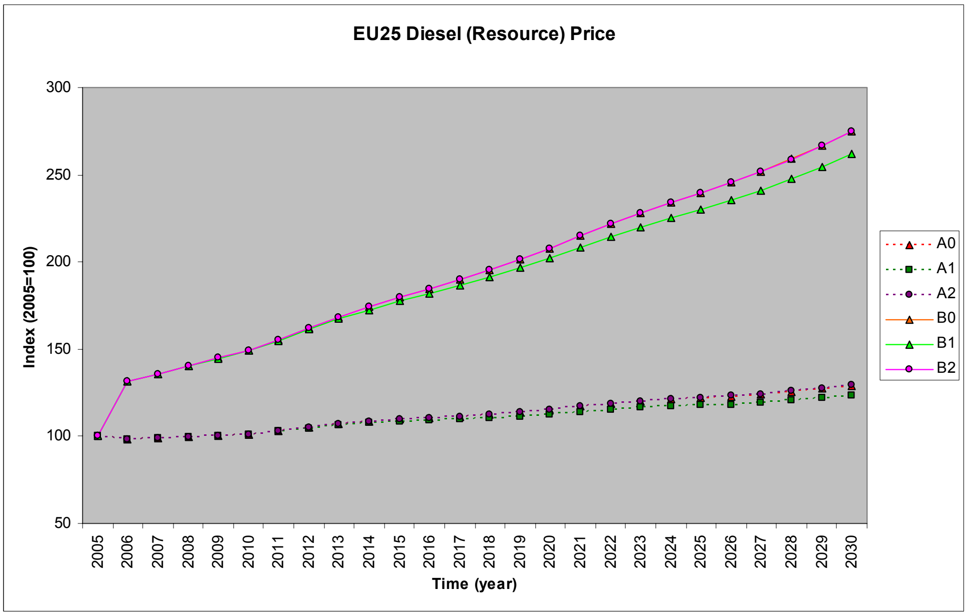


Figure 4.3.5 POLES model: Average diesel (resource) price for EU 25 (2005=100)

Table 4.3.4 POLES model: Average diesel (resource) price (euros/litre)

	2005	2010	2015	2020	2025	2030
EU15						
A0	0,424513	0,427061	0,459205	0,48002	0,504883	0,53024
A1	0,424608	0,427244	0,45474	0,466572	0,482072	0,502607
A2	0,424789	0,427931	0,460408	0,481297	0,506154	0,53309
B0	0,424774	0,631053	0,75491	0,867153	0,991224	1,125525
B1	0,424608	0,629938	0,743534	0,835489	0,937603	1,058167
B2	0,424789	0,631064	0,754868	0,867153	0,991201	1,125321
NMS						
A0	0,307604	0,312855	0,342114	0,361937	0,38456	0,409413
A1	0,305227	0,310029	0,337264	0,353209	0,371994	0,393563
A2	0,305312	0,310401	0,339895	0,359405	0,382229	0,407423
B0	0,305312	0,457561	0,556898	0,646899	0,752382	0,870614
B1	0,305227	0,457053	0,552559	0,635917	0,732258	0,841154
B2	0,305312	0,45755	0,556842	0,646766	0,752119	0,870133

Society

Car ownership increases significantly and durably in A0 and A1 scenarios, while it decreases strongly in the B2 scenario. Application of demand regulation measures in the A2 scenario decreases the car ownership level from around the year 2025. Scenarios B0 and B1 show relatively very little change for the whole period. Technological measures recorded in the scenarios 1 increase slightly the car ownership in comparison to the corresponding business-as-usual scenarios. This should due to the lower fuel price effect which is generated in the case of applying technological measures.

In absolute values, the new member states show lower level of car ownership than the EU15 (Table 4.3.5). However, the growth of car ownership level in New Member States is higher than in the EU15 in every scenario.

Table 4.3.5 POLES model: Car ownership per 1000 inhabitants

	1995	2000	2005	2010	2015	2020	2025	2030
EU15								
A0	425,7	481,5	514,3	546,3	575,7	602,2	626,4	641,3
A1	425,7	481,5	514,3	546,4	576,6	605,4	633,2	650,8
A2	425,7	481,5	514,3	531,6	530,8	519,7	503,8	488,2
B0	425,7	481,5	514,3	512,3	511,7	510,8	510,6	512,8
B1	425,7	481,5	514,3	512,4	512,6	514,0	516,6	521,0
B2	425,7	481,5	514,3	498,0	471,9	443,5	417,8	398,0
NMS								
A0	218,4	274,5	310,2	346,8	381,6	413,3	442,2	468,2
A1	218,4	274,5	310,2	346,9	382,2	415,3	446,5	475,3
A2	218,4	274,5	310,2	336,5	346,5	342,3	328,0	307,3
B0	218,4	274,5	310,2	322,4	329,6	331,6	329,6	324,9
B1	218,4	274,5	310,2	322,5	330,1	333,0	332,4	329,0
B2	218,4	274,5	310,2	312,8	299,3	275,6	248,5	222,4

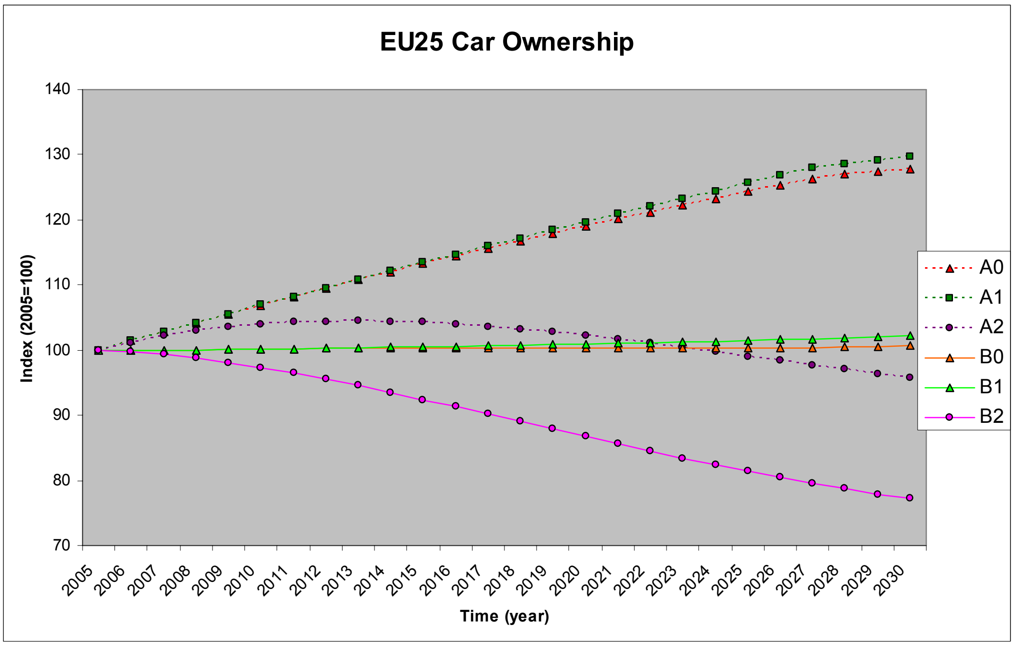


Figure 4.3.6 POLES model: Car ownership level for EU 25 (2005=100)

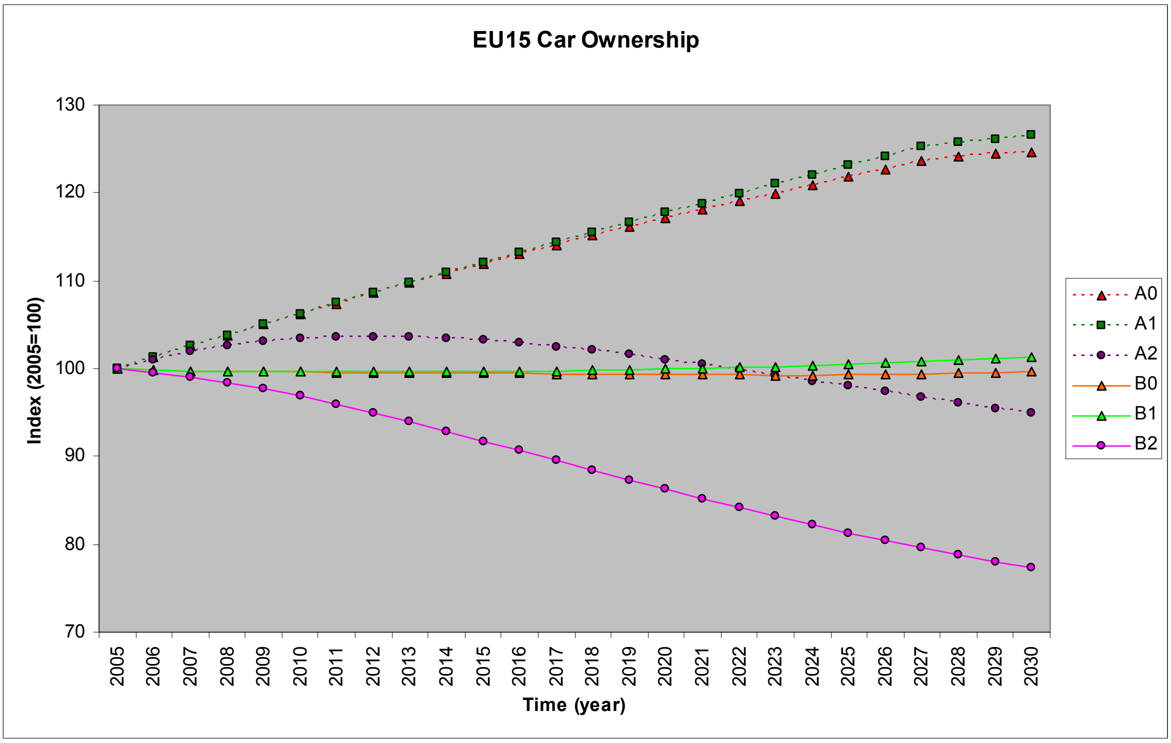


Figure 4.3.7 POLES model: Car ownership level for EU 15 (2005=100)

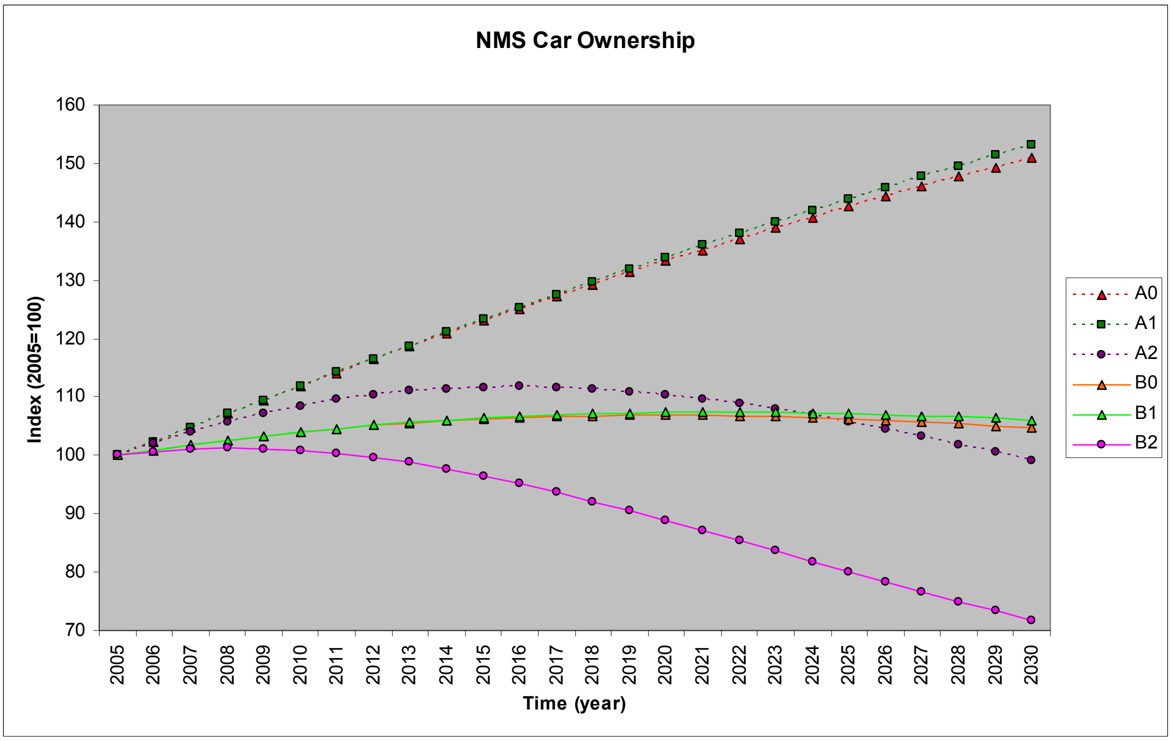


Figure 4.3.8 POLES model: Car ownership level for EU NMS (2005=100)

Figure 4.3.9 shows that total fleet evolutions do not have the same trends as those of car ownership. Fleet grows continuously in the low oil price growth scenarios and it decreases slightly in the high oil price growth scenarios. As for the car ownership level, the technological measures stimulate slightly faster growth in total fleet number. It is interesting to mention that the total fleet of the high oil price growth scenarios of the New Member States decreases more strongly in the observed period than that of EU15.

Diesel cars shares increase to a certain point in all scenarios (Figure 4.3.10). The application of technological measures in the B1scenario decreases significantly the diesel cars shares in the last decade of the observed period within EU15; as can be seen from Figure 4.3.11, the New Member States behave differently. It seems that the increasing fuel consumption efficiency doesn’t favour the development of diesel fuel price which in turn stimulate users to choose other types of car.

Innovative (electric, hybrid, natural gas, and fuel cell) cars shares increase continuously in all scenarios (Figure 4.3.12 and Figure 4.3.13). These increases are higher in EU15 countries than in the New Member States. The fastest increase can be found in the technology investments scenarios especially under the high oil price growth assumption.

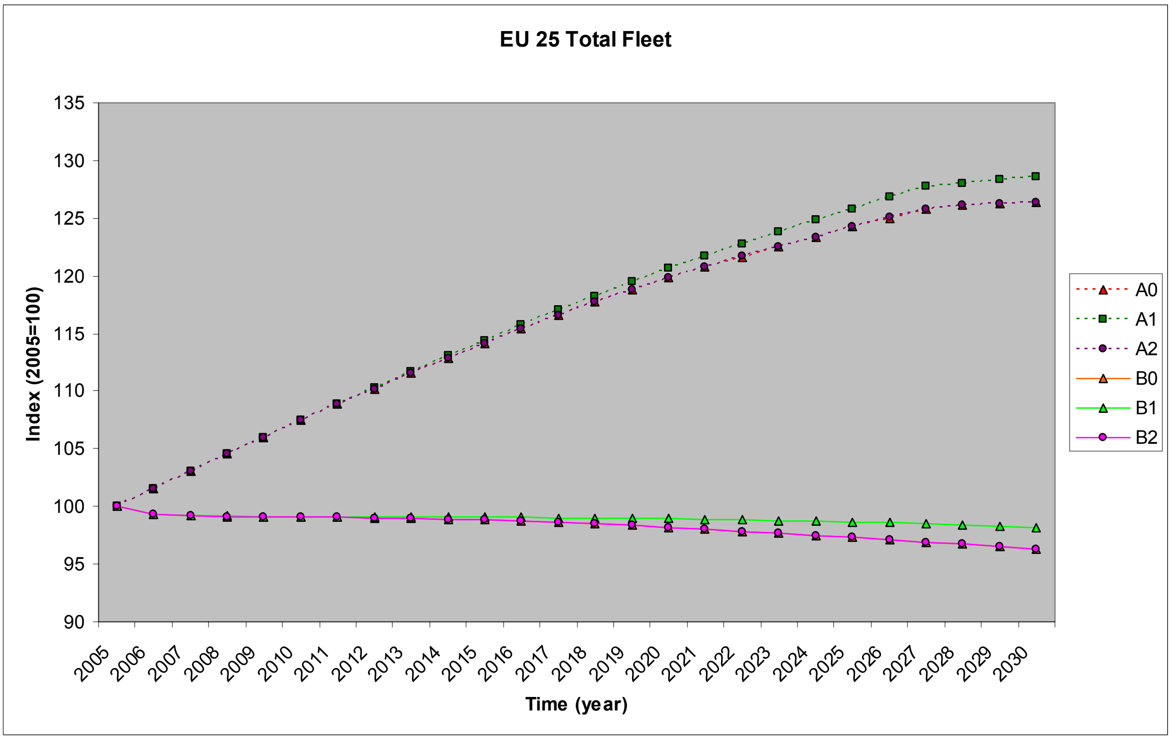


Figure 4.3.9 POLES model: Total fleet for EU 25 (2005=100)

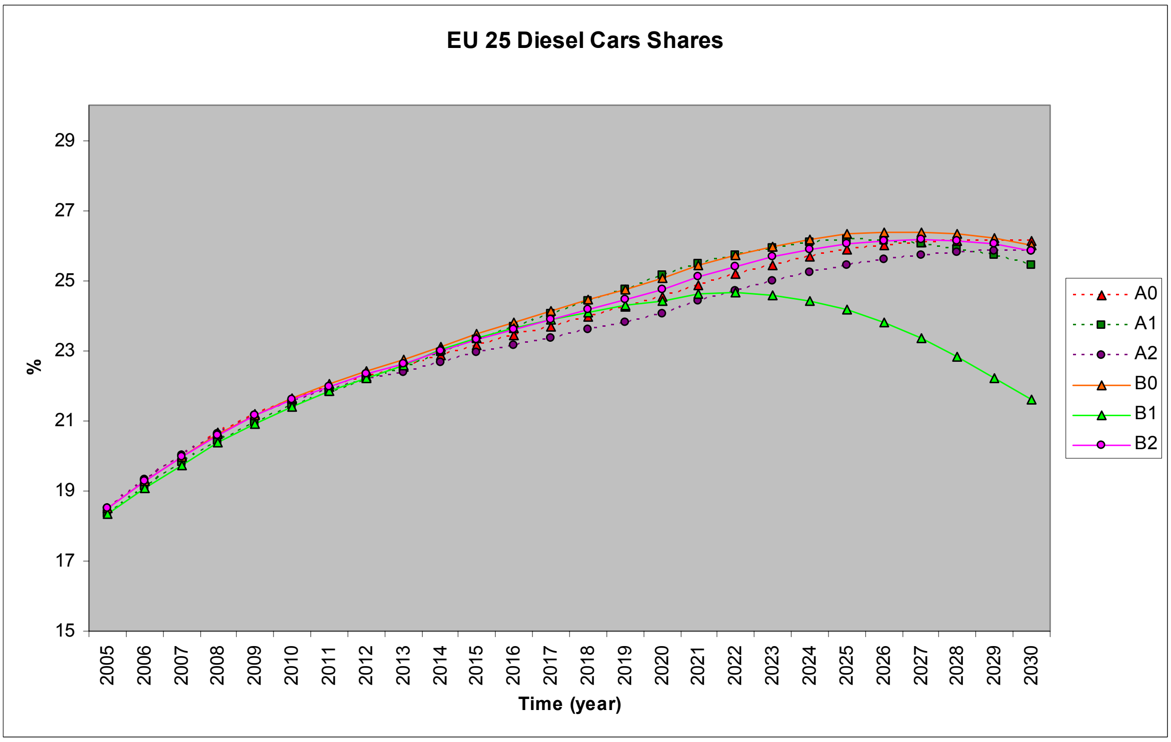


Figure 4.3.10 POLES model: Diesel cars shares (%) for EU 25 (2005=100)

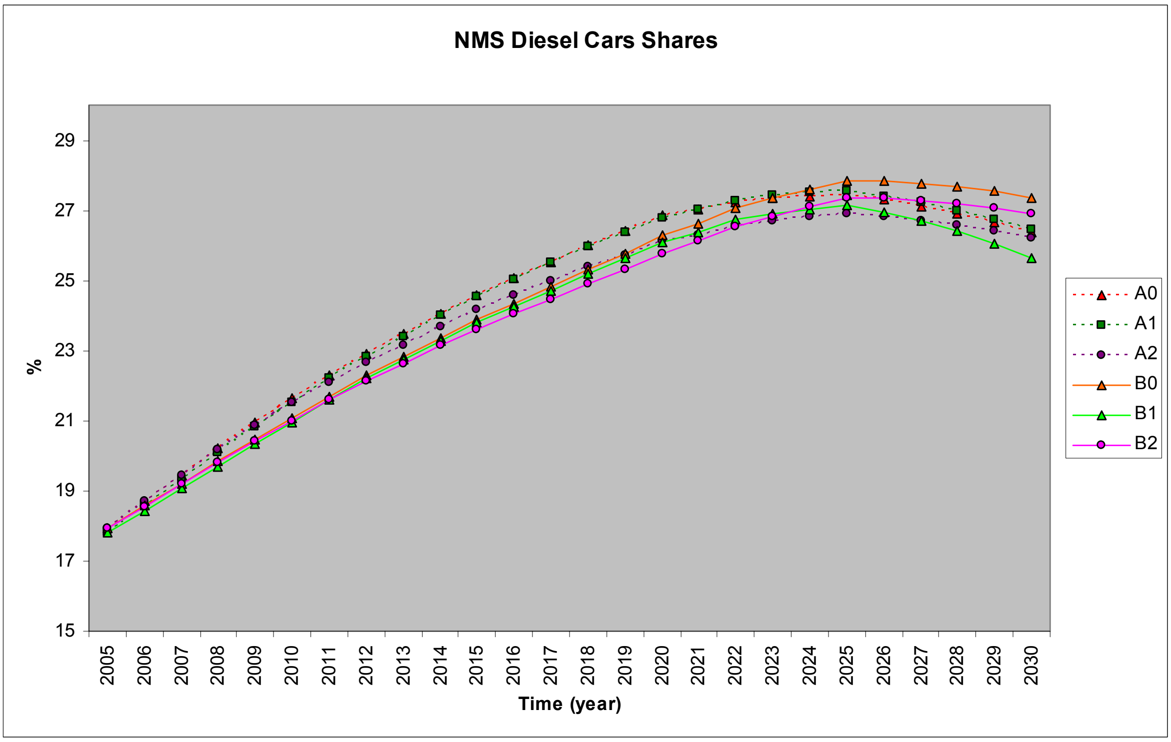


Figure 4.3.11 POLES model: Diesel cars shares (%) for NMS (2005=100)

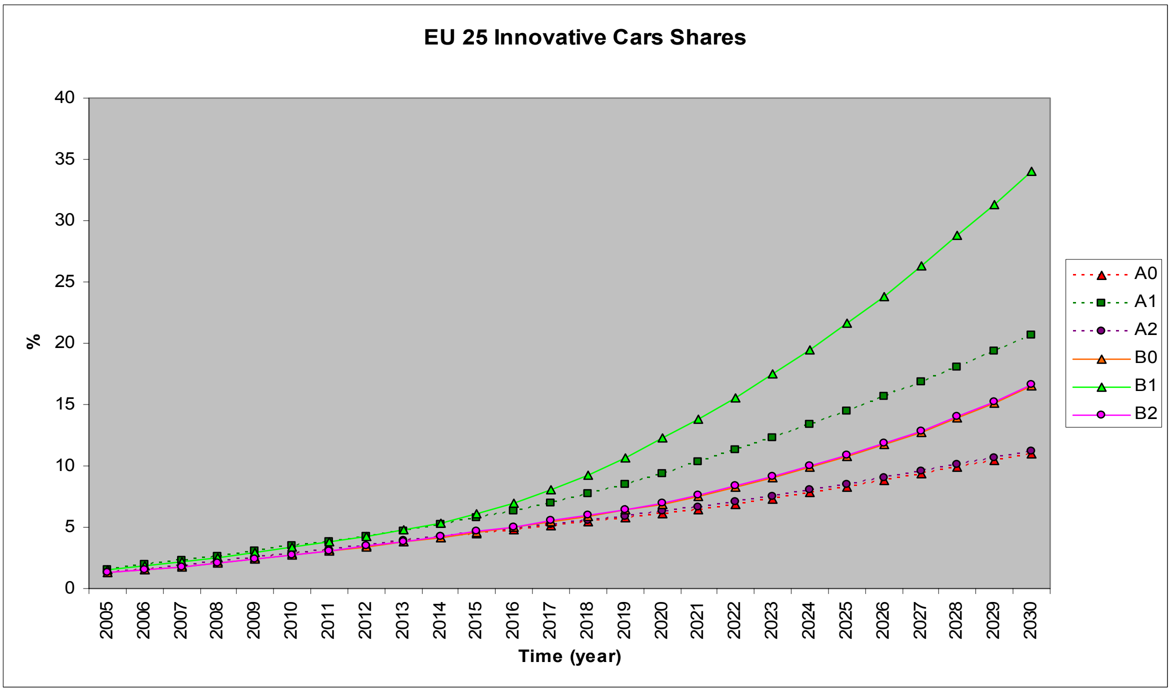


Figure 4.3.12 POLES model: Innovative Cars Shares (%) for EU 25

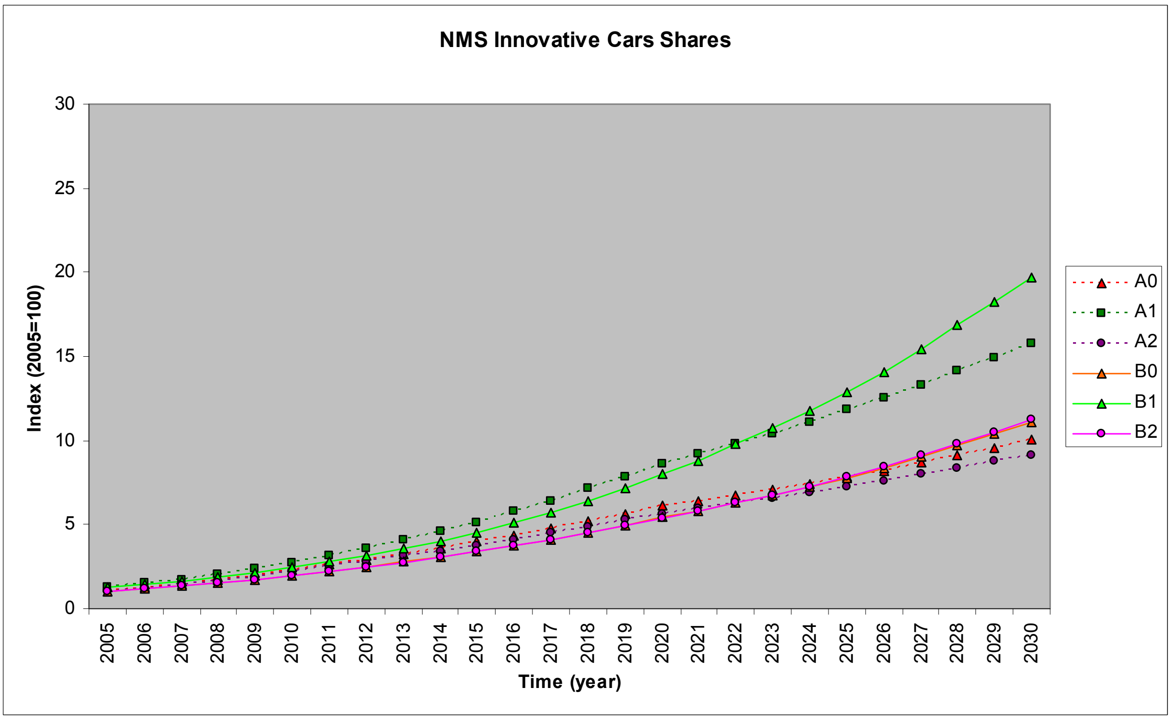


Figure 4.3.13 POLES model: Innovative Cars Shares (%) for NMS

For all scenarios, light gasoline and diesel cars shares in EU25 fall down after 2020 (Figure 4.3.14). The strongest decrease seems to be in the technology investments scenario under the high oil price growth assumption (B1 scenario). These decreasing curves are as well found within the New Member States, although here they are much less significant. For the whole observed period, it can be seen that light cars shares in New Member States articulate not far from 60% of all car shares.

Big cars shares show significant decrease for all scenarios for EU15 and New Member States (Figure 4.3.15 and Figure 4.3.16). Technology investments, in scenarios A1 and B1, are again the principle factor that strongly triggers the decrease. It can be concluded that the application of these policies favours the raise of innovative car shares and at the same time stimulates users to abandon conventional vehicles.

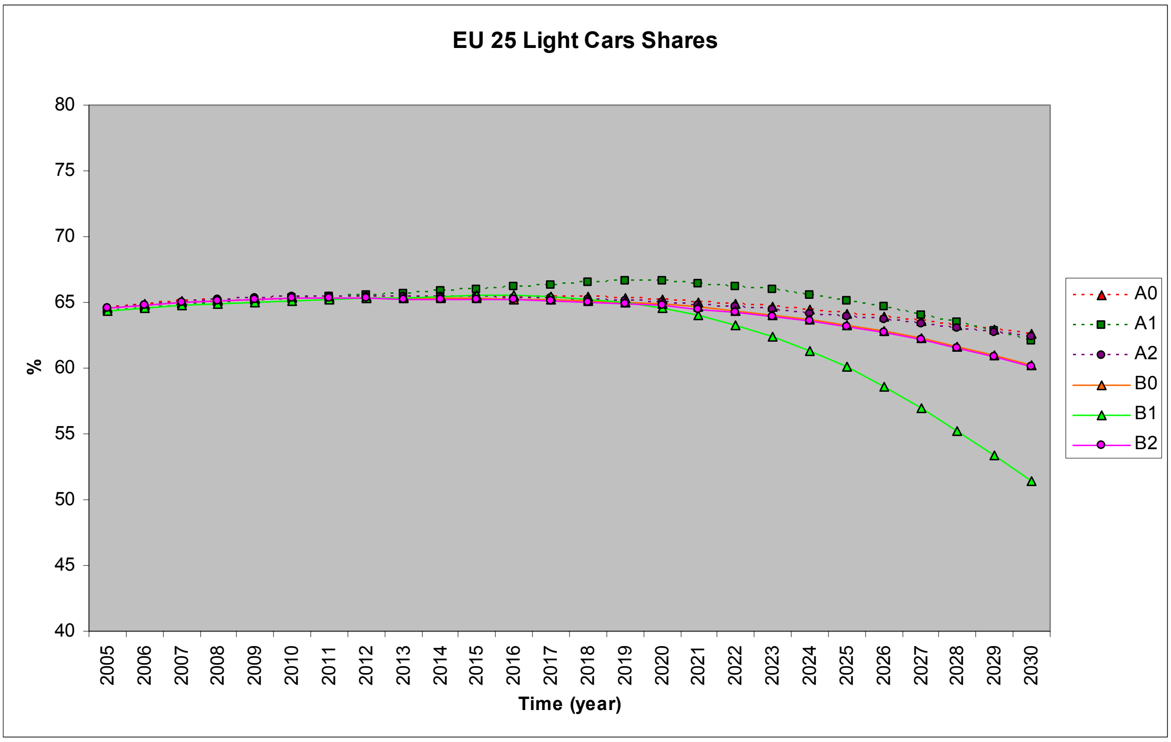


Figure 4.3.14 POLES model: Light diesel and gasoline cars shares (%) for EU25

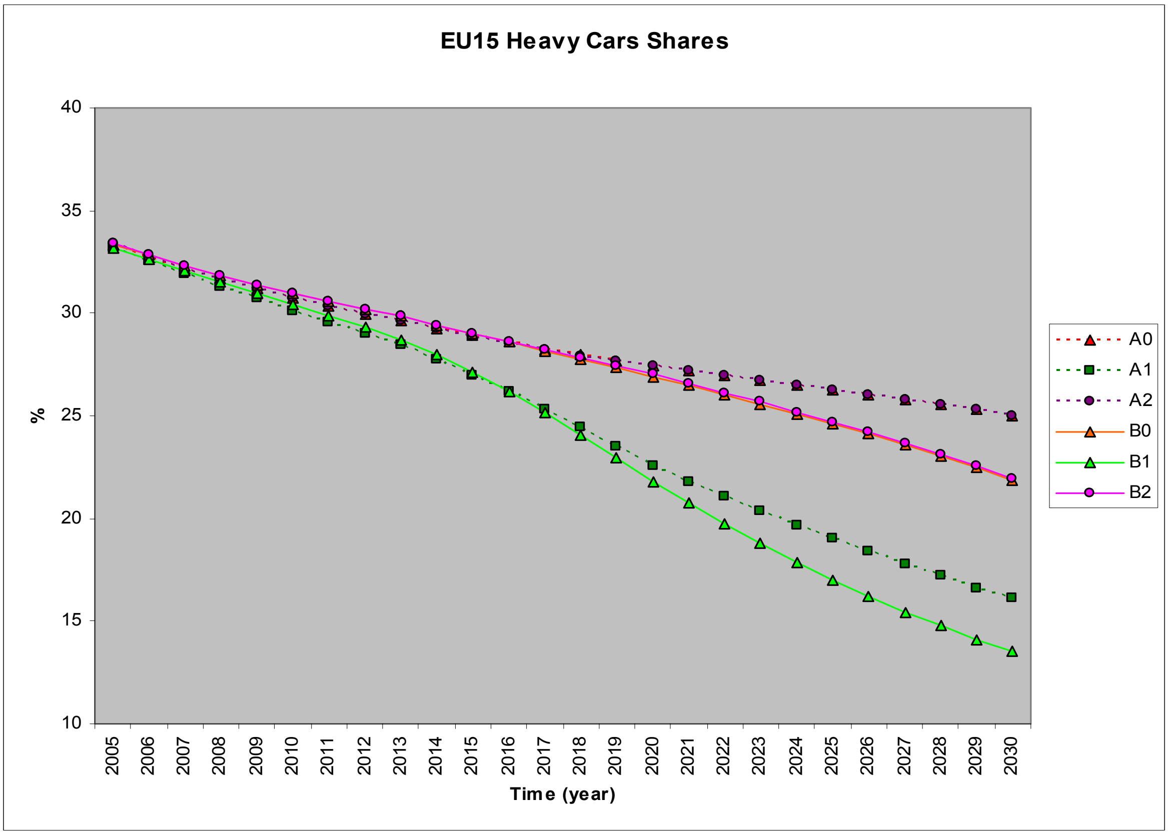


Figure 4.3.15 POLES model: Big diesel and gasoline cars shares (%) for EU15

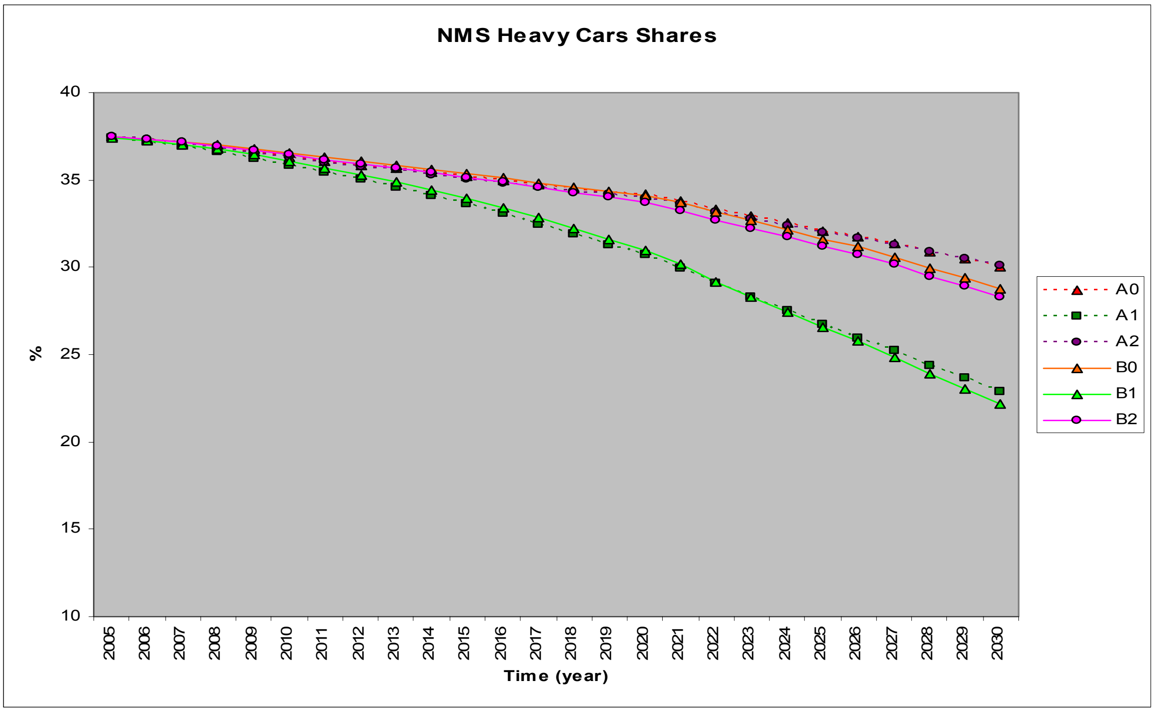


Figure 4.3.16 POLES model: Big diesel and gasoline cars shares (%) for NMS

Energy

The following tables reports the impact of the scenarios on two indicators concerning the use of energy. Table 4.3.6 shows the development of the dependency of EU from third countries for the energy required by the transport system. At the base year, about 79% of energy for transport is imported. In all scenarios this percentage is increasing and the differences between scenarios are small. In the high oil price growth scenarios the share of imported energy is slightly lower than in the low oil price growth scenarios, but the difference is not really significant.

Table 4.3.6 POLES model: % of imported energy for transport

	2005	2010	2015	2020	2025	2030
A0	78.6%	81.4%	84.5%	86.1%	87.2%	88.5%
A1	78.6%	81.3%	84.0%	85.3%	86.0%	87.1%
A2	78.6%	81.0%	83.6%	84.9%	85.7%	86.3%
B0	78.6%	80.6%	83.1%	84.7%	85.7%	86.4%
B1	78.6%	80.5%	82.5%	83.1%	83.4%	84.5%
B2	78.6%	80.4%	82.4%	83.1%	83.3%	84.2%

Definitely more visible are the impacts of the scenarios on the usage of energy produced from renewable sources in the transport sector. The starting point is a very limited share and in all scenarios renewable sources increase their share sharply. In the A0 scenario, at year 2030 such a share is about 8% (i.e. six times the base year value). If the high oil price growth is assumed, the pressure for a diversification is stronger and the share of renewable source goes beyond 10%. Whatever hypothesis on fuel price development is adopted, the demand regulation scenarios are more effective than technology investments scenarios for increasing the usage of renewable sources. In the B2 scenario about 14% of all energy used in the transport sector is produced by renewable sources.

Table 4.3.7 POLES model: % of energy for transport from renewable sources

	2005	2010	2015	2020	2025	2030
A0	1.3%	3.3%	4.2%	5.5%	7.1%	8.1%
A1	1.3%	3.3%	4.3%	5.8%	7.8%	9.1%
A2	1.3%	3.4%	4.6%	6.3%	8.7%	10.8%
B0	1.3%	5.9%	8.2%	9.5%	10.1%	10.5%
B1	1.3%	5.9%	8.5%	10.5%	11.8%	12.0%
B2	1.3%	6.0%	8.9%	11.5%	13.8%	13.9%

Environment

Carbon dioxide emissions (gram of CO_2 per km) of innovative cars are reduced in all scenarios but technological measures recorded in scenarios 1 seem to generate more reduction.

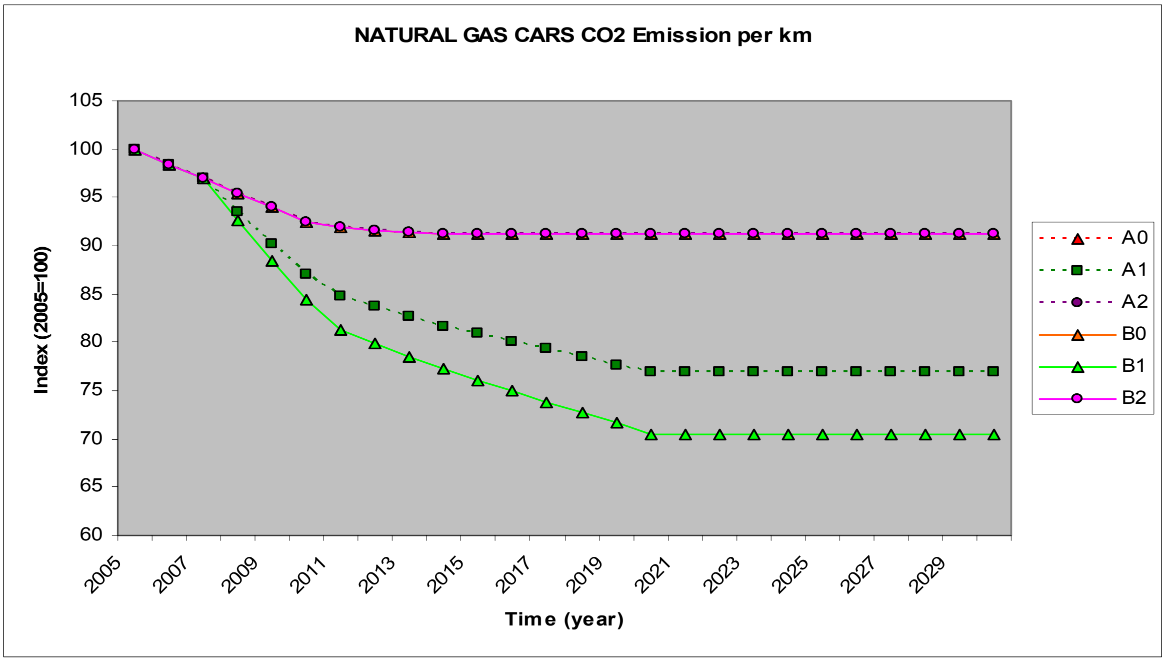


Figure 4.3.17 POLES model: Natural gas cars CO_2 emission per km (2005=100)

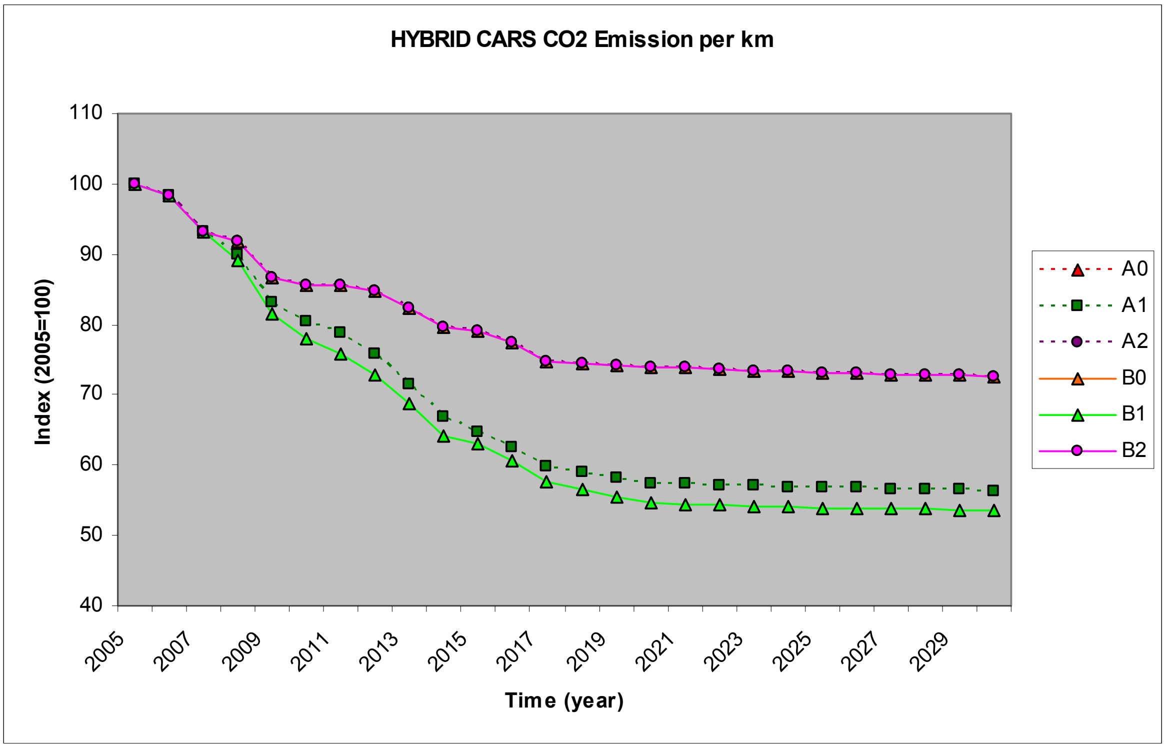


Figure 4.3.18 POLES model: Hybrid cars CO_2 emission per km (2005=100)

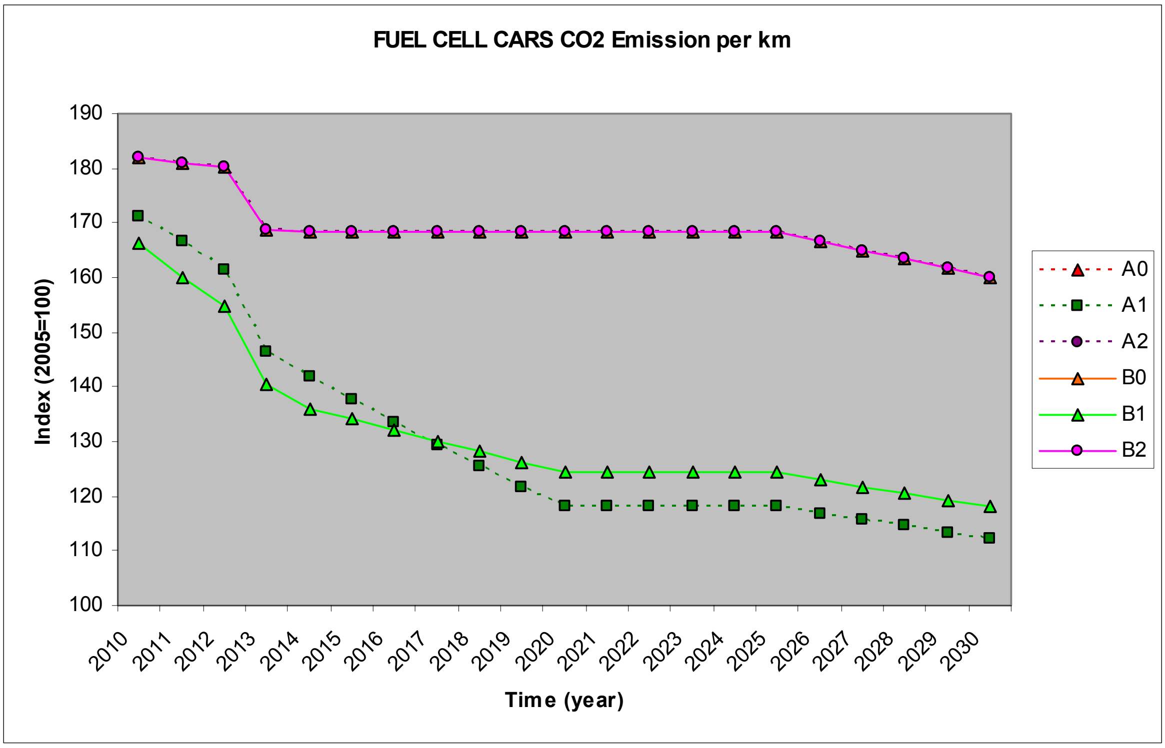


Figure 4.3.19 POLES model: Fuel cell cars CO_2 emission per km (2005=100)

4.4 The SASI model results

4.4.1 The SASI model

The SASI model is a recursive simulation model of socio-economic development of 1,330 regions in Europe subject to exogenous assumptions about the economic and demographic development of the European Union as a whole and transport infrastructure investments, in particular of the trans-European transport networks (TEN-T), and other transport policies.

The study area of the model are the 25 countries of the European Union plus Norway and Switzerland and the two accession countries Bulgaria and Romania and the western Balkan countries Albania, Bosnia-Herzegovina, Croatia, Macedonia and Serbia and Montenegro. The SASI model forecasts accessibility and GDP per capita of 1,330 NUTS-3 or equivalent regions in the study area (see Figure 4.4.1). These 1,330 regions are the 'internal' regions of the model. The remaining European countries, including the European part of Russia, are the 'external' regions, which are used as additional destinations when calculating accessibility indicators.

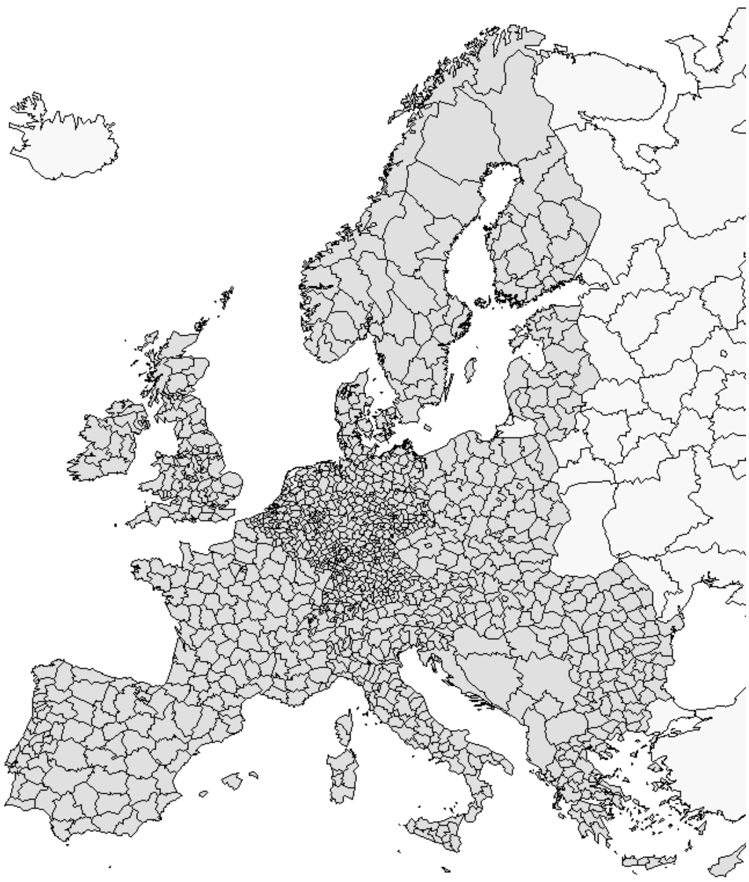


Figure 4.4.1 The SASI system of regions

The spatial dimension of the system of regions is established by their connection via networks. In SASI road, rail and air networks are considered. The 'strategic' road and rail networks used in SASI are subsets of the pan-European road and rail networks developed by the Institute of Spatial Planning of the University of Dortmund (IRPUD). The 'strategic' road and rail networks contain all TEN-T links according to the most recent EU planning documents and the east European road and rail corridors defined by the TINA consortium as well as additional links selected for connectivity reasons.

The temporal dimension of the SASI model is established by the division of time into simulation periods of one year duration. In order to show the development of the modelled system in the past, all simulations start in the year 1981. However, all scenarios are identical until the STEPs base year, which for reasons of the SASI database, is 2006. (and not 2005 as in the other models). For the same reason the target year of all simulations is 2031.

The SASI model differs from other approaches to model the impacts of transport on regional development by modelling not only production (the demand side of regional labour markets) but also population (the supply side of regional labour markets). The impacts of transport infrastructure investments and transport system improvements on regional production is modelled by regional production functions in which, besides non-transport regional endowment factors, different accessibility indicators are included.

For the application in the STEPs project, the SASI model was re-calibrated and extended to produce the output indicators required for STEPs. A description of the SASI model and additional references are contained in STEPs Deliverable D 4.1.

4.4.2 Implementation of the scenarios in the SASI model

The SASI model was used to simulate fifteen scenarios. Eight of these are the 'obligatory' A and B scenarios defined for STEPs. Each of them is a combination of one assumption about fuel supply and one set of policy response (see Table 4.4.1). Seven additional scenarios were simulated to examine the effects of more comprehensive policy combinations (A3, B3 and C3) and even stronger fuel price increases (C scenarios).

Table 4.4.1 SASI model: Scenario framework

	No-policy	Business as usual	Technology investments	Demand regulation	Integrated policy
Fuel price +1% p.a.	A-1	A0	A1	A2	A3
Fuel price +4% p.a.	B-1	B0	B1	B2	B3
Fuel price +7% p.a.	C-1	C0	C1	C2	C3

The assumptions associated with each scenario are listed in Tables 4.4.2 and 4.4.3. The tables show all assumptions and policies proposed in STEPs Deliverable D 3.

Table 4.4.2 SASI model Scenario definitions A-1/B-1 to A3/B3

	Measure	Indicator	Annual change (%) A-1 B-1	A0 B0	A1 B1	A2 B2	A3 B3
Socio-economic	Fuel supply	Fuel price	+1% +4%	+1% +4%	+1% +4%	+1% +4%	+1% +4%
	Fuel tax	Petrol	0%	+0.7%	as A0	+4.7%	as A2
		Diesel	0%	+1.5%	as A0	+4,7%	as A2
		Kerosene (% of petrol)	0%	50%	as A0	200%	as A2
	Travel cost due to tax increases	Car/lorry cost per km	0%	+0.5%	as A0	+3%	as A2
		Air cost per km	0%	-0.5%	as A0	+3%	as A2
	Telework	Work trips saved	0%	0%	as A0	-0.3%[a]	as A2
	Car sharing etc.	Car ownership	0%	+1%	as A0	-0.6%	as A2
Spatial	Residential	Central area	+	+	as A0	++	as A2
		Inner suburbs	++	++	as A0	+++	as A2
		Outer suburbs	+++	+++	as A0	0	as A2
	Services	Central area	0/+	0/+	as A0	+	as A2
		Inner suburbs	+	+	as A0	++	as A2
		Outer suburbs	++	++	as A0	0	as A2
	Industrial	Central area	0	0	as A0	0	as A2
		Inner suburbs	+	+	as A0	+++	as A2
		Outer suburbs	+++	+++	as A0	0/+	as A2
Travel	European rail	European rail speed	0%	+0.8%	+2%	as A0	as A1
	Regional rail	Regional rail speed	0%	+0.4%	+1.7%	as A0	as A1
	Public transport	Public transport speed	0%	+0.3%	+1.1%	as A0	as A1
	Traffic calming	Car speed in cities	0%	-0.4%	as A0	-1%	as A2
	Road pricing	€ per car-km[e]	0%	+2%	as A0	+6%	as A2
	Public transport cost	Bus cost per km	0%	+0.8%	as A0	-1.7%	as A2
		Train cost per km	0%	+0.8%	as A0	-1.7%	as A2
Freight	Traffic calming	Lorry speed in cities	0%	-0.4%	as A0	-1%	as A2
	Road pricing	€ per ton-km	0%	+2%	as A0	+6%	as A2
	City logistics	Distance in cities	0%	-0.2%	-0.5%	as A0	as A1
		Load factor in cities	0%	+0.8%	+2.4%	as A0	as A1
	Rail freight	Rail freight speed	0%	+0.7%	+2%	as A0	as A1
		Rail freight cost	0%	+0.6%	-1.5%	as A0	as A1
Energy	Energy use cars and lorries	Petrol per km	-0.5%	-0.5%	-2%	as A0	as A1
		Diesel per km	-1%	-1%	-3%	as A0	as A1
	Alternative vehicles	Car fleet in 2030[a]	2.1%	11.8%	19.3%	as A0	as A1
		Car/lorry cost per km	0%	+0.8%	+3%	as A0	as A1
	Energy use rail	Energy per km	-0.8%	-0.8%	-4%	as A0	as A1
	Energy use ship	Energy per km	-0.4%	-0.4%	-1.6%	as A0	as A1

[a] Share of alternative vehicles in 2030 (ASTRA)

Only for information (yellow)

Not used in SASI model (grey)

Table 4.4.3 SASI model scenario definitions C-1 to C3

	Measure	Indicator	Annual change (%)				
			C-1	C0	C1	C2	C3
Socio-economic	Fuel supply	Fuel price	+7%	+7%	+7%	+7%	+7%
	Fuel tax	Petrol	0%	-0.7%	as C0	+6%	as C2
		Diesel	0%	-1.5%	as C0	+6%	as C2
		Kerosene (% of petrol)	0%	0%	as C0	200%	as C2
	Travel cost due to tax increases	Car/lorry cost per km	0%	-0.5%	as C0	+5%	as C2
		Air cost per km	0%	-1%	as C0	+5%	as C2
	Telework	Work trips saved	0%	+0.5%	as C0	-1%	as C2
	Car sharing etc.	Car ownership	0%	+0.5%	as C0	-1.2%	as C2
Spatial	Residential	Central area	+	++	as C0	+++	as C2
		Inner suburbs	++	++	as C0	++	as C2
		Outer suburbs	+++	++	as C0	0	as C2
	Services	Central area	0/+	++	as C0	+++	as C2
		Inner suburbs	+	++	as C0	++	as C2
		Outer suburbs	++	+	as C0	0	as C2
	Industrial	Central area	0	++	as C0	++	as C2
		Inner suburbs	+	++	as C0	++	as C2
		Outer suburbs	+++	+	as C0	0	as C2
Travel	European rail	European rail speed	0%	+0.4%	+1%	as C0	as C1
	Regional rail	Regional rail speed	0%	as A0	as A1	as C0	as C1
	Public transport	Public transport speed	0%	as A0	as A1	as C0	as C1
	Traffic calming	Car speed in cities	0%	as A0	as C0	-2%[c]	as C2
	Road pricing	€ per car-km[e]	0%	0%	as C0	+10%	as C2
	Public transport cost	Bus cost per km	0%	as A0	as C0	0%	0%
		Train cost per km	0%	as A0	as C0	0%	0%
Freight	Traffic calming	Lorry speed in cities	0%	as A0	as C0	as A2	as C2
	Road pricing	€ per ton-km	0%	+0%	as C0	+10%	as C2
	City logistics	Distance in cities	0%	as A0	as A1	as C0	as C1
		Load factor in cities	0%	as A0	as A1	as C0	as C1
	Rail freight	Rail freight speed	0%	as A0	as A1	as C0	as C1
		Rail freight cost	0%	as A0	as A1	as C0	as C1
Energy	Energy use cars and lorries	Petrol per km	-0.5%	as A0	-3%	as C0	as C1
		Diesel per km	-1%	as A0	-4%	as C0	as C1
	Alternative vehicles	Car fleet in 2030[a]	2.1%	14.2%	32.5%	as C0	as C1
		Car/lorry cost per km	0%	as A0	+3%	as C0	as C1
	Energy use rail	Energy per km	-0.8%	as A0	as A1	as C0	as C1
	Energy use ship	Energy per km	-0.4%	as A0	as A1	as C0	as C1

[a] Share of alternative vehicles in 2030 (ASTRA)

Only for information (yellow)

Not used in SASI model (grey)

However, assumptions and policies that cannot be addressed by the SASI model are shaded in grey. Policies that cannot be addressed directly by the model are shaded in yellow; these are considered in the form of assumptions about the likely cost effects of the policies. All assumptions and policies are expressed in terms of annual change from the base year 2006. For instance, a one-percent annual rise of fuel price between 2006 and 2031 results in a rise of 28 percent, an annual rise of 4 percent in a rise of 167 percent, and an annual rise of 7 percent in a rise of 443 percent until 2031. The common assumptions and policies associated with the STEPs scenarios are presented in Section 2.2. Here only the adjustments made for their implementation in the SASI model are summarised:

- *A scenarios*. The A-1 Scenario in the SASI model is a true do-nothing scenario; i.e. it is assumed that no government policies to respond to the changes in energy prices, such as changes in fuel taxes, promotion of alternative vehicles, road pricing or changes in rail fares or new high-speed rail lines, are implemented. However, it is assumed that technical innovation and market response will lead to moderate reductions in energy use of cars, lorries and trains. Assumptions about changes in fleet composition in the policy scenarios were taken from the ASTRA model (see Section 4.2). The additional costs of alternative vehicles are assumed to affect per-km costs of cars and lorries, as the fixed costs of vehicles are not explicitly accounted for in the SASI model.

- *B scenarios*. Except the assumed higher fuel prices, the B scenarios in the SASI model are the exact counterpart of the corresponding A scenarios, including the assumptions about the diffusion of energy-saving and alternative vehicles.

- *C scenarios*. The C scenarios in the SASI model are based on the assumption that fuel prices will grow dramatically by seven percent per year, or almost fivefold, until 2030, a pessimistic scenario in which besides the growth in fuel consumption by China and India the diminishing fossil fuel resources are taken into account. Again Scenario C-1 is a do-nothing scenario in which no policy response is assumed. However, the remaining C scenarios assume a stronger policy response than the corresponding A and B scenarios. Scenario C0 assumes that governments attempt to compensate their economies for the high costs of transport by tax rebates and even subsidies (as in the case of aircraft kerosene), even at the expense of less investment in high-speed rail. Scenario C1 invests more in transport technology to promote energy-saving cars and trains and more alternative vehicles, with the fleet composition taken from the assumptions for the B scenarios in ASTRA (see Section 4.2). Scenario C2 uses heavy fuel taxes and road user charges to save fuel by reducing travel by all modes. Scenario C3, which applies the policies of Scenarios C1 and C2 together, is the strongest imaginable policy response.

The forecasts of regional economic development of the SASI model were transmitted to the Dortmund model (see Section 5.3). This was done by adjusting the regional employment control totals of the Dortmund model to the GDP forecasts of the SASI model for the ten NUTS-3 regions of the Dortmund metropolitan area. As in the SASI model all fuel price and policy scenarios result in lower regional GDP per capita than in the A-1 scenario, the SASI model predicts GDP per capita in these regions between 1.0 percent (Scenario A1) and 10.6 percent (Scenario C2) lower than in the A-1 Scenario in 2031. These reductions in economic activity affect employment, non-residential construction, household incomes and work trips and transport emissions in the Dortmund model.

4.4.3 Main results from the SASI model

In this section the results of the SASI model for the fifteen scenarios modelled are reported. The section is structured along the three main output categories of the SASI model, Accessibility, Economy and Society. The last sub-section summarises the effects of all scenarios in a comprehensive manner in form of tables and diagrams for all main output indicators of the model and draws tentative conclusions.

Each diagram in this section shows the development of one indicator. As the scenario policies are introduced only after 2006, all scenarios have the same historical path represented by the thick black line of the No-policy scenario A-1 until 2006. The future, scenario-dependent development of the indicator is drawn on the right-hand side of the diagram. Scenarios with the same assumption concerning fuel price increases are drawn in the same colour; blue for the A scenarios, red for the B scenarios and green for the C scenarios. Individual scenarios can be identified by the scenario number.

Accessibility

All scenarios have significant impacts on the accessibility indicators of the SASI model. Both, the magnitude of average European accessibility and the spatial distribution of accessibility among the European regions are affected. The effects vary with the scenario assumption on fuel price increases and the different forms of policy intervention. The development of multimodal accessibility based on road, rail and air travel is shown as average value for the 34 European countries of the SASI model in Figure 4.4.2; the corresponding diagram for freight based on road and rail is displayed in Figure 4.4.3.

In the past multimodal accessibility has grown continuously because of the infrastructure development and because of the removal of political, social or cultural barriers also incorporated in the SASI accessibility indicators. Although the No-policy scenario A-1 has no network development or acceleration of modes in the future, accessibility will slightly grow, because of the underlying assumptions on further European integration.

In all scenarios, multimodal accessibility is below the A-1 Scenario. This is to be expected for Scenarios B-1 and C-1 as their fuel cost increases are higher than in Scenario A-1. But there is also no policy scenario that leads to higher accessibility than Scenario A-1. This is so because in all policy scenarios transport, in particular road transport, is made even more expensive than the increase in fuel cost. This is also true for policy scenarios in which rail is favoured either by assumptions on network development and an increase in speed (as in the technology investments scenarios A1, B1 and C1) or through a reduction of rail fares per km (as in the demand regulation scenarios A2, B2 and C2). Even the combination of both (in integrated policy scenarios A3, B3 and C3) does not lead to gains in multimodal accessibility because of the massive policies against car and lorry use in these scenarios. For passenger travel, the magnitude of the negative impact depends primarily on the assumption about fuel cost. However, policies can clearly influence the position within the broad corridor prescribed by the fuel price increase. For freight transport, the grouping according to fuel price increase is less pronounced.

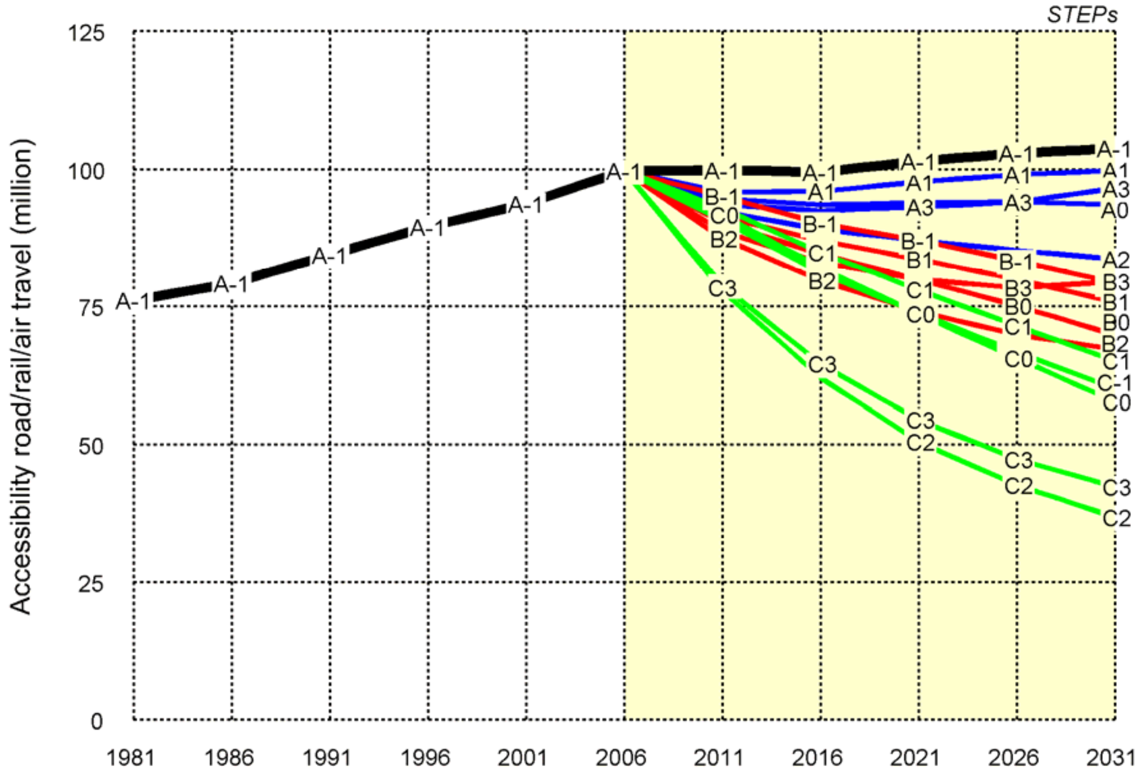


Figure 4.4.2 SASI model results: accessibility road/rail/air travel 1981-2031 (million)

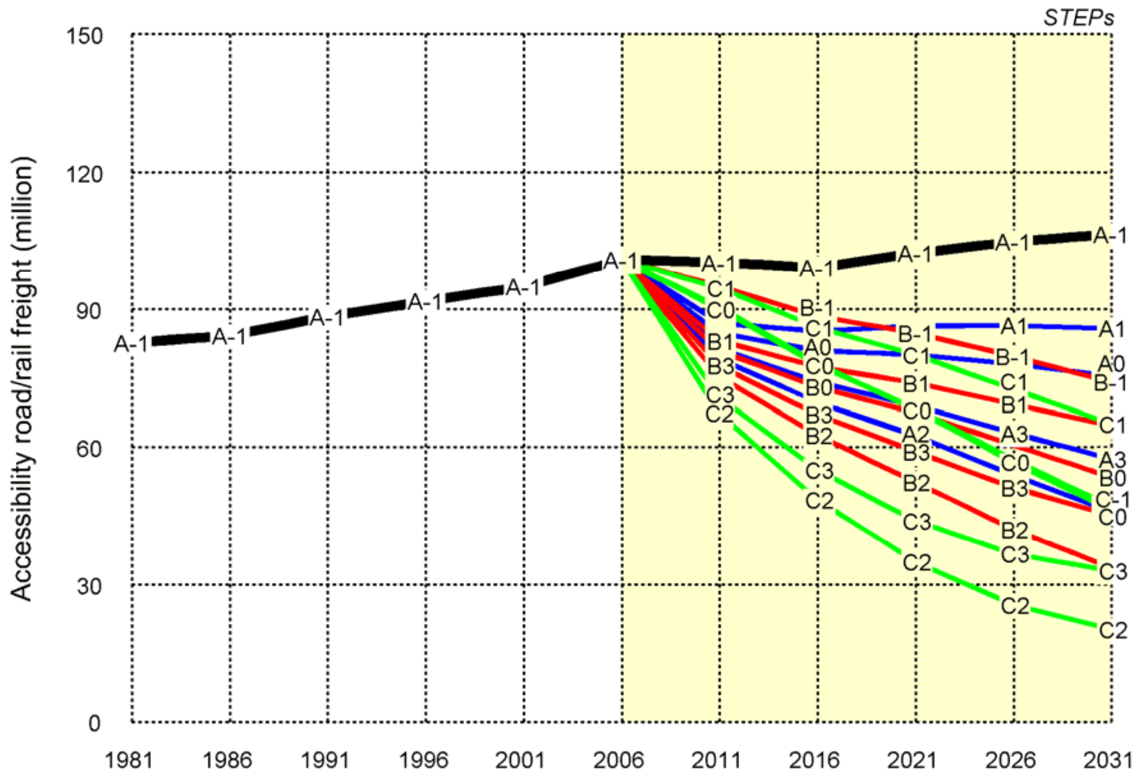


Figure 4.4.3 SASI model results: accessibility road/rail freight 1981-2031 (million)

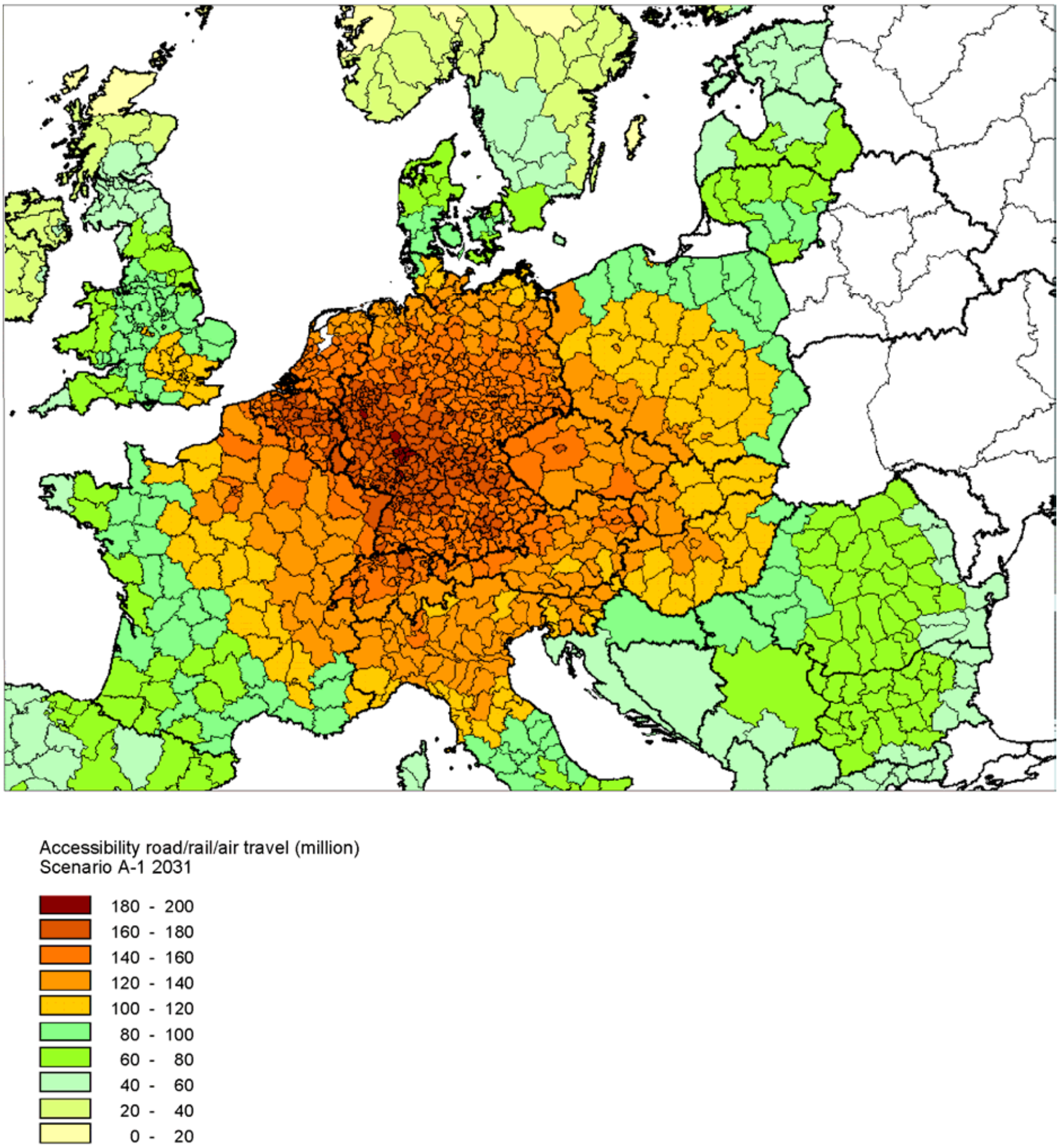


Figure 4.4.4 SASI model results: accessibility road/rail/air travel, Scenario A-1 2031 (million)

The spatial variation of accessibility in the No-policy Scenario A-1 is shown in Figure 4.4.4 using multimodal travel by road, rail and air as example. By using generalised costs, i.e. network and time costs, as impedance term in the accessibility model, the map underlines the traditional core-periphery pattern in Europe. Highest accessibility values are found in the Benelux countries and parts of Germany followed by the surrounding countries and then gradually going down to the edges of Europe. The lowest accessibility values are found in the Nordic countries.

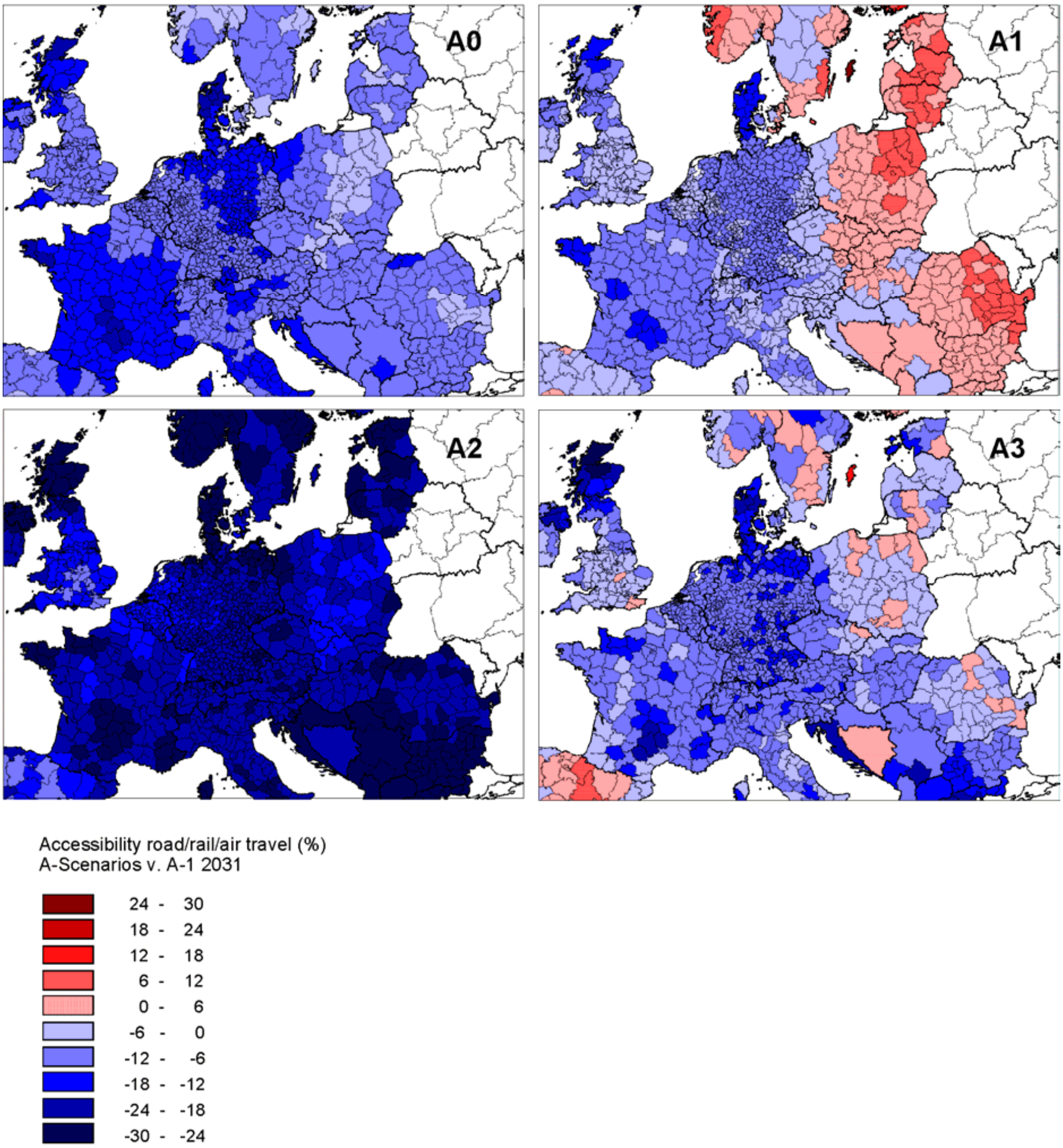


Figure 4.4.5 SASI model results: accessibility road/rail/air travel, Scenarios A0 to A3, difference to Scenario A-1 2031 (%)

The different policy scenarios result in different spatial patterns of accessibility change. Figure 4.4.5 shows the difference in accessibility compared to the A-1 Scenario for the low oil price growth scenarios. The spatial variation is mainly an outcome of the dynamic network database which contains the development of the TEN-T priority projects as an assumption (which is not part of the Scenario A-1). The technology investments scenario A1 even leads to gains in accessibility in several regions of the new member states, in regions of the Nordic countries and in Spain. Even in combination with the more drastic policies against the car in the integrated policy scenario A3, some regions gain in accessibility compared to the No-policy scenario A-1. The overall spatial pattern is similar in the same policy groups in the B and C scenarios. However, the decrease in accessibility is larger, and there are no regions with accessibility gains.

Economy

The economic impacts of the fuel price and policy scenarios predicted by the SASI model are presented for GDP and for employment.

The development of GDP is shown in Figure 4.4.6 expressed as GDP per capita in Euro of 2005. In the No-policy scenario A-1 the economic growth of the past will continue in the future. However, there is no scenario which leads to additional growth; quite the opposite: the fuel cost increases and all policy interventions slow down economic growth. Whereas in the scenario A-1 the average GDP per capita in 2031 will be about 38,000 Euro, the combination of high fuel price increases and strong policy response as in Scenarios C2 and C3 leads to an average GDP per capita of only about 34,000 Euro, i.e. more than ten percent less than in the A-1 scenario.

With respect to the development of employment over time, the absolute number of jobs in Europe will peak in the A-1 scenario and most of the policy scenarios between the years 2016 and 2021 (Figure 4.4.7). The employment curve follows the population decline. The reduced economic growth results in less employment in all scenarios than in the A-1 Scenario. In the next years job growth rates in all scenarios are lower than in Scenario A-1, also the peak will be reached earlier, i.e. job decline starts earlier and is more severe than in Scenario A-1. Not a single policy scenario brings additional jobs. Better visible for employment than in the GDP diagram is that the economic effect is at first hand related to the degree of fuel cost increases and only after that to the outcome of transport policies.

The spatial structure of richer and poorer regions in Europe in the No-policy Scenario A-1 will be rather similar to today (Figure 4.4.8). The SASI model predicts that the economic dominance of regions located in the central parts of Europe as well as in the Nordic countries will continue and that the regions of the new member states will not fully catch up to the economic level of the old member states during the forecasting period.

The spatial distribution of scenario effects is presented in Figure 4.4.9 taking the A scenarios as examples. As to be expected from the average European GDP development, economic decline is the major consequence for all regions in Europe. Only in Scenario A1, which is a combination of moderate fuel price increases, some infrastructure network development and only modest additional costs for road transport, some regions have a better economic performance than in the A-1 Scenario. The benefiting regions are nearly all located in the new member states or in the two accession countries Bulgaria and Romania. However, in the B and C scenarios there are no regions with higher GDP per capita than in the A-1 Scenario, i.e. the higher rates of fuel cost increases cannot be compensated by the policies considered in the scenarios.

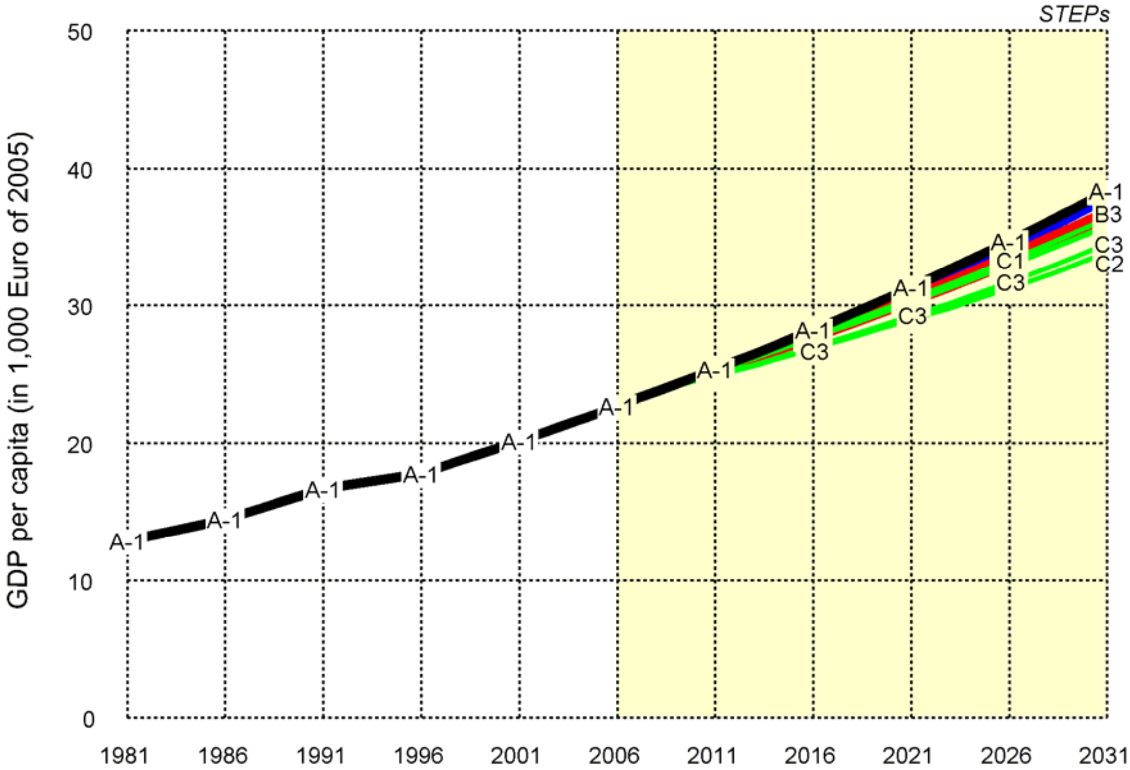


Figure 4.4.6 SASI model results: GDP per capita 1981-2031 (1,000 Euro of 2005)

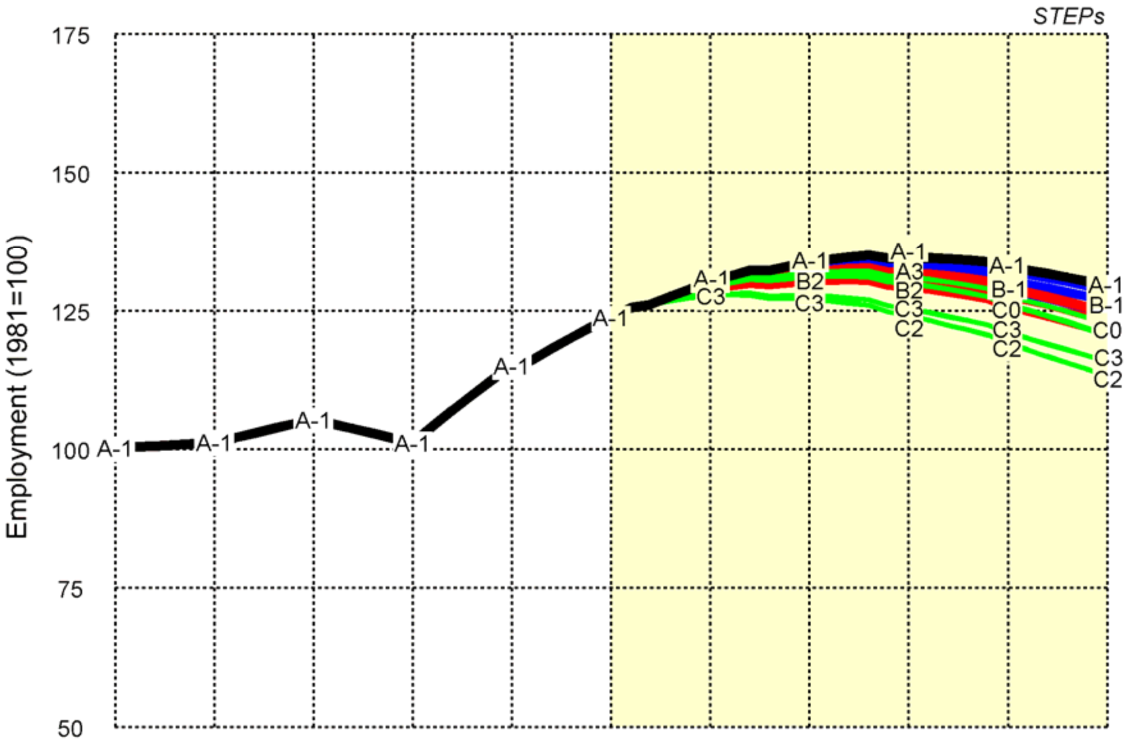


Figure 4.4.7 SASI model results: employment 1981-2031 (1981=100)

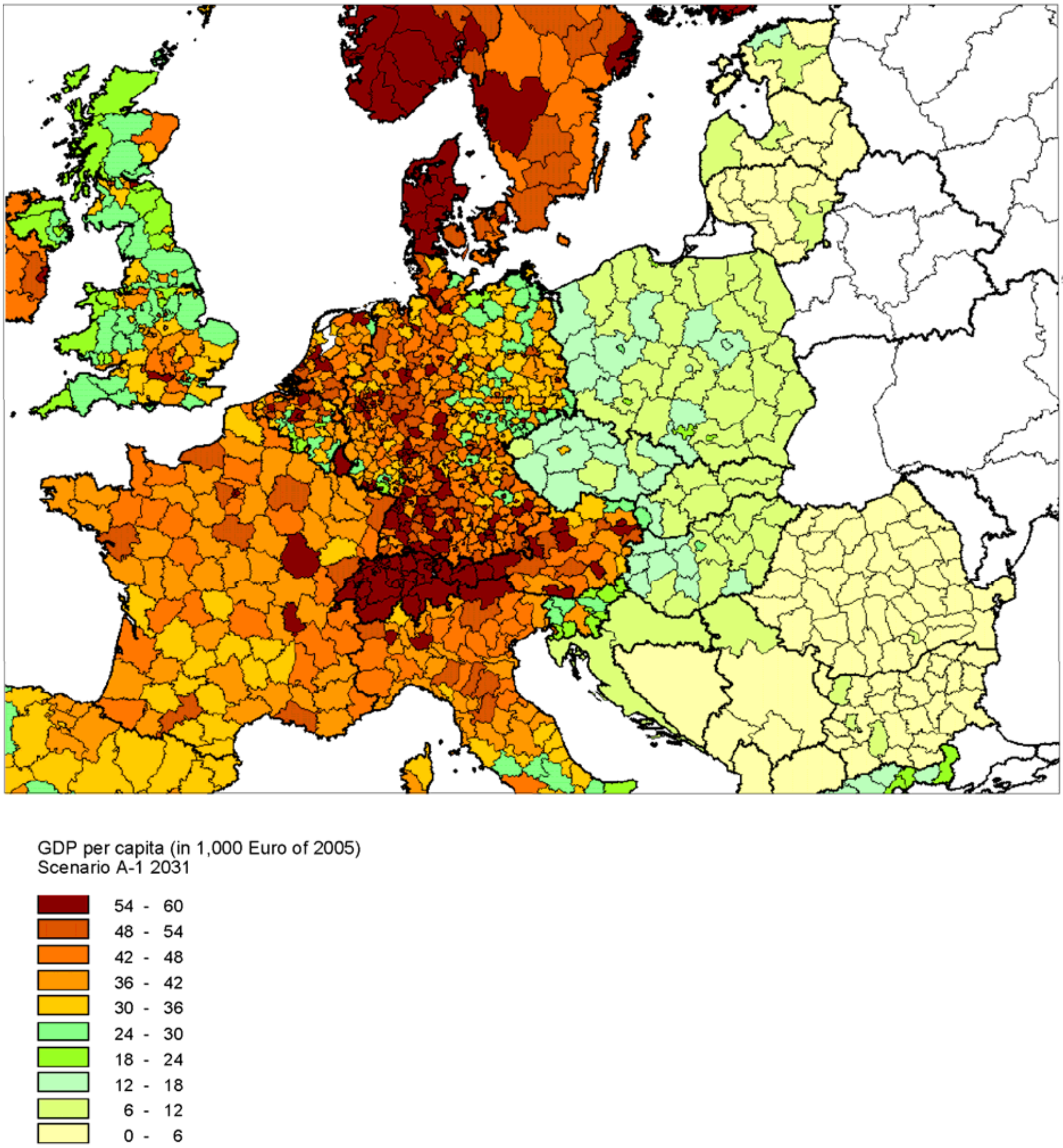


Figure 4.4.8 SASI model results: GDP per capita, Scenario A-1 2031(1,000 Euro of 2005)

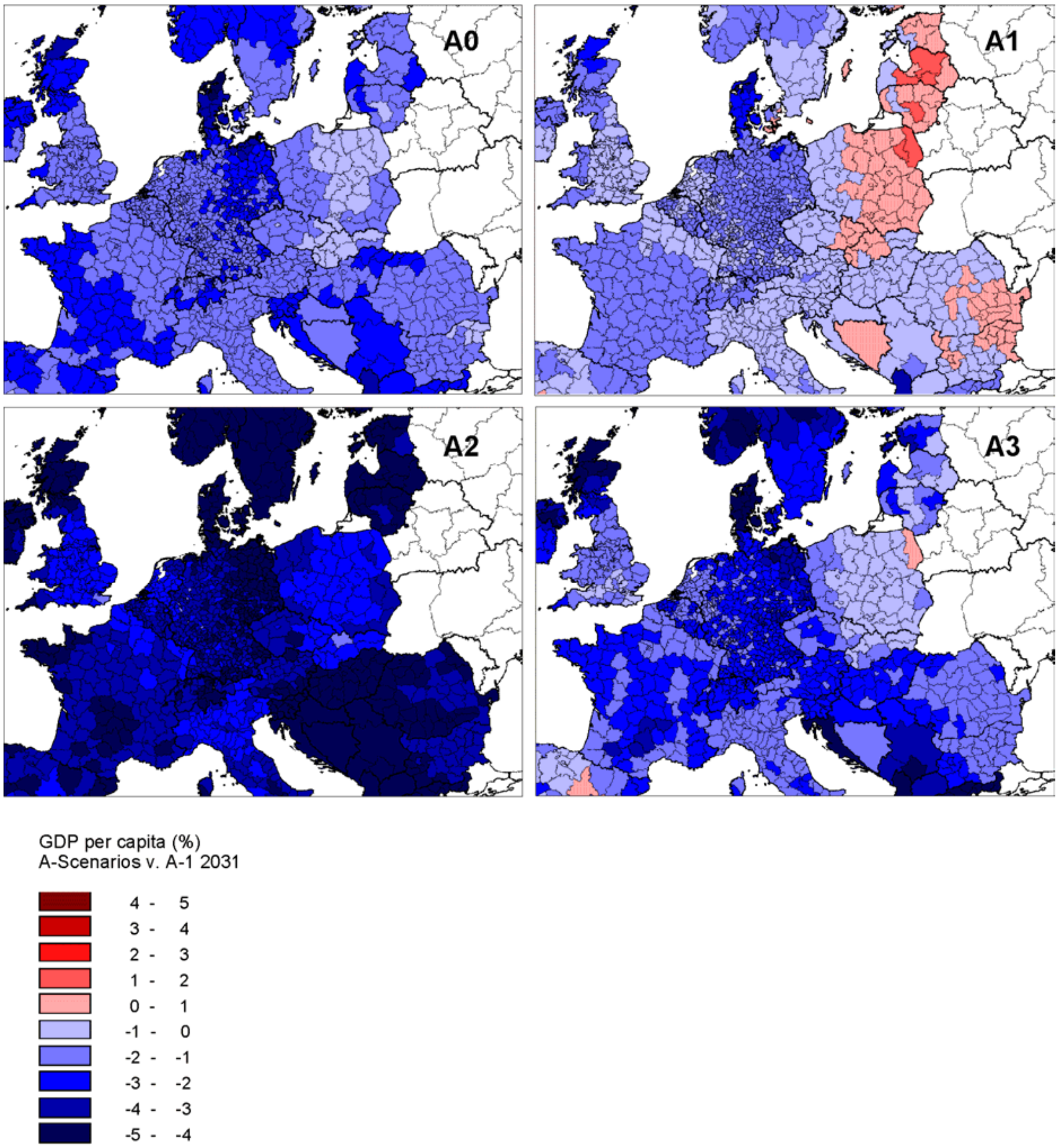


Figure 4.4.9 SASI model results: GDP per capita, Scenarios A0 to A3, difference to Scenario A-1 2031 (%)

Society

The SASI model calculates a range of cohesion indicators to measure the convergence or divergence of economic conditions under different scenarios. Cohesion at the European level means a reduction of economic disparities between the rich regions in the European core and the poorer regions at the European periphery or, after the enlargement of the EU, between the old and new member states. However, it has been demonstrated in the EU projects IASON and ESPON 2.1.1 that different cohesion indicators give different results (Bröcker et al., 2004; ESPON 2.1.1, 2004). Some commonly used indicators even indicate convergence where in fact divergence has occurred. One important distinction is whether the indicator measures relative or absolute convergence or divergence – if, for instance, all regions gain in relative terms by the same percentage, the richer regions gain more in absolute terms. Therefore, both types of cohesion indicators are used here.

Figures 4.4.10 and 4.4.11 show the cohesion effects of the assumed fuel price increases and policies on the distribution of GDP per capita compared to the A-1 Scenario. The convergence indicators are based on the correlation between the level of GDP per capita in the regions in the A-1 Scenario and the change induced by each scenario. In Figure 4.4.10 relative changes are considered, in Figure 4.4.11 absolute changes. The value of the A-1 scenario is set to 0.5; larger values of a scenario indicate convergence, smaller values divergence.

The message of both diagrams is clear: if relative cohesion indicators are used, the assumed increases in fuel prices and policies enlarge the disparities in economic development between the regions in Europe in most scenarios. There is an overall tendency in the scenarios towards more convergence in the long run, but only few scenarios end up with higher convergence indicator values than the A-1 Scenario. However, in absolute terms, there is convergence in all scenarios. The stronger regions lose more in GDP per capita because of their much higher levels of GDP per capita. Strongest cohesion effects occur in the C scenarios, i.e. the scenarios with the highest fuel price increases.

A further indicator, the polycentricity index, addresses the effects of the scenarios on the European urban system. Polycentricity is associated with major spatial policy objectives of the European Union: countries with a polycentric urban system are in general economically more successful and environmentally more sustainable than countries with a dominant capital city, but not necessarily spatially more equitable if also rural regions are included (see ESPON 1.1.1, 2004).

An approach to measure polycentricity has been developed and integrated in the SASI model (ESPON 2.1.1, 2004). The approach measures polycentricity by identifying three dimensions of polycentricity: the *size* or importance of cities (population, economic activity), their *distribution in space* or *location* and the *spatial interactions* or *connections* between them. In this way, the polycentricity index measures the degree of polarisation of the European urban system and its development over time. Cities included are 76 Metropolitan Growth Areas (MEGAs) defined in ESPON 1.1.1 (ESPON 1.1.1, 2004) representing the top level of the European urban system. Figure 4.4.12 displays the development of European polycentricity over time for all scenarios.

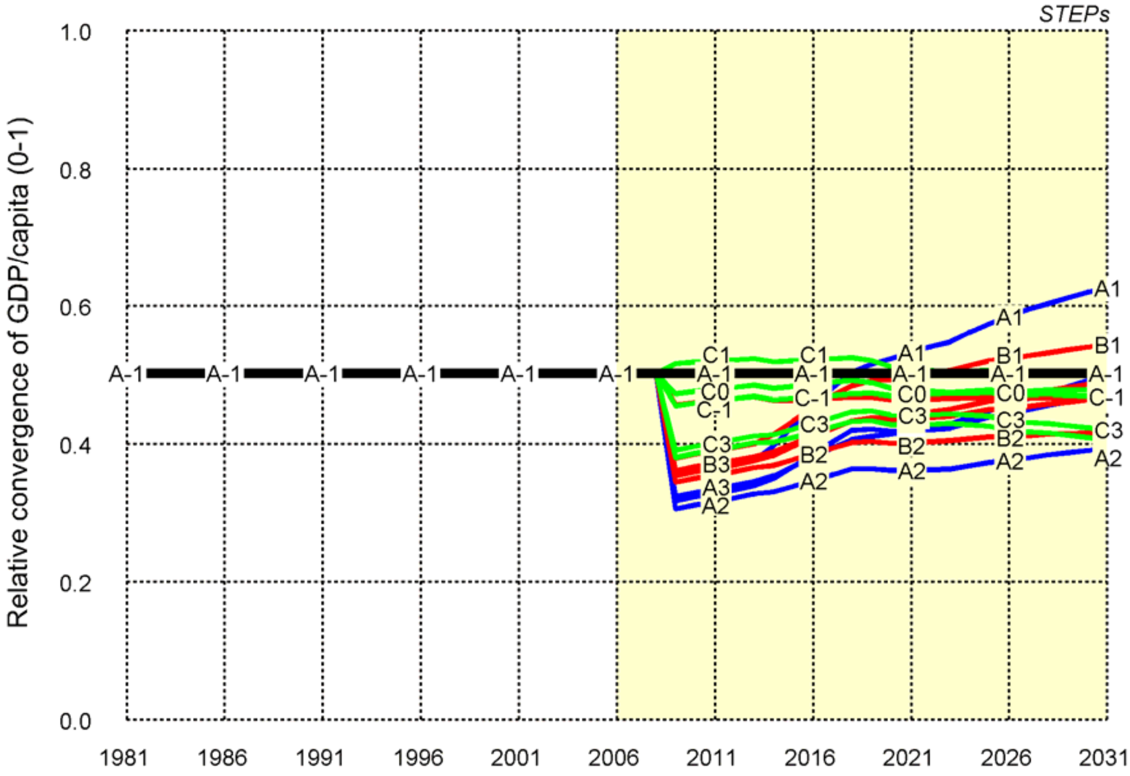


Figure 4.4.10 SASI model results: relative convergence of GDP per capita (0-1)

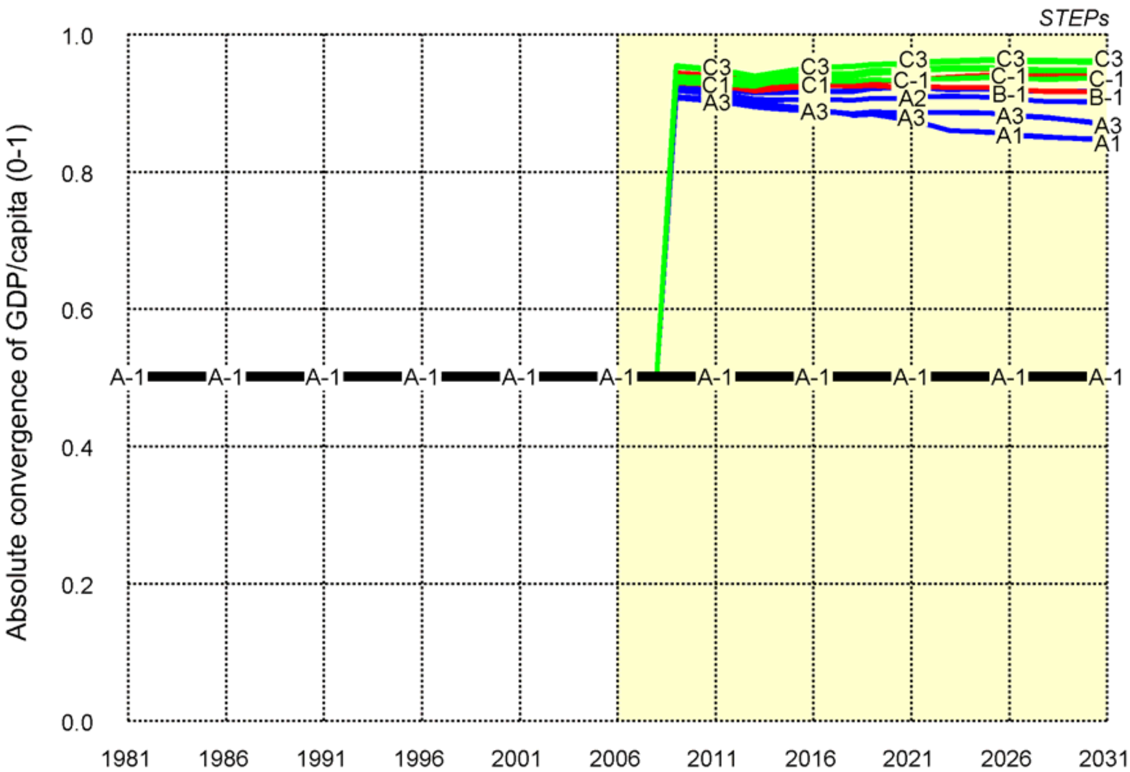


Figure 4.4.11 SASI model results: absolute convergence of GDP per capita (0-1)

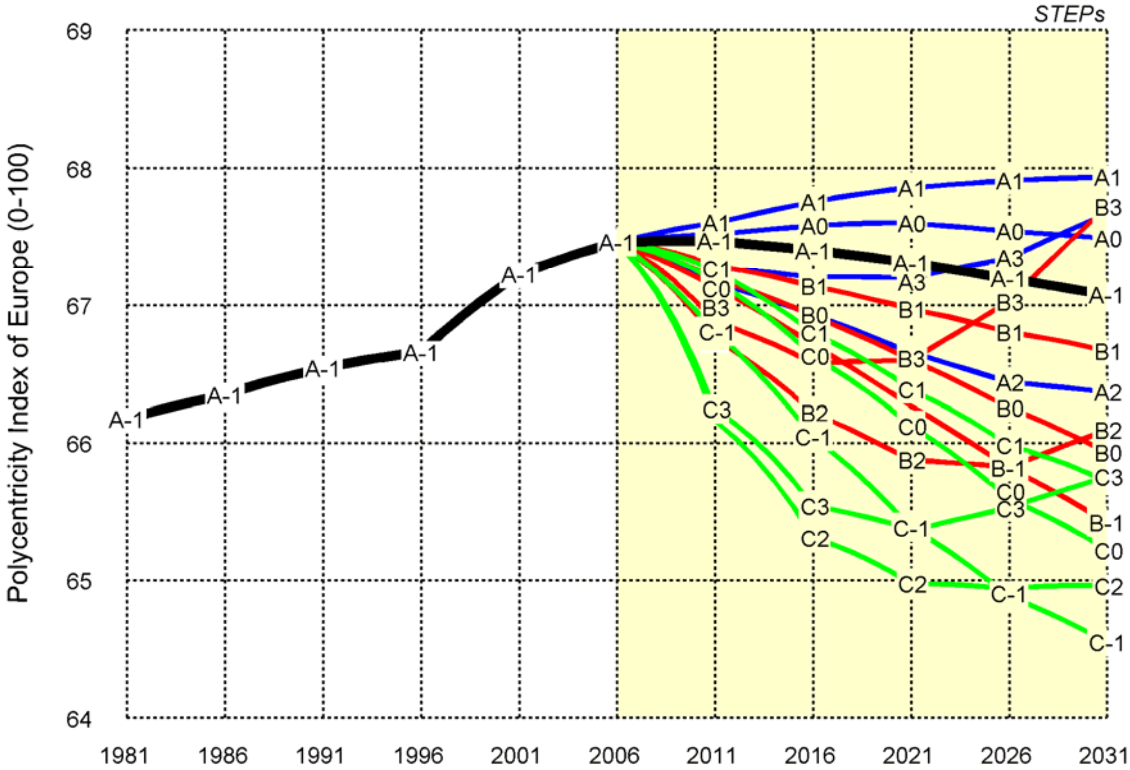


Figure 4.4.12 SASI model results: polycentricity Index of Europe (0-100)

Figure 4.4.12 shows that, in the past, polycentricity has slightly grown, mainly because of the positive development of more peripheral agglomerations and also of the major cities in the new member states of the European Union. However, already the Scenario A-1 constitutes a break with the past trend. The slight increase in fuel prices leads to a decrease in European polycentricity. If the rise in fuel price is stronger, the polarisation of the urban system grows more rapidly. Also most policy scenarios lead to lower degrees of polycentricity. However, the policies considered reduce the polarisation effect of the fuel price increases, i.e. their polycentricity indices are in general higher than those of the no-policy scenarios A-1, B-1 and C-1. In particular the integrated policy scenarios might reverse the trend of growing polarisation of the European urban system. If the fuel price increase is moderate as in the A scenarios, polycentricity might even rise above the level of the A-1 Scenario.

Conclusions

Which main messages about the spatial impacts of increases in fuel costs and related policy responses can be taken from the results of the SASI model? In order to address this question, main results from the SASI model are summarised in Tables 4.4.4 to 4.4.6 and Figure 4.4.13. The tables contain key indicator values for the year 2006 and for all scenarios for the year 2031 in absolute values and as relative differences to no-policy Scenario A-1. Figure 4.4.13 presents the relative differences to Scenario A-1 of all key indicators for all scenarios in graphical form.

Table 4.4.4 SASI model scenario results A-1 to A3

		2006	2031				
			A-1	**A0**	**A1**	**A2**	**A3**
Transport	Accessibility travel road/rail (million)	76.4	82.0	69.6	76.3	69.4	82.7
			0.0%	*-15.1%*	*-6.9%*	*-15.4%*	*+0.8%*
	Accessibility travel road/rail /air (million)	99.4	103.4	93.2	99.4	83.3	96.2
			0.0%	*-9.9%*	*-3.9%*	*-19.4%*	*-7.0%*
	Accessibility freight road (million)	78.4	91.6	59.3	57.9	30	29.6
			0.0%	*-35.2%*	*-36.8%*	*-67.3%*	*-67.7%*
	Accessibility freight road/rail (million)	100.5	106.1	75.1	85.5	45.7	57.2
			0.0%	*-29.2%*	*-19.4%*	*-56.9%*	*-46.1%*
Economy	GDP (million Euro of 2005)	11.7	18.3	18.0	18.1	17.7	17.9
			0.0%	*-1.6%*	*-0.8%*	*-3.5%*	*-1.9%*
	GDP per capita (1,000 Euro of 2005)	22.6	38.2	37.6	37.9	36.9	37.5
			0.0%	*-1.6%*	*-0.8%*	*-3.5%*	*-1.9%*
	Employment (million)	249.6	260.8	256.0	258.5	250.1	254.7
			0.0%	*-1.8%*	*-0.9%*	*-4.1%*	*-2.3%*
Society	Relative convergence of accessibility (0-1)	0.50	0.50	0.15	0.22	0.19	0.28
			0.0%	*-69.8%*	*-56.7%*	*-61.4%*	*-44.6%*
	Absolute convergence of accessibility (0-1)	0.50	0.50	0.96	0.94	0.96	0.95
			0.0%	*+92.6%*	*+87.7%*	*+92.4%*	*+90.7%*
	Relative convergence of GDP (0-1)	0.50	0.50	0.47	0.62	0.39	0.5
			0.0%	*-6.1%*	*24.8%*	*-21.8%*	*-0.6%*
	Absolute convergence of GDP (0-1)	0.50	0.50	0.91	0.84	0.90	0.87
			0.0%	*+82.8%*	*+68.8%*	*+79.7%*	*+73.2%*
	European polycentricity index	67.4	67.1	67.5	67.9	66.4	67.7
			0.0%	*+0.6%*	*+1.3%*	*-1.0%*	*+0.9%*

In conclusion, the model simulations with the SASI model have shown that fuel price increases and related policy responses have a strong negative impact on accessibility in all scenarios (except Scenario A3). The magnitude of the negative impact depends on the rate of fuel cost increases. The transport-related policies do not improve the situation. Even worse, most of the policies, in particular those with demand regulation, contain so much additional costs for road and to a lesser degree for air transport, that average accessibility in the policy scenarios is lower than in the corresponding no-policy scenarios with the same oil price growth assumption. The improvements of rail transport are not strong enough to compensate the cost increases in the two other modes. This can be seen for example by comparing the extreme losses in accessibility for freight by road with the somewhat lower reductions in accessibility for freight by road/rail. In summary, the SASI model suggests that fuel price increases lead to notably lower levels of accessibility and that policies that try to influence demand even worsen the situation. This results in levels of accessibility that are not only lower than in the moderate A-1 Scenario but even lower than today.

Table 4.4.5 SASI model scenario results B-1 to B3

		2006	2031				
			B-1	B0	B1	B2	B3
Transport	Accessibility travel road/rail (million)	76.4	66.9	56.8	63.3	60	72.8
			-18.4%	*-30.7%*	*-22.9%*	*-26.9%*	*-11.2%*
	Accessibility travel road/rail /air (million)	99.4	79	69.5	75.5	66.9	79.2
			-23.6%	*-32.8%*	*-27.0%*	*-35.3%*	*-23.4%*
	Accessibility freight road (million)	78.4	59.3	37.5	36.8	17.6	17.3
			-35.2%	*-59.1%*	*-59.8%*	*-80.7%*	*-81.1%*
	Accessibility freight road/rail (million)	100.5	73.8	53.2	64.4	33.4	44.9
			-30.4%	*-49.8%*	*-39.3%*	*-68.5%*	*-57.7%*
Economy	GDP (trillion Euro of 2005)	11.7	17.7	17.4	17.6	17.2	17.5
			-3.3%	*-5.0%*	*-4.0%*	*-6.1%*	*-4.3%*
	GDP per capita (1,000 Euro of 2005)	22.6	36.9	36.3	36.7	35.9	36.6
			-3.3%	*-5.0%*	*-4.0%*	*-6.1%*	*-4.3%*
	Employment (million)	249.6	252.0	247.2	250.2	243.1	248.4
			-3.4%	*-5.2%*	*-4.1%*	*-6.8%*	*-4.8%*
Society	Relative convergence of accessibility (0-1)	0.50	0.11	0.15	0.19	0.23	0.33
			-77.6%	*-70.0%*	*-62.2%*	*-53.2%*	*-34.3%*
	Absolute convergence of accessibility (0-1)	0.50	0.96	0.98	0.98	0.98	0.98
			+92.9%	*+95.7%*	*+95.1%*	*+95.9%*	*+95.4%*
	Relative convergence of GDP (0-1)	0.50	0.47	0.46	0.54	0.41	0.49
			-6.8%	*-7.2%*	*8.3%*	*-17.2%*	*-2.3%*
	Absolute convergence of GDP (0-1)	0.50	0.91	0.94	0.95	0.93	0.94
			+82.6%	*+88.1%*	*+89.1%*	*+86.6%*	*+87.5%*
	European polycentricity index	67.4	65.4	65.9	66.7	66.1	67.7
			-2.5%	*-1.7%*	*-0.6%*	*-1.5%*	*+1.0%*

All the scenarios have therefore significant impacts on the economic development of Europe and its regions, with a clear reduction of economic performance in Europe. The reduction is higher if fuel cost increases are larger. Most transport policies further reduce GDP. However, seen against the steady growth in GDP in the A-1 Scenario, the reductions are not a loss compared with today, but slight reductions in growth rates. That means that even in the worst scenarios, the level of GDP per capita in real terms in 2031 is much higher than today.

In the scenarios with stronger negative impacts on GDP growth the employment situation might become problematic. In some of the C scenarios, employment is more than ten percent below employment in the A-1 Scenario: and, the reduction of the number of jobs starts earlier in the fuel cost and policy scenarios than in the A-1 Scenario.

Table 4.4.6 SASI model scenario results C-1 to C3

		2006	2031				
			C-1	**CO**	**C1**	**C2**	**C3**
Transport	Accessibility travel road/rail (million)	76.4	52.0	49.4	56.3	33.7	38.8
			-36.6%	*-39.8%*	*-31.3%*	*-58.9%*	*-52.6%*
	Accessibility travel road/rail /air (million)	99.4	59.8	57.5	64.8	36.6	42.1
			-42.2%	*-44.4%*	*-37.3%*	*-64.6%*	*-59.3%*
	Accessibility freight road (million)	78.4	32.3	30.2	37.3	4.3	5.3
			-64.7%	*-67.0%*	*-59.3%*	*-95.3%*	*-94.2%*
	Accessibility freight road/rail (million)	100.5	46.8	45.9	64.7	20.1	32.8
			-55.9%	*-56.7%*	*-39.0%*	*-81.1%*	*-69.1%*
Economy	GDP (trillion Euro of 2005)	11.7	17.1	17	17.3	16.1	16.5
			-6.6%	*-6.8%*	*-5.3%*	*-11.7%*	*-10.0%*
	GDP per capita (1,000 Euro of 2005)	22.6	35.7	35.6	36.2	33.7	34.4
			-6.6%	*-6.8%*	*-5.3%*	*-11.7%*	*-10.0%*
	Employment (million)	249.6	243.2	242.7	247.1	228.1	233.3
			-6.7%	*-6.9%*	*-5.2%*	*-12.5%*	*-10.5%*
Society	Relative convergence of accessibility (0-1)	0.50	0.16	0.18	0.18	0.26	0.30
			-68.4%	*-64.9%*	*-64.7%*	*-48.3%*	*-40.5%*
	Absolute convergence of accessibility (0-1)	0.50	0.98	0.98	0.98	0.99	0.99
			+95.9%	*+96.6%*	*+95.7%*	*+98.9%*	*+98.6%*
	Relative convergence of GDP (0-1)	0.50	0.47	0.48	0.50	0.40	0.42
			-6.7%	*-4.7%*	*0.7%*	*-19.1%*	*-16.3%*
	Absolute convergence of GDP (0-1)	0.50	0.93	0.95	0.94	0.96	0.96
			+86.7%	*+89.1%*	*+88.7%*	*+91.3%*	*+91.5%*
	European polycentricity index	67.4	64.5	65.2	65.7	64.9	65.7
			-3.8%	*-2.8%*	*-2%*	*-3.1%*	*-2.0%*

All the scenarios have also strong impacts on the spatial organisation of Europe. Important territorial policy goals of the European Union such as cohesion and polycentricity are affected. However, at least in terms of cohesion, the predicted development might be considered not so negative. Because in absolute terms the economically stronger regions are affected more, they will lose more in absolute terms (though less in relative terms) than the poorer regions. The consequence is in all scenarios a reduction in socio-economic polarisation in Europe. However, at the same time this might lead to a somewhat higher polarisation of the urban system in Europe in most scenarios.

In summary, the SASI model predicts that growing fuel costs and related policy responses will lead to a strong reduction in accessibility and economic growth in Europe. But at the same time the lower growth rates might lead to an increase in cohesion among the European regions, i.e. a more balanced spatial structure.

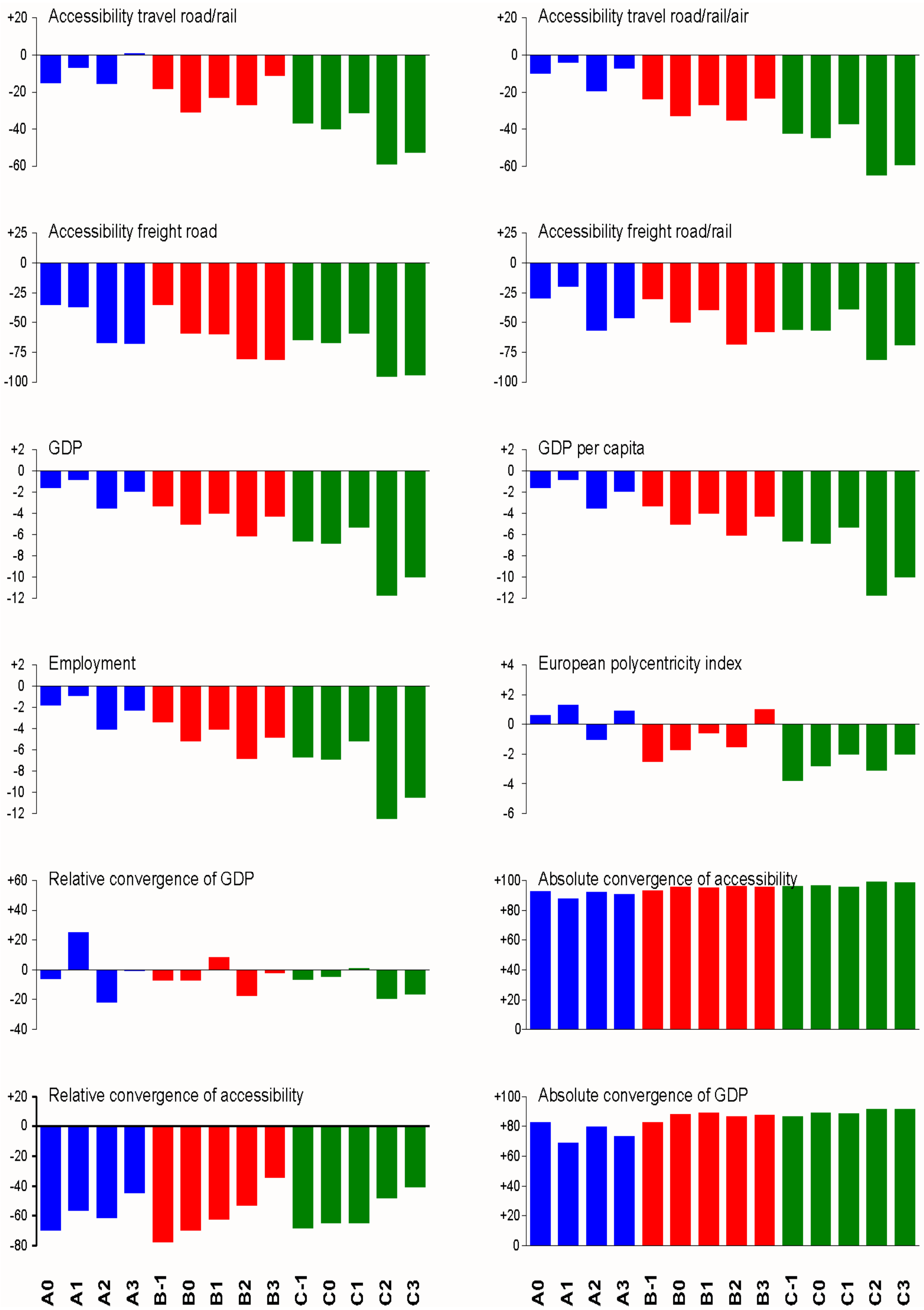


Figure 4.4.13 SASI model results: differences to Reference Scenario A-1 (%)

Chapter 5 Results of the regional models

5.1 Introduction

In this chapter, the results of the simulation of the STEPs scenarios by means of the regional models are reported. As much as possible, the same structure is adopted, addressing separately the impacts on different systems: transport demand, economy, environment, energy, etc. However, as explained in Chapter 2, models have worked as independent tools, exploiting their specific capabilities. So, each model has produced a different set of outcomes that are only partially overlapping.

5.2 The Brussels model results

5.2.1 The Brussels model

The model has been used to study the displacements inside the Brussels Capital Region (BCR) as well as its suburban region also called the Regional Express Network (REN) area. We have decided in this Brussels Case study (BCS) to focus on the largest one (including the BCR). The studied zone is shown at the following picture.

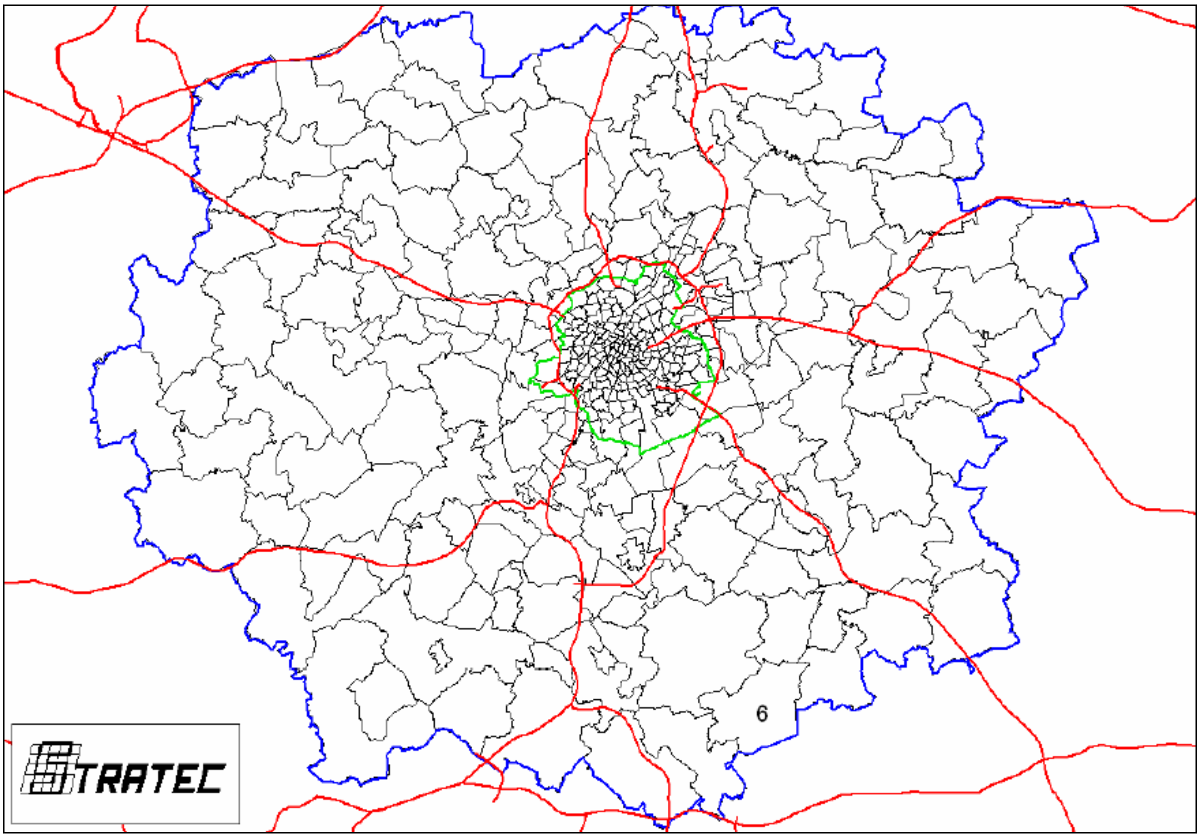


Figure 5.2.1 Brussels model: Studied region : Brussels Capital Region and Regional Express Network area

In this study, the two regions are considered as one main region in terms of results. However, the specificities of both regions have being included in the model in terms of specific socio-economic variables, modal split, specific car ownership and specific population characteristics (in terms of cost sensibility).

The Brussels model has been used to study the evolution perspectives of transport for the year 2001 and for the horizon 2015 taking into account the perspectives of employment and population for these years. The model has been calibrated on 2001 data. Forecast on the demand for the several modes has initially been done for 2015, but for the needs of the STEPs project extrapolations have been made for the year 2020.
The IRIS model is based on the SATURN software (Atkins), which is a road traffic model with dynamic assignment. The whole BCR is modelled with a high level of details. The modal split is defined through several variables. The most important ones are the *time*, the *price* (for the user) and the *car ownership.* But many others are included (headways for public transports,…).

5.2.2 Implementation of the scenarios in the Brussels model

Most of values were issued from European models (POLES/ASTRA). These variables are the following one:

1) *car ownership*: the actual figures (issued from the IRIS model) have been used for the base year (2001). We used the used POLES/ASTRA forecasts to forecast future car ownership levels. The POLES/ASTRA differences for each scenarios have been integrated, but not the absolute data;
2) *car fleet*: car fleet changes have been integrated in the study. Data input come from POLES/ASTRA (European models, see WP4);
3) *fuel consumption percentage change*;
4) *fuel resource cost*;
5) *fuel taxes*;
6) *emissions factors CO, CO_2, NO_x and VOC*;
7) *cold emissions factors*.

Car ownership, fuel resource cost and taxes are presented in the following.

As written above, variation of fuel cost and of taxes have been considered together as one main variable in the utility function impacting the total cost for travel. Modal share have then been computed taking into account the following variables (Car Ownership and fuel cost) variations:

Table 5.2.1 Brussels model: Percentage change in Car ownership and cost for the 8 scenarios for the years 2001, 2015 and 2020

				2001				
Change	A-1	A0	A1	A2	B-1	B0	B1	B2
Car Ownership	0%	0%	0%	0%	0%	0%	0%	0%
€	0%	0%	0%	0%	0%	0%	0%	0%
				2015				
Change	A-1	A0	A1	A2	B-1	B0	B1	B2
Car Ownership	18%	18%	19%	7%	4%	4%	4%	-6%
€	19%	8%	6%	45%	97%	44%	40%	80%
				2020				
Change	A-1	A0	A1	A2	B-1	B0	B1	B2
Car Ownership	23%	23%	24%	4%	4%	4%	4%	-12%
€	24%	12%	6%	66%	129%	58%	43%	113%

These data are represented at the two next figures.

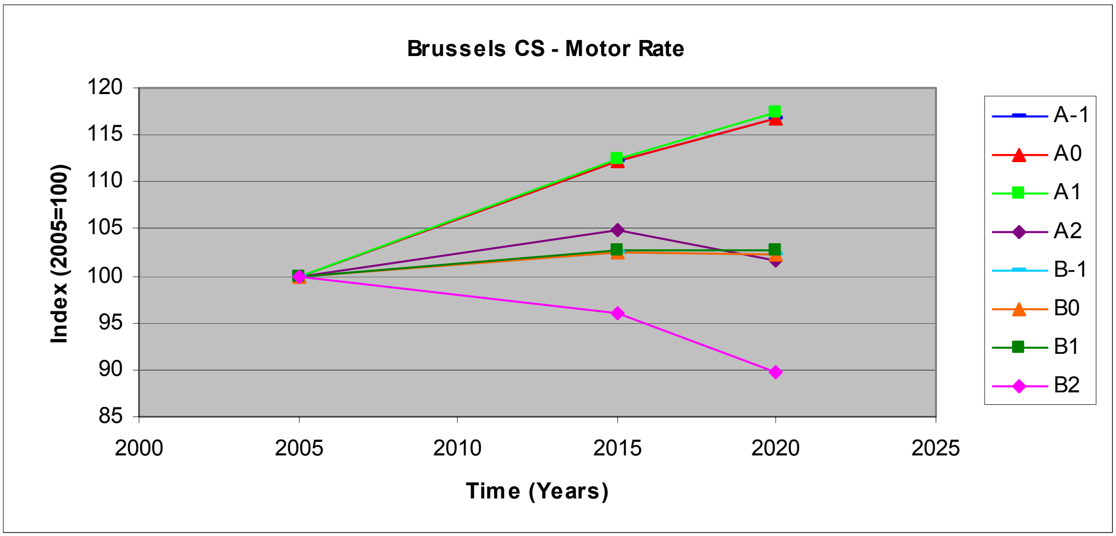


Figure 5.2.2 Brussels model: Motor Rate index

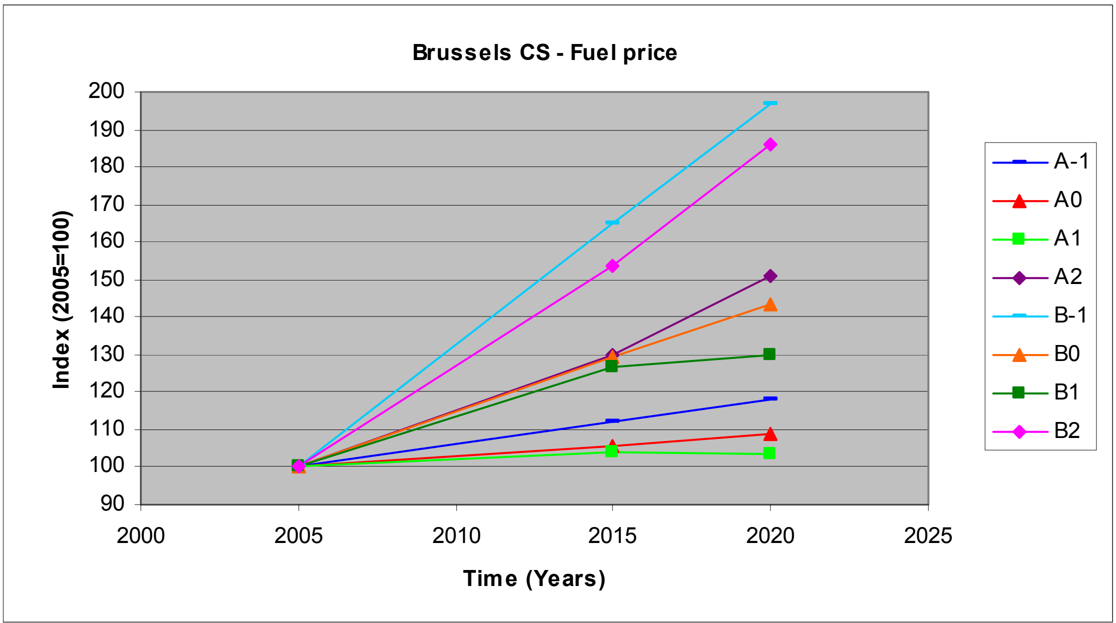


Figure 5.2.3 Brussels model: Fuel price index

5.2.3 Main results from the Brussels model

Mode shares

Modal share have been computed taking into account Car Ownership and fuel cost changes presented above.

The next table presents for the different scenarios the modal share which have been obtained.

Table 5.2.2 Brussels model: Evolution of Modal Shares for the 8 scenarios for the years 2001, 2015 and 2020.

				2001				
Modes	*A-1*	*A0*	*A1*	*A2*	*B-1*	*B0*	*B1*	*B2*
Private car driver	54.8%	54.8%	54.8%	54.8%	54.8%	54.8%	54.8%	54.8%
Public transport	34.8%	34.8%	34.8%	34.8%	34.8%	34.8%	34.8%	34.8%
Bike	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%
Private car passenger	9.7%	9.7%	9.7%	9.7%	9.7%	9.7%	9.7%	9.7%
				2015				
Modes	*A-1*	*A0*	*A1*	*A2*	*B-1*	*B0*	*B1*	*B2*
Private car driver	56.0%	57.2%	57.5%	50.7%	43.2%	50.1%	50.7%	43.7%
Public transport	33.7%	32.7%	32.5%	38.1%	43.9%	38.6%	38.1%	43.7%
Bike	0.6%	0.6%	0.6%	0.7%	0.8%	0.7%	0.7%	0.8%
Private car passenger	9.7%	9.5%	9.4%	10.6%	12.0%	10.7%	10.6%	11.8%
				2020				
Modes	*A-1*	*A0*	*A1*	*A2*	*B-1*	*B0*	*B1*	*B2*
Private car driver	56.1%	57.6%	58.4%	47.3%	39.1%	48.3%	50.3%	38.5%
Public transport	33.6%	32.4%	31.7%	40.7%	47.0%	40.0%	38.4%	47.8%
Bike	0.6%	0.6%	0.6%	0.7%	0.9%	0.7%	0.7%	0.9%
Private car passenger	9.8%	9.5%	9.3%	11.2%	12.9%	11.0%	10.6%	12.8%

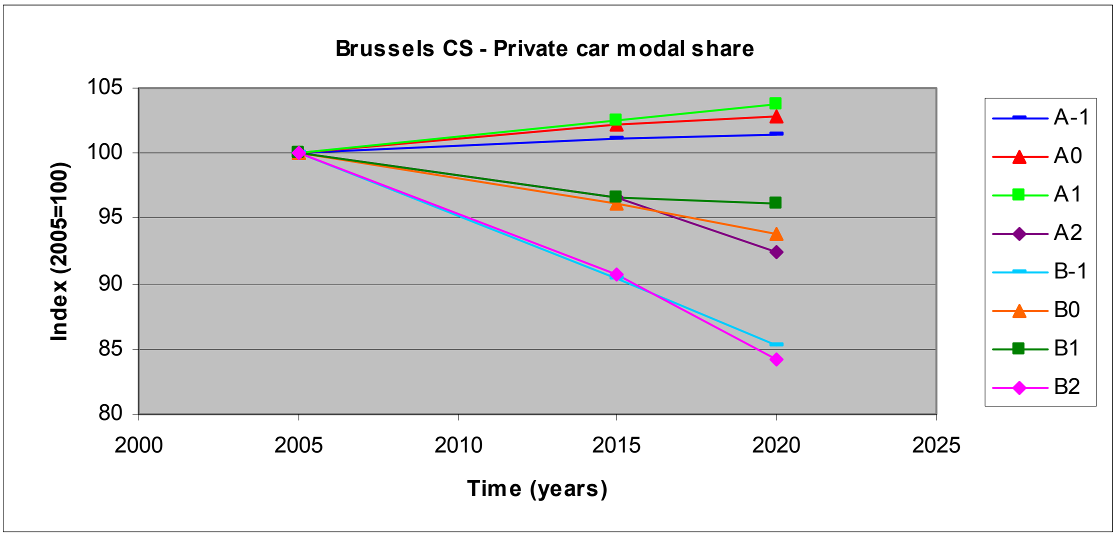


Figure 5.2.4 Brussels model: Private car share index for the 8 scenarios for the years 2001, 2015 and 2020

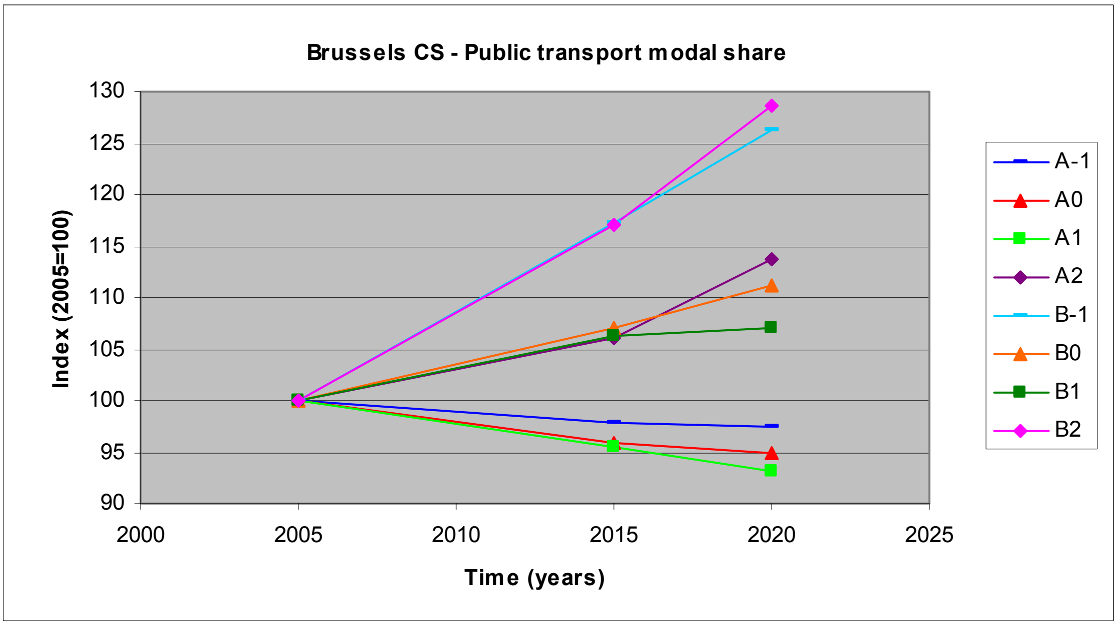


Figure 5.2.5 Brussels model: Public transport share index for the 8 scenarios for the years 2001, 2015 and 2020

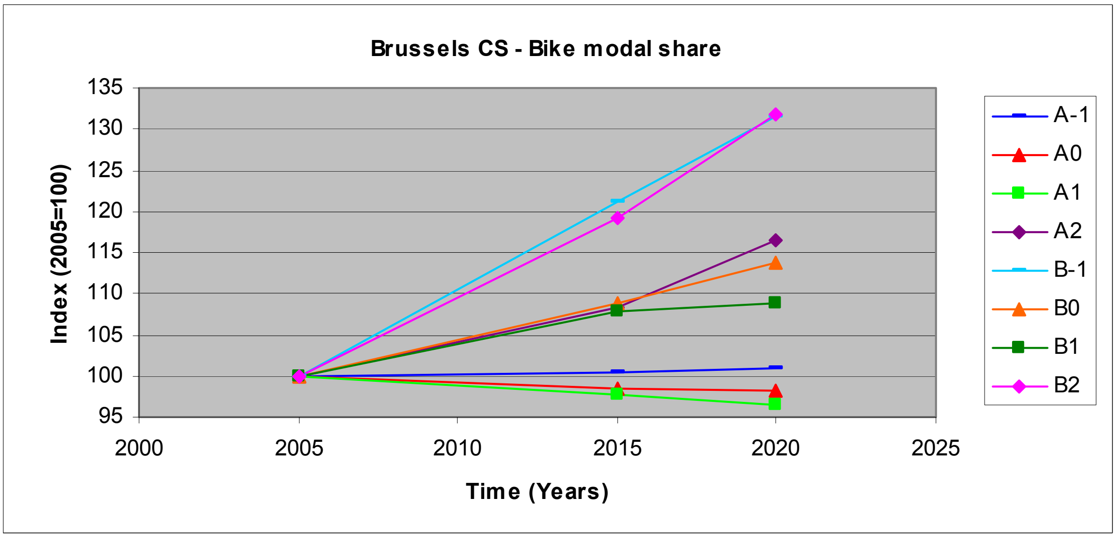


Figure 5.2.6 Brussels model: Bicycle share index for the 8 scenarios for the years 2001, 2015 and 2020

At this stage, it is already clear that the scenarios with the highest positive impact on environment are the B2 one and the B-1 one. Absolute changes value have been presented above.

The determination of modal share let us the opportunity to compute PCU*km and car trips for each scenario.

The next table present car trips number and PCU*km for the year 2015 and 2020. Value for the reference year 2001 for the 8 scenarios are 536 657 trips and 15 001 573 PCU*km.

*Table 5.2.3 Brussels model: Evolution of trips and CPU*km for the 8 scenarios for the years 2015 and 2020.*

				2015				
	A-1	*A0*	*A1*	*A2*	*B-1*	*B0*	*B1*	*B2*
Car trips	558 749	562 379	563 269	542 365	512 791	540 703	542 725	516 057
PCU*km	15 940 845	16 649 338	16 823 419	13 594 302	10 180 695	13 460 239	13 743 381	10 751 461
				2020				
	A-1	*A0*	*A1*	*A2*	*B-1*	*B0*	*B1*	*B2*
Car trips	565 415	570 035	572 333	536 777	499 007	540 434	547 942	497 864
PCU*km	16 252 237	17 168 427	17 633 091	12 462 716	8 696 738	12 945 834	13 959 834	8 975 148

The two next figures present these data in term of changes index in comparison with the reference year 2005.

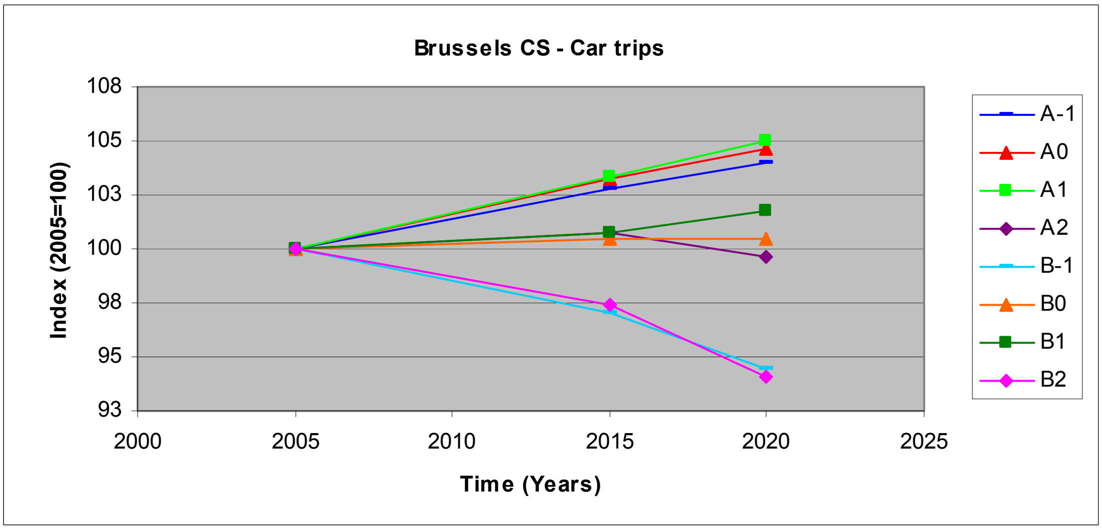


Figure 5.2.7 Brussels model: Representation of trips for the period 6PM-10PM for the years 2005, 2015 and 2020.

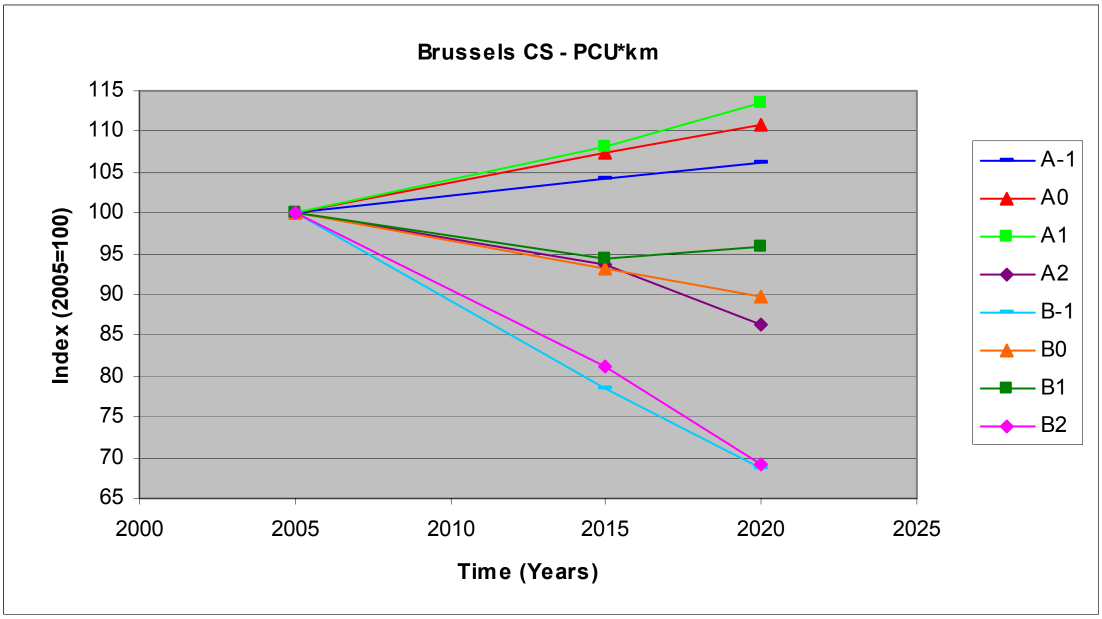


*Figure 5.2.8 Brussels model: PCU*km for the period 6PM-10PM for the years 2005, 2015 and 2020.*

Changes of PCU*km and trips are going in the same direction. However, the effect of variations of Car Ownership and cost do not affect the trips amount and the vehicle*km in the same order:

- the number of trips seems to be more sensitive to the variation in costs;
- the amount of vehicle*km seems to be more sensitive to the variation in car ownership.

In all cases there are trip length increases (for car trips).
This is probably the consequence of the mix between Brussels inhabitants and the suburbs inhabitants.
The car trips evolution are also represented in the next figure showing changes between the 2001 and 2015 horizons for the Brussels and its suburb region.

Average trip lengths

The next table presents the mean travelled distances by car for different scenarios.

Table 5.2.4 Brussels model: Evolution of mean distance per car trips for the 8 scenarios for the years 2015 and 2020

	Mean distances [km]							
	A-1	***A0***	***A1***	***A2***	***B-1***	***B0***	***B1***	***B2***
2005	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
2015	28.5	29.6	29.9	25.1	19.9	24.9	25.3	20.8
2020	28.7	30.1	30.8	23.2	17.4	24.0	25.5	18.0

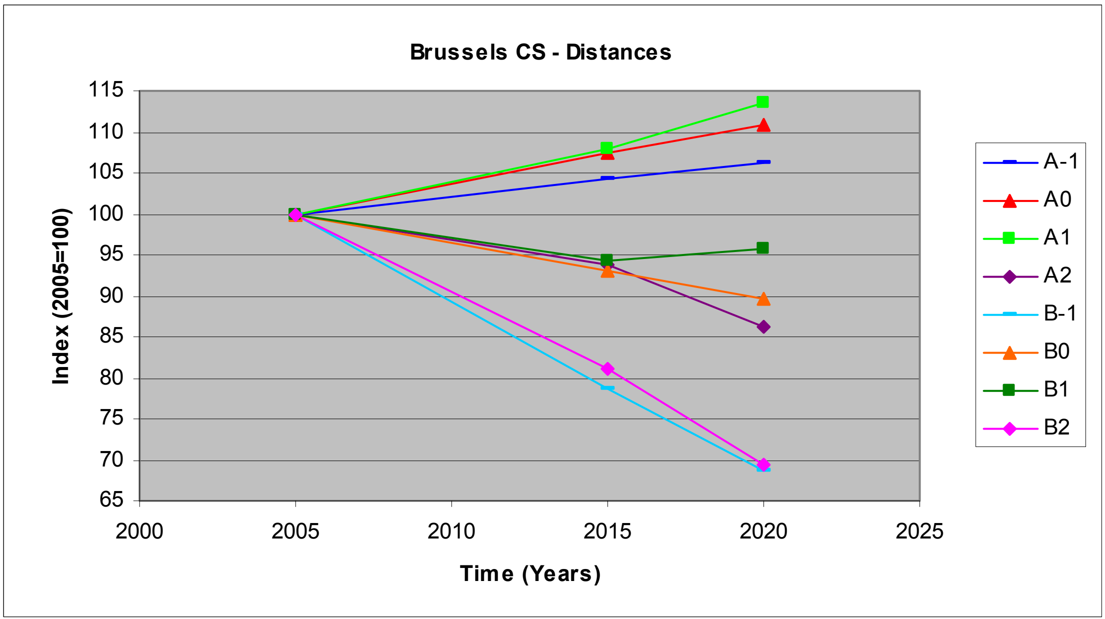


Figure 5.2.9 Brussels model: Evolution of mean distance per car trips for the 8 scenarios for the years 2015 and 2020.

Environment

Consumptions have been computed for the six types of vehicle: diesel, gasoline, electric, hybrid, CNG and hydrogen.
In order to compute these consumption, the variation in terms of fleet composition have been integrated, these are presented in the tables and figures below.

Table 5.2.5 Brussels model: Fleet composition evolution for the 8 scenarios for the years 2001, 2015 and 2020.

				2001				
Fleet composition	*A-1*	*A0*	*A1*	*A2*	*B-1*	*B0*	*B1*	*B2*
CNG	0.3%	0.3%	0.4%	0.3%	0.3%	0.3%	0.4%	0.3%
Diesel	17.0%	17.0%	16.9%	17.0%	17.0%	17.0%	16.9%	17.0%
Electric	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Fuel Cell	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Gasoline	82.3%	82.3%	82.2%	82.3%	82.3%	82.3%	82.2%	82.3%
Hybrid	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
				2015				
Fleet composition	*A-1*	*A0*	*A1*	*A2*	*B-1*	*B0*	*B1*	*B2*
CNG	0.3%	0.5%	0.6%	0.5%	0.3%	0.5%	0.6%	0.5%
Diesel	17.0%	24.5%	24.7%	24.2%	17.0%	25.7%	25.6%	25.6%
Electric	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Fuel Cell	0.1%	2.6%	3.1%	2.7%	0.1%	2.5%	3.3%	2.5%
Gasoline	82.3%	69.5%	67.7%	69.7%	82.3%	68.0%	66.3%	68.2%
Hybrid	0.3%	2.8%	3.8%	2.8%	0.3%	3.1%	4.2%	3.0%

				2020				
Fleet composition	*A-1*	*A0*	*A1*	*A2*	*B-1*	*B0*	*B1*	*B2*
CNG	0.3%	0.6%	0.5%	0.6%	0.3%	0.5%	0.4%	0.5%
Diesel	17.0%	25.7%	26.4%	25.0%	17.0%	27.5%	26.5%	27.4%
Electric	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Fuel Cell	0.1%	3.3%	4.6%	3.6%	0.1%	3.4%	7.2%	3.3%
Gasoline	82.3%	66.8%	62.1%	67.2%	82.3%	63.9%	58.1%	64.2%
Hybrid	0.3%	3.6%	6.3%	3.5%	0.3%	4.5%	7.8%	4.4%

No significant difference in terms of fleet composition are present inside year 2001.
Changes to 2015 are quite small because many of the change in vehicle fleet composition only come at the end of the STEPs study period (2020-2030). However, the main changes are:

- a decrease of gasoline vehicles;
- an increase of diesel vehicles;
- no change for electric vehicles;
- a small increasing share of hybrid vehicles;
- an increase of fuel cell car and hybrid vehicles.

Taking into account the vehicle*km and the fleet composition considered above, the consumptions have been computed. The table here below presents the results. The consumptions are presented in terms of fuel, electric power and Hydrogen. The consumptions are related to the various types of fuel used.

Table 5.2.6 Brussels model: Consumptions for the for the 8 scenarios for the years 2001, 2015 and 2020.

				2001				
Consumptions	A-1	A0	A1	A2	B-1	B0	B1	B2
Fuel [L]	1.347.040	1.347.040	1.347.197	1.346.843	1.347.040	1.346.843	1.347.197	1.346.843
Electricity [Wh]	3.727.214	3.727.214	4.618.509	3.719.256	3.727.214	3.726.572	4.618.509	3.726.572
H [kg]	269	269	332	268	269	269	332	269

				2015				
Consumptions	A-1	A0	A1	A2	B-1	B0	B1	B2
Fuel [L]	1.310.023	1.276.280	1.228.659	1.043.163	836.652	1.025.422	995.835	821.420
Electricity [Wh]	3.773.958	7.994.734	7.904.594	6.796.726	2.410.256	6.640.058	6.420.038	5.268.997
H [kg]	273	6.071	6.576	5.222	174	4.854	5.662	3.808
				2020				
Consumptions	A-1	A0	A1	A2	B-1	B0	B1	B2
Fuel [L]	1.263.891	1.221.890	1.127.684	887.957	676.321	905.599	852.699	630.525
Electricity [Wh]	3.771.572	9.131.263	6.304.576	7.148.550	2.018.207	7.289.115	4.000.719	4.964.191
H [kg]	273	7.818	9.529	6.230	146	6.160	11.653	4.173

Emissions have been computed with the emissions functions issued from MEET study with the distance band definition as given:

- LOCAL (LC): 0 – 3.2 km (reference speed =50 km/h)
- VERY SHORT (VS): 3.2 – 8 km (reference speed =60 km/h)
- SHORT (ST): 8 – 40 km (reference speed =75 km/h)
- MEDIUM (MD): 40 – 160 km (reference speed =90 km/h)
- LONG (LG): >160 km (reference speed =120 km/h)

The computation of the amount of trips and the vehicle*km were required to determine the total amount of emissions (cold emissions factor as well as emission factors). The following points give the pollutant emissions pollutant per pollutant.

Table 5.2.7 Brussels model: Pollutant emissions for the 8 scenarios for the years 2001, 2015 and 2020.

				2001				
Pollutant emissions [kg]	A-1	A0	A1	A2	B-1	B0	B1	B2
CO	32.143	32.143	32.123	32.139	32.143	31.748	32.123	32.140
CO2	4.865.911	4.865.911	4.861.519	4.865.246	4.865.911	4.773.735	4.861.519	4.865.256
NOx	10.027	10.027	10.021	10.026	10.027	9.841	10.021	10.026
VOC	2.536	2.536	2.535	2.535	2.536	2.513	2.535	2.536

				2015				
Pollutant emissions [kg]	A-1	A0	A1	A2	B-1	B0	B1	B2
CO	33.907	13.805	13.103	11.868	25.030	11.598	11.085	9.849
CO2	5.169.134	5.131.899	5.124.450	4.160.724	3.320.795	4.196.222	4.221.888	3.340.676
NOx	10.647	2.605	2.465	2.146	6.904	2.182	2.072	1.764
VOC	2.666	977	861	862	2.090	846	758	730
				2020				
Pollutant emissions [kg]	A-1	A0	A1	A2	B-1	B0	B1	B2
CO	34.477	11.639	10.952	9.263	22.701	9.168	8.689	7.138
CO2	5.269.578	4.971.301	4.965.120	3.578.374	2.844.374	3.802.049	3.882.719	2.644.881
NOx	10.853	1.965	1.875	1.457	5.938	1.552	1.494	1.114
VOC	2.707	769	693	641	1.937	640	612	517

The figures corresponding to these data are presented below.

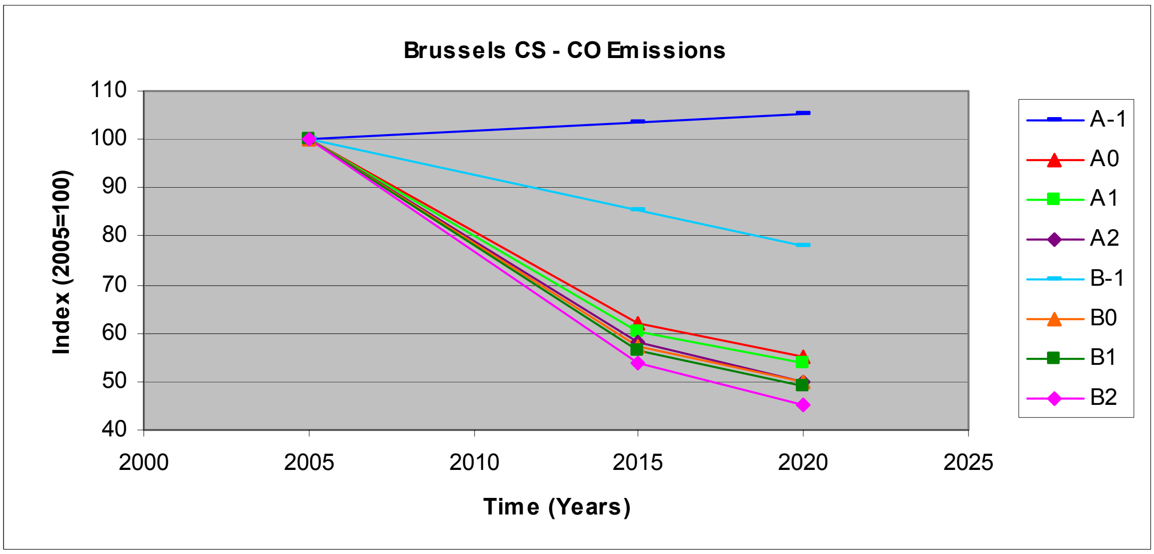


Figure 5.2.10 Brussels model: CO Emissions (period 6PM-10PM) index for the 8 scenarios and the time horizon 2005, 2015 and 2020

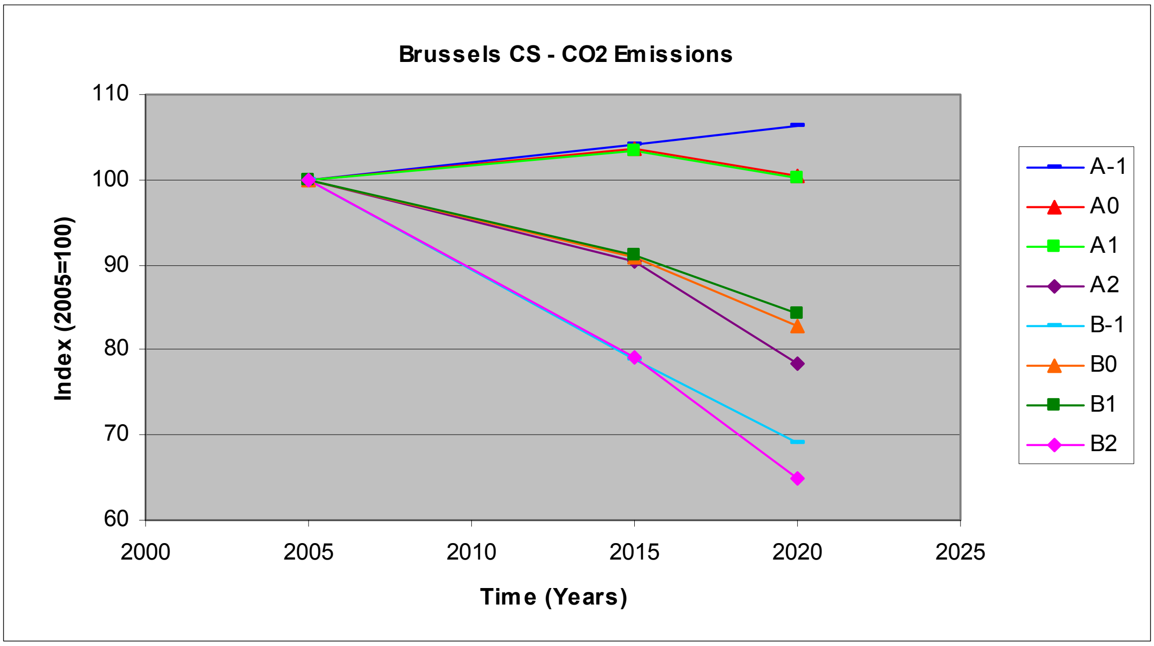


Figure 5.2.11 Brussels model: CO2 Emissions (period 6PM-10PM) index for the 8 scenarios and the time horizon 2005, 2015 and 2020

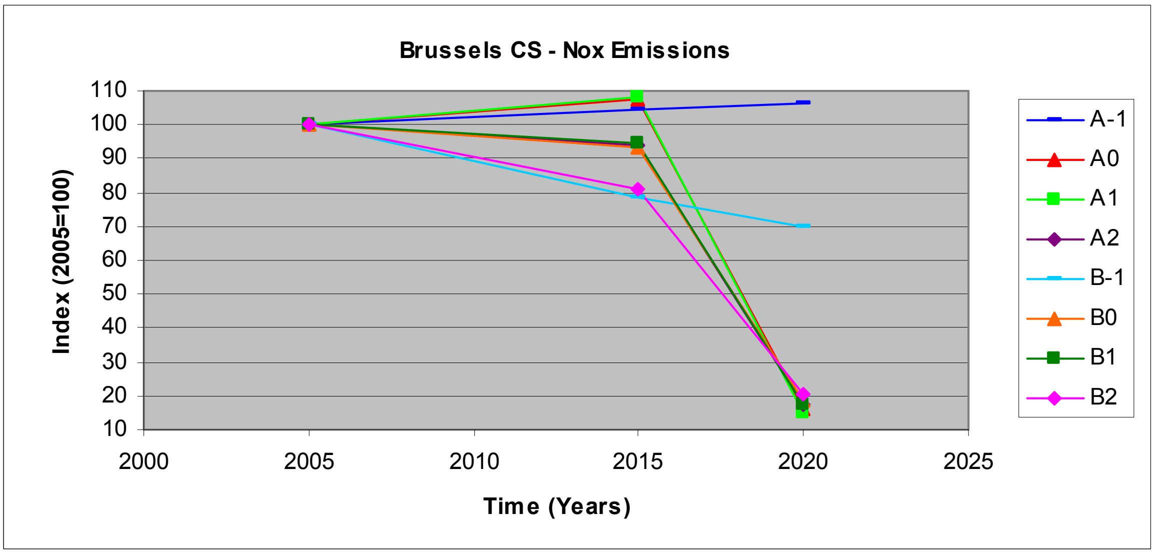


Figure 5.2.12 Brussels model: NOx Emissions (period 6PM-10PM) index for the 8 scenarios and the time horizon 2005, 2015 and 2020

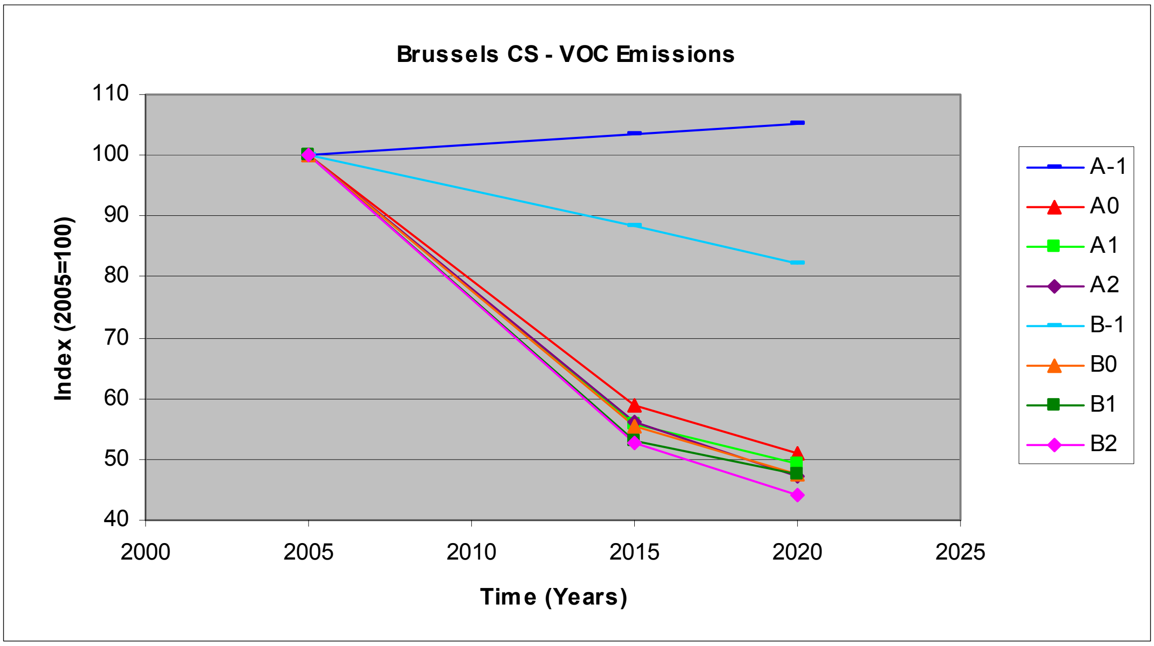


Figure 5.2.13 Brussels model: VOC Emissions (period 6PM-10PM) index for the 8 scenarios and the time horizon 2005, 2015 and 2020

Society

The Car ownership index has already been presented above but is repeated here.

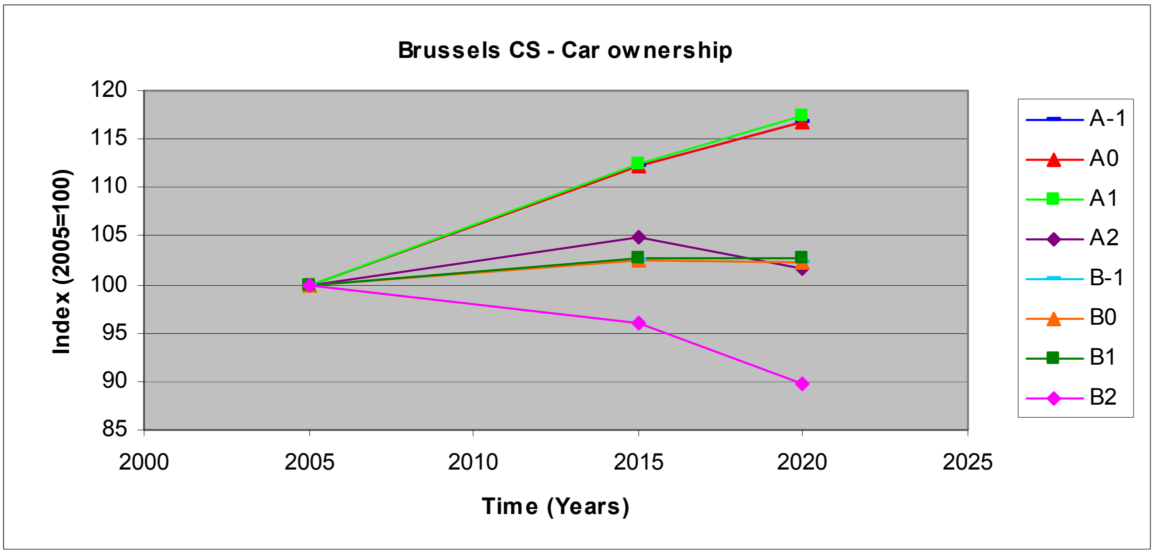


Figure 5.2.14 Brussels model: Car ownership index

5.3 The Dortmund model results

5.3.1 The Dortmund model

The Dortmund model was developed at the Institute of Spatial Planning of the University of Dortmund (IRPUD) for the simulation of intraregional location and mobility decisions in metropolitan areas. The model study area is the metropolitan area of Dortmund with a population of 2.6 million, which is sub-divided into 246 zones (Figure 5.3.1). In addition the model has 54 external zones representing its rural hinterland and most of the Rhine-Ruhr conurbation. (Figure 5.3.2).

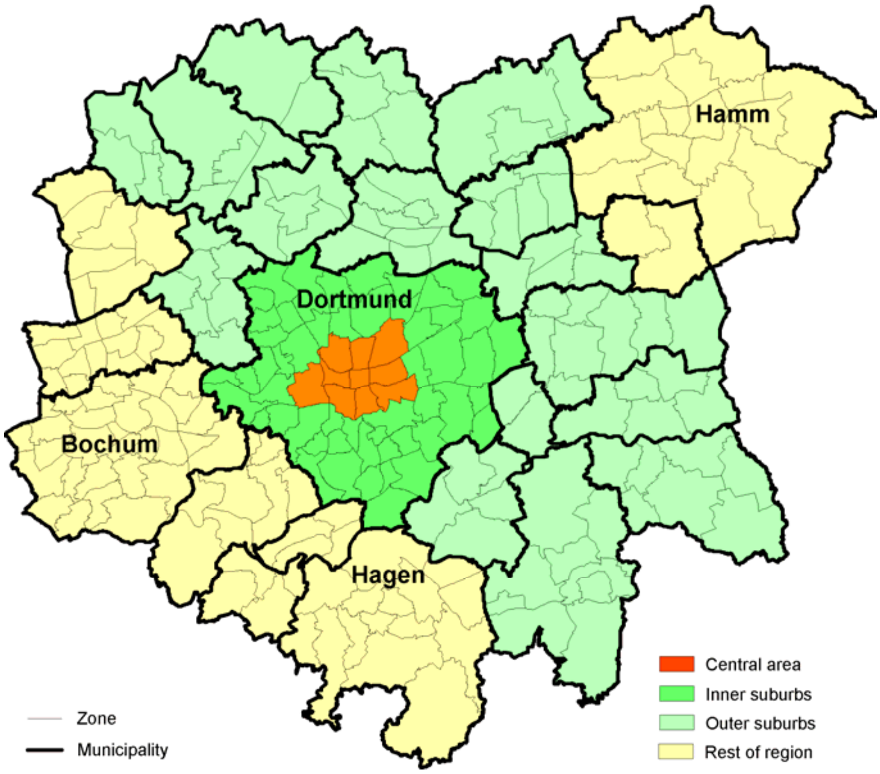


Figure 5.3.1 The Dortmund model internal zones

The zones are connected by transport networks containing the most important links of the road and public transport networks.

The Dortmund model was designed to study the impacts of policies from the fields of industrial development, housing, public facilities, land use and transport. Exogenous inputs are forecasts of total regional employment and net migration of the metropolitan area and global policies (taxation, regulation) and local policies (land use, transport). In the application for STEPs the forecasts of total employment in the study region were adjusted according to the forecasts of the SASI model (see Section 5.3.4).

Figure 5.3.2 Internal and external zones of the Dortmund model

5.3.2 Implementation of the scenarios in the Dortmund model

The Dortmund model was used to simulate fifteen scenarios. Eight of these are the ‘obligatory’ A and B scenarios defined for STEPs. Each of them is a combination of one assumption about fuel supply and one set of policy response (see Table 5.3.1). Seven additional scenarios were simulated to examine the effects of more comprehensive policy combinations (A3, B3 and C3) and even stronger fuel price increases (C scenarios).

Table 5.3.1 Scenario framework

	No-policy	Business as usual	Technology investments	Demand regulation	Integrated policy
Fuel price +1% p.a.	A-1	A0	A1	A2	A3
Fuel price +4% p.a.	B-1	B0	B1	B2	B3
Fuel price +7% p.a.	C-1	C0	C1	C2	C3

The assumptions associated with each scenario are listed in Tables 5.3.2 and 5.3.3. The tables show all assumptions and policies proposed in STEPs Deliverable D 3.

Table 5.3.2 Dortmund Model: Scenario definitions A-1/B-1 to A3/B3

	Measure	Indicator	Annual change (%)				
			A-1 B-1	A0 B0	A1 B1	A2 B2	A3 B3
Socio-economic	Fuel supply	Fuel price	+1% +4%	+1% +4%	+1% +4%	+1% +4%	+1% +4%
	GDP	GDP in 2030[a]	0% -2.5%	-1.5% -4.1%	-1% -3.5%	-2.8% -5.1%	-1.7% -3.9%
	Fuel tax	Petrol	0%	+0.7%	as A0	+4.7%	as A2
		Diesel	0%	+1.5%	as A0	+4,7%	as A2
		Kerosene (% of petrol)	0%	50%	as A0	200%	as A2
	Travel cost due to tax increases	Car cost per km	0%	+0.5%	as A0	+3%	as A2
		Air cost per km	0%	-0.5%	as A0	+3%	as A2
	Telework	Work trips saved	0%	0%	as A0	-0.3%[a]	as A2
	Car sharing etc.	Car ownership	0%	+1%	as A0	-0.6%	as A2
Spatial	Residential	Central area	+	+	as A0	++	as A2
		Inner suburbs	++	++	as A0	+++	as A2
		Outer suburbs	+++	+++	as A0	0	as A2
	Services	Central area	0/+	0/+	as A0	+	as A2
		Inner suburbs	+	+	as A0	++	as A2
		Outer suburbs	++	++	as A0	0	as A2
	Industrial	Central area	0	0	as A0	0	as A2
		Inner suburbs	+	+	as A0	+++	as A2
		Outer suburbs	+++	+++	as A0	0/+	as A2
Travel	European rail	European rail speed	0%	+0.8%	+2%	as A0	as A1
	Regional rail	Regional rail speed	0%	+0.4%	+1.7%	as A0	as A1
	Public transport	Public transport speed	0%	+0.3%	+1.1%	as A0	as A1
	Traffic calming	Car speed in cities	0%	-0.4%	as A0	-1%	as A2
	Road pricing	€ per car-km	0%	+2%	as A0	+6%	as A2
	Public transport cost	Bus cost per km	0%	+0.8%	as A0	-1.7%	as A2
		Train cost per km	0%	+0.8%	as A0	-1.7%	as A2
Freight	Traffic calming	Lorry speed in cities	0%	-0.4%	as A0	-1%	as A2
	Road pricing	€ per ton-km	0%	+2%	as A0	+6%	as A2
	City logistics	Distance in cities	0%	-0.2%	-0.5%	as A0	as A1
		Load factor in cities	0%	+0.8%	+2.4%	as A0	as A1
	Rail freight	Rail freight speed	0%	+0.7%	+2%	as A0	as A1
		Rail freight cost	0%	+0.6%	-1.5%	as A0	as A1
Energy	Energy use car	Petrol per km	-0.5%	-0.5%	-2%	as A0	as A1
		Diesel per km	-1%	-1%	-3%	as A0	as A1
	Alternative vehicles	Car fleet in 2030[b]	2.1%	11.8%	19.3%	as A0	as A1
		Car cost per km	0%	+0.8%	+3%	as A0	as A1
	Energy use rail	Energy per km	-0.8%	-0.8%	-4%	as A0	as A1
	Energy use ship	Energy per km	-0.4%	-0.4%	-1.6%	as A0	as A1

[a] Difference to Scenario A-1 in 2030 (SASI)
[b] Share of alternative vehicles in 2030 (ASTRA)

Yellow: Only for information
Grey: Not used in Dortmund Model

Table 5.3.3 Dortmund Model: Scenario definitions C-1 to C3

	Measure	Indicator	Annual change (%)				
			C-1	C0	C1	C2	C3
Socio-economic	Fuel supply	Fuel price	+7%	+7%	+7%	+7%	+7%
	GDP	GDP in 2030[a]	-5.2%	-5.7%	-4.6%	-10.6%	-9.3%
	Fuel tax	Petrol	0%	-0.7%	as C0	+6%	as C2
		Diesel	0%	-1.5%	as C0	+6%	as C2
		Kerosene (% of petrol)	0%	0%	as C0	200%	as C2
	Travel cost due to tax increases	Car cost per km	0%	-0.5%	as C0	+5%	as C2
		Air cost per km	0%	-1%	as C0	+5%	as C2
	Telework	Work trips saved	0%	+0.5%	as C0	-1%[a]	as C2
	Car sharing etc.	Car ownership	0%	+0.5%	as C0	-1.2%	as C2
Spatial	Residential	Central area	+	+	as C0	+++	as C2
		Inner suburbs	++	++	as C0	++	as C2
		Outer suburbs	+++	+++	as C0	0	as C2
	Services	Central area	0/+	0/+	as C0	+++	as C2
		Inner suburbs	+	+	as C0	++	as C2
		Outer suburbs	++	++	as C0	0	as C2
	Industrial	Central area	0	0	as C0	++	as C2
		Inner suburbs	+	+	as C0	++	as C2
		Outer suburbs	+++	+++	as C0	0	as C2
Travel	European rail	European rail speed	0%	+0.4%	+1%	as C0	as C1
	Regional rail	Regional rail speed	0%	as A0	as A1	as C0	as C1
	Public transport	Public transport speed	0%	as A0	as A1	as C0	as C1
	Traffic calming	Car speed in cities	0%	as A0	as C0	-2%	as C2
	Road pricing	€ per car-km	0%	0%	as C0	+10%	as C2
	Public transport cost	Bus cost per km	0%	as A0	as C0	0%	0%
		Train cost per km	0%	as A0	as C0	0%	0%
Freight	Traffic calming	Lorry speed in cities	0%	as A0	as C0	as A2	as C2
	Road pricing	€ per ton-km	0%	+0%	as C0	+10%	as C2
	City logistics	Distance in cities	0%	as A0	as A1	as C0	as C1
		Load factor in cities	0%	as A0	as A1	as C0	as C1
	Rail freight	Rail freight speed	0%	as A0	as A1	as C0	as C1
		Rail freight cost	0%	as A0	as A1	as C0	as C1
Energy	Energy use car	Petrol per km	-0.5%	as A0	-3%	as C0	as C1
		Diesel per km	-1%	as A0	-4%	as C0	as C1
	Alternative vehicles	Car fleet in 2030[b]	2.1%	14.2%	32.5%	as C0	as C1
		Car cost per km	0%	as A0	+3%	as C0	as C1
	Energy use rail	Energy per km	-0.8%	as A0	as A1	as C0	as C1
	Energy use ship	Energy per km	-0.4%	as A0	as A1	as C0	as C1

[a] Difference to Scenario A-1 in 2030 (SASI)
[b] Share of alternative vehicles in 2030 (ASTRA)

Only for information (yellow)
Not used in Dortmund Model (grey)

However, assumptions and policies that cannot be addressed by the Dortmund model are shaded in grey. Policies that cannot be addressed directly by the model are shaded in yellow; these are considered in the form of assumptions about the likely cost effects of the policies. All assumptions and policies are expressed in terms of annual change from the base year 2005. For instance, a one-percent annual rise of fuel price between 2005 and 2030 results in a rise of 28 percent, an annual rise of 4 percent in a rise of 167 percent, and an annual rise of 7 percent in a rise of 443 percent until 2030. The common assumptions and policies associated with the STEPs scenarios are presented in Section 2.2. Here only the adjustments made for their implementation in the Dortmund model are summarised:

- *A scenarios*. The Scenario A-1 in the Dortmund model is a true do-nothing scenario; i.e. it is assumed that no government policies to respond to the changes in energy prices, such as changes in fuel taxes, promotion of alternative vehicles, road pricing or changes in rail fares or new high-speed rail lines, are implemented. However, it is assumed that technical innovation and market response will lead to moderate reductions in energy use of cars and trains. Assumptions about changes in fleet composition in the policy scenarios were taken from the ASTRA model (see Section 4.2). The additional costs of alternative vehicles are assumed to affect the costs of owning a car.

- *B scenarios. Except the assumed higher fuel prices, the B scenarios in the Dortmund model* are the exact counterpart of the corresponding A scenarios, including the assumptions about the diffusion of energy-saving and alternative vehicles.

- *C scenarios*. The C scenarios in the Dortmund model are based on the assumption that fuel prices will grow dramatically by seven percent per year, or almost fivefold, until 2030, a pessimistic scenario in which besides the growth in fuel consumption by China and India the diminishing fossil fuel resources are taken into account. Again Scenario C-1 is a do-nothing scenario in which no policy response is assumed. However, the remaining C scenarios assume a stronger policy response than the corresponding A and B scenarios. Scenario C0 assumes that governments attempt to compensate their economies for the high costs of transport by tax rebates. Scenario C1 invests more in transport technology to promote energy-saving cars and trains and more alternative vehicles, with the fleet composition taken from the assumptions for the B scenarios in ASTRA (see Section 4.2). Scenario C2 uses heavy fuel taxes and road user charges to save fuel by reducing travel by all modes. In addition Scenario C2 applies strict anti-sprawl land use policies allowing development only on brownfield sites in the inner urban areas of the three largest cities in the metropolitan area, Dortmund, Bochum and Hagen. Scenario C3, which applies the policies of Scenarios C1 and C2 together, is the strongest imaginable policy response.

All scenarios simulated with the Dortmund model were linked to the results of the SASI model (see Section 4.4) by adjusting the regional employment control totals of the model to the GDP forecasts of the SASI model for the ten NUTS-3 regions of the Dortmund metropolitan area. As in the SASI model all the scenarios result in lower regional GDP per capita than in the Scenario A-1, the SASI model predicts GDP per capita in these regions between 1.0 percent (Scenario A1) and 10.6 percent (Scenario C2) lower than in the A-1 Scenario in 2030. These reductions in economic activity affect employment, non-residential construction, household incomes and work trips and transport emissions in the Dortmund model.

Unlike in other applications of the Dortmund model, the impacts of transport infrastructure improvements are not the focus of interest here. For the sake of comparability with the other urban-regional models in STEPs, no different region-specific scenarios of transport network development were associated with the fifteen scenarios. Only network improvements that are more or less certain to occur were included in the network scenario, and the same network scenario was used for all fifteen scenarios. Instead, different assumptions about general changes of travel times and travel costs were made for each scenario, and these were applied to the travel times and travel costs derived from the common network scenario.

5.3.3 Main results from the Dortmund model

This section presents the main results from the Dortmund model following the five themes of the subsequent evaluation Transport, Environment, Society, Environment and Land Use. First the results of the fifteen scenarios for the five themes are discussed with the help of diagrams and maps. The results are then presented in detail in summary tables and bar charts. The section closes with tentative conclusions.

All scenarios were run starting in the year 1970 and ending in the year 2030, and in the time series diagrams used also the development of the indicator of interest in the past is shown to illustrate the continuity – or discontinuity – of the future with the past and the magnitude of the policy responses compared to the long-term trend. All scenarios are identical until the STEPs base year 2005, with the first policies becoming effective in 2006. Each line in the time series diagrams represents one scenario indicated by the scenario acronym and its colour: The A scenarios are shown in blue, the B scenarios in red and the C scenarios in green. The heavy black line represents the Scenario A-1.

Transport

The first eight diagrams (Figures 5.3.3 to 5.3.10) show the results of the fifteen scenarios for selected transport indicators. The diagrams show that indeed all scenarios are identical until 2005 and then diverge due to the assumed further fuel price increases or policies. The difference between the coloured lines representing the policy scenarios and the heavy black line representing the A-1 Scenario indicate the effect of the assumed further fuel price increases or policies.

The first thing to note is that all assumed further fuel price increases and policies work in the same direction: they constrain mobility – despite the fact that some policies are intended to compensate or at least mitigate the negative effects of increasing fuel prices. In no case are these counter-policies strong enough to compensate the fuel price effect.
If one looks at the no-policy scenarios A-1, B-1 and C-1, the results are consistent with expectations. The higher the fuel price increase, the stronger are the effects: As fuel prices

go up, travel distances go down. However, it is instructive to relate this decline to the growth in travel distances in the last three decades. Travel distances per capita per day the urban area (Figure 5.3.3) have more than doubled since 1970. Compared to this growth, the reductions in distance travelled predicted by he model appear rather small.

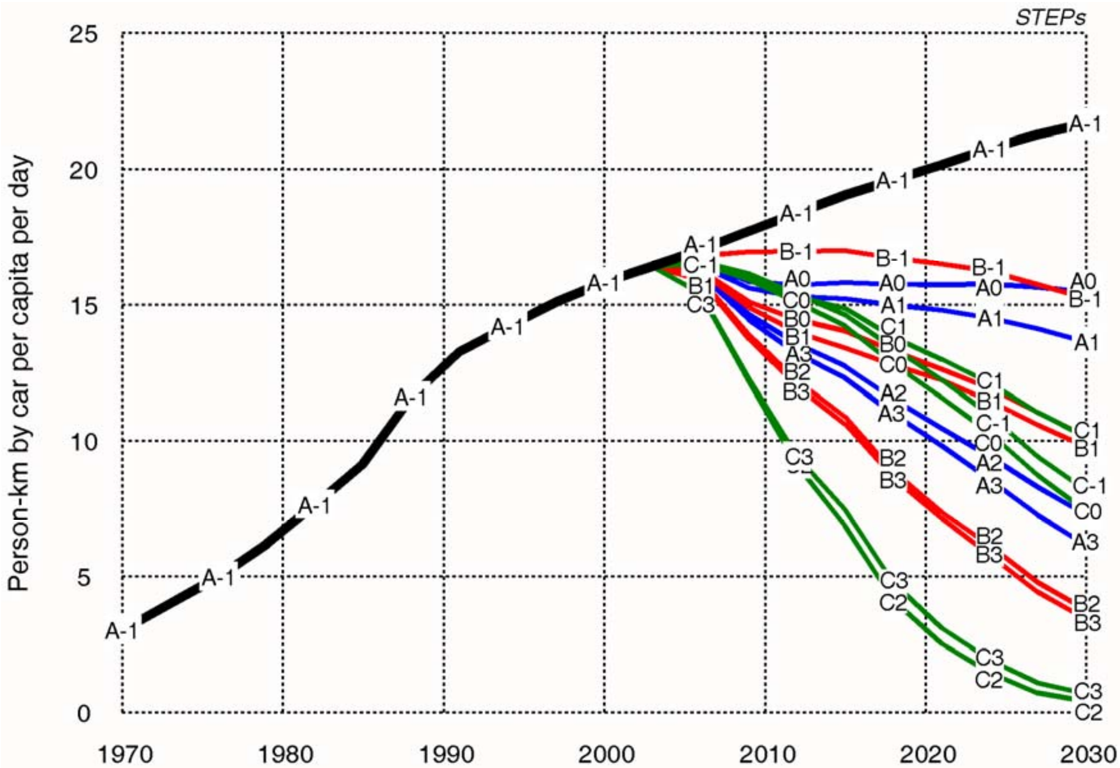


Figure 5.3.3 Dortmund model results: travel distance per capita per day 1981-2030 (km)

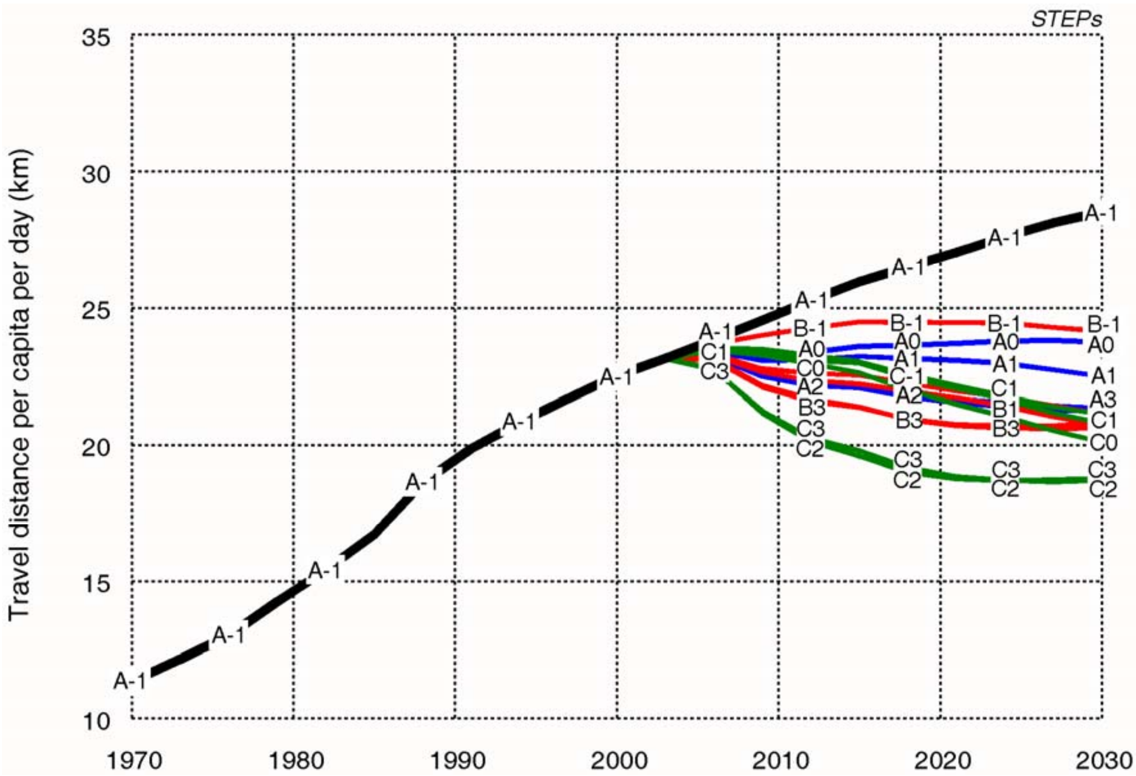


Figure 5.3.4 Dortmund model results: person-km by car per capita per day 1981-2030 (km)

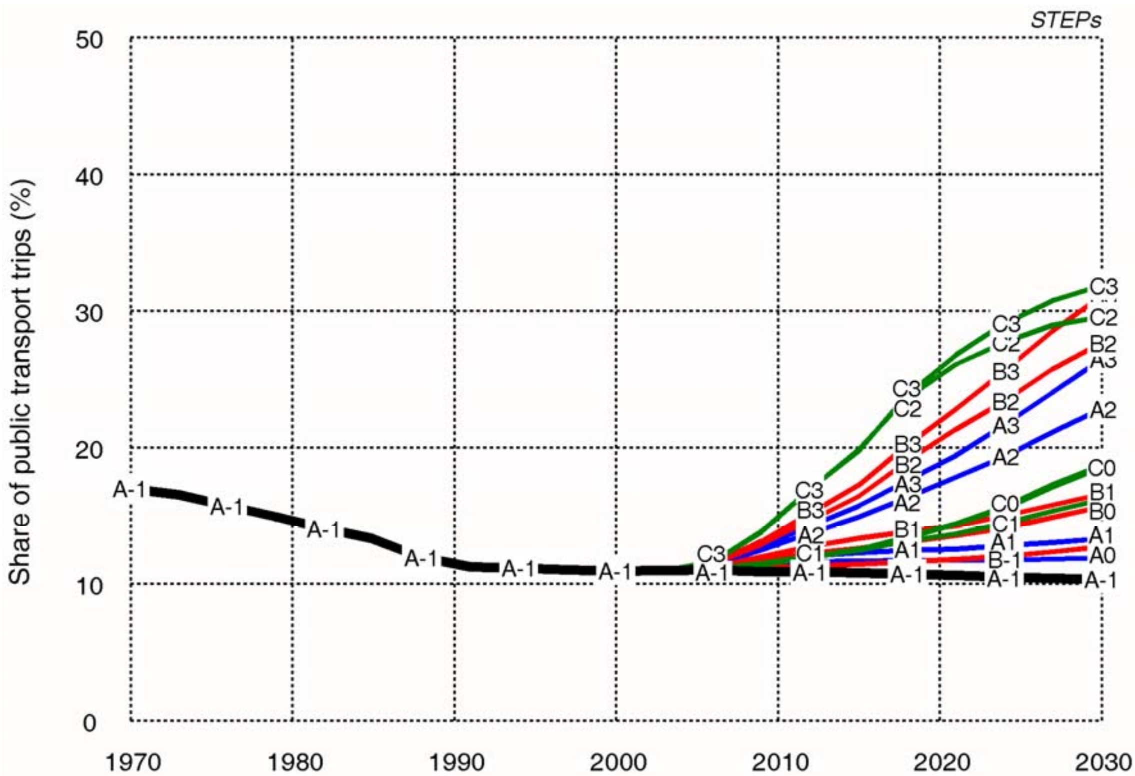


Figure 5.3.5 Dortmund model results: share of walking and cycling trips 1981-2030 (%)

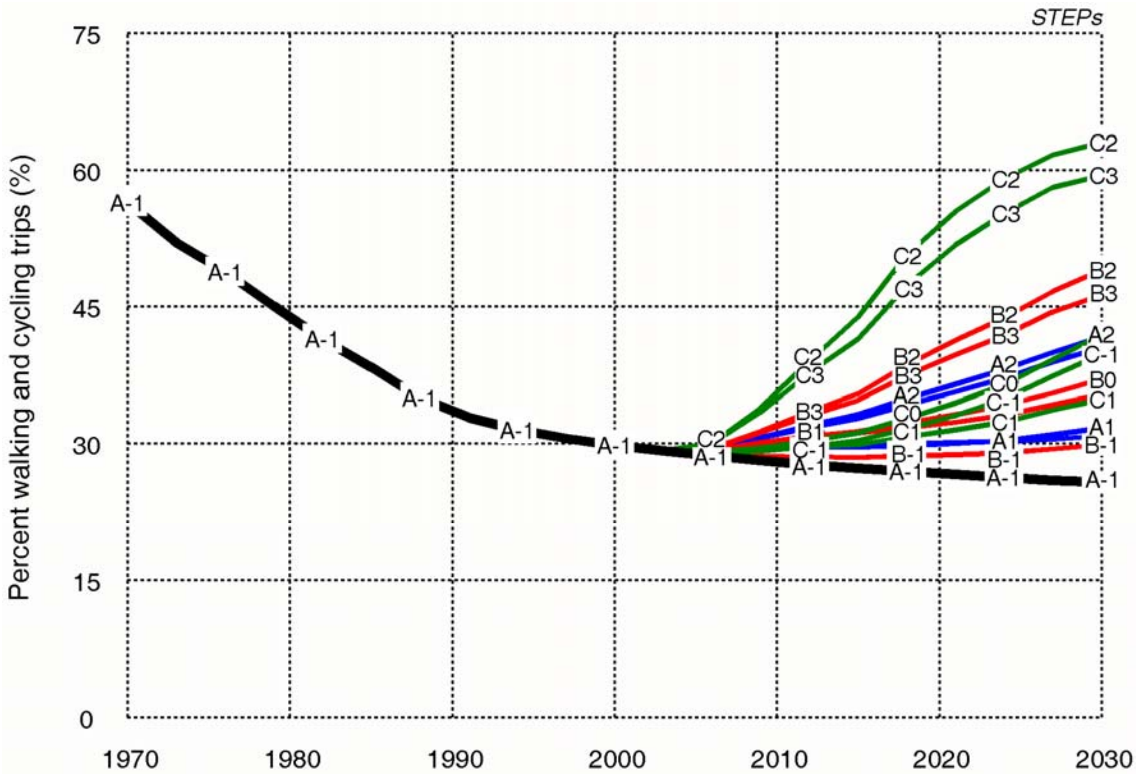


Figure 5.3.6 Dortmund model results: share of public transport trips 1981-2030 (%)

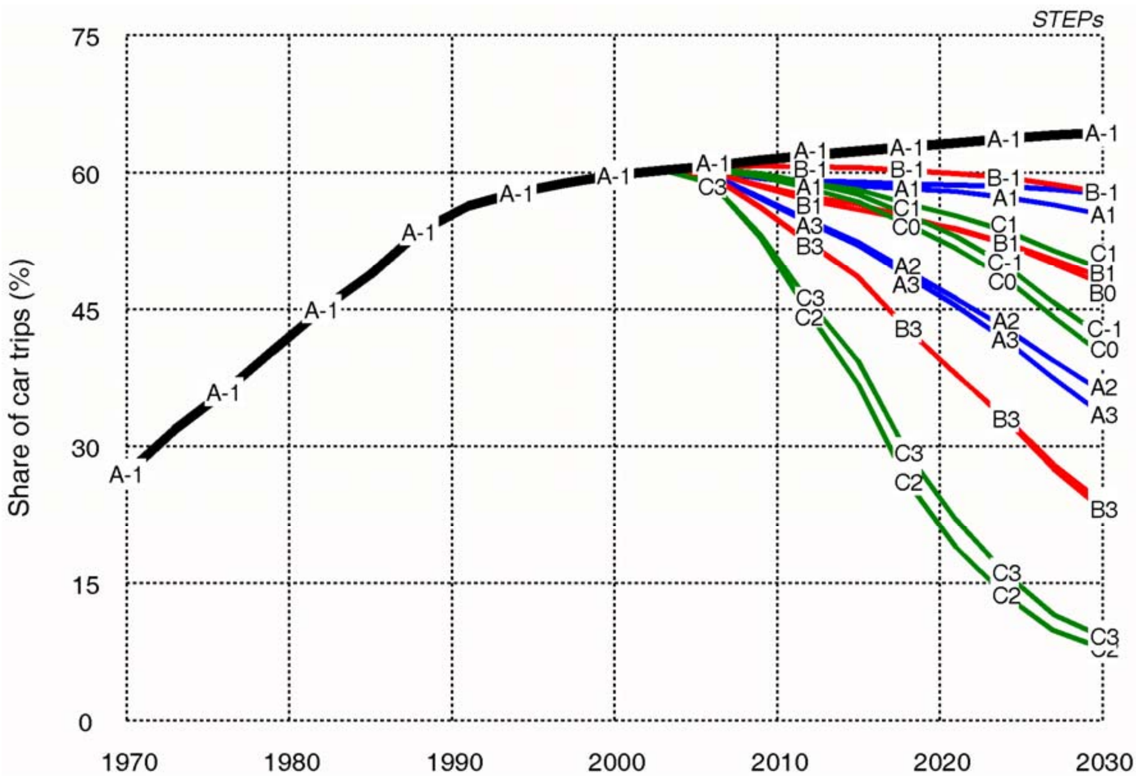


Figure 5.3.7 Dortmund model results: share of car trips 1981-2030 (%)

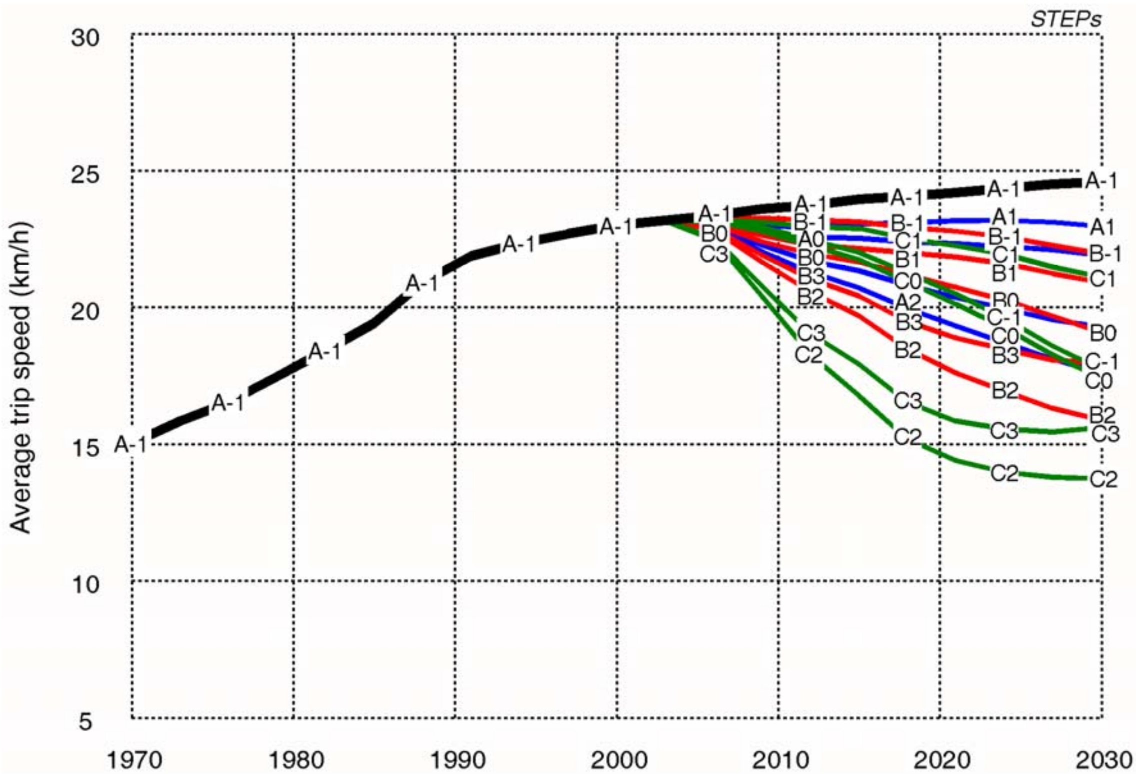


Figure 5.3.8 Dortmund model results: average trip speed 1981-2030 (km/h)

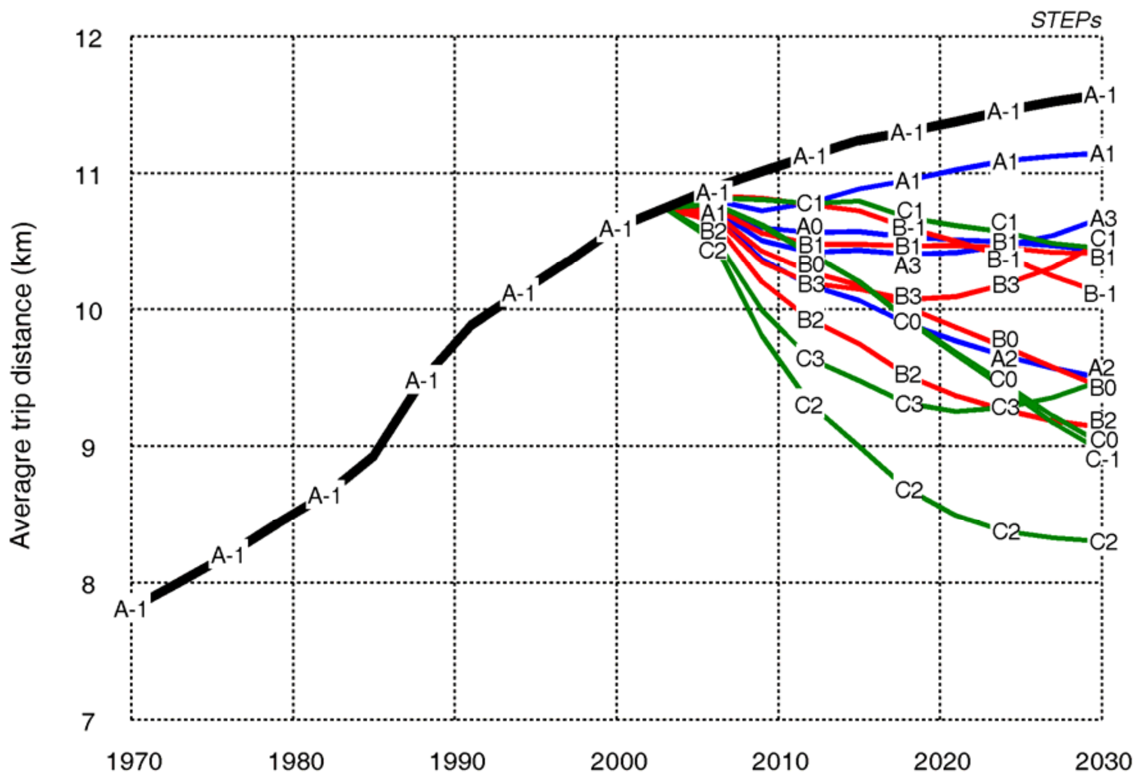


Figure 5.3.9 Dortmund model results: average trip distance 1981-2030 (km)

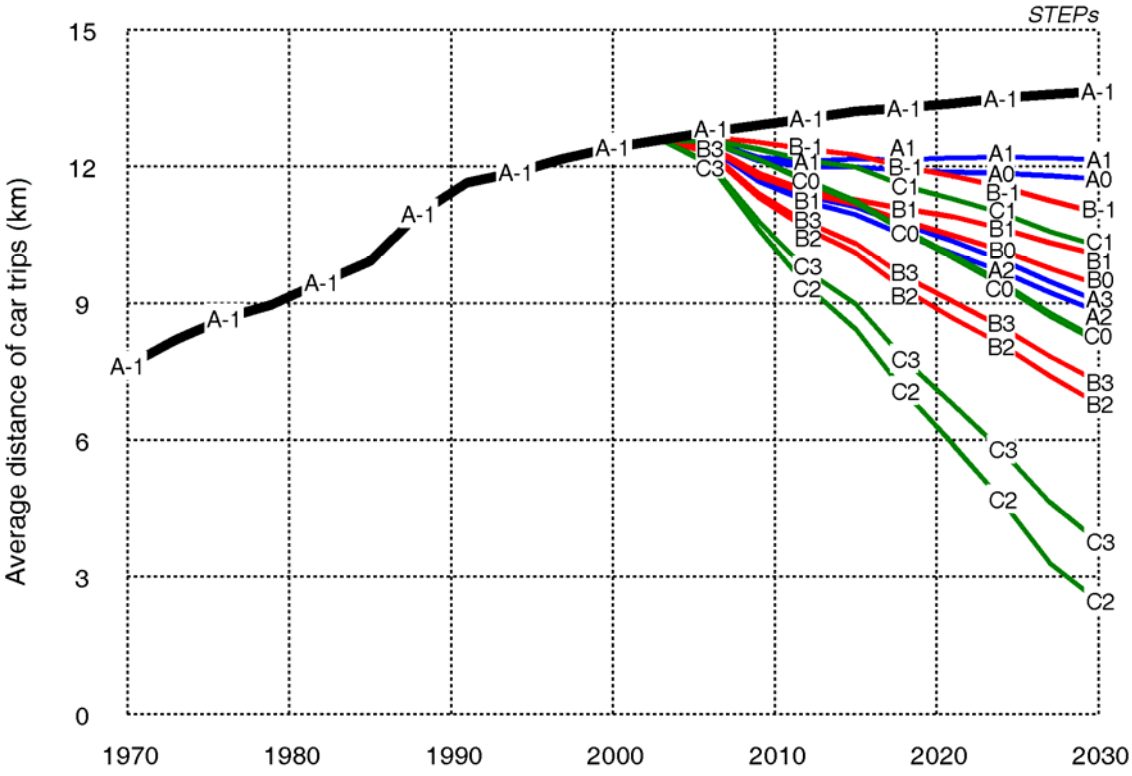


Figure 5.3.10 Dortmund model results: average trip distance of car trips 1981-2030 (km)

The effect is much stronger if only person-km by car are considered (Figure 5.3.4). Distances travelled by car have grown almost fivefold since 1970 and can be expected to continue to grow if fuel remains cheap. If, however, fuel prices grow as assumed in the B and C scenarios, people avoid longer trips by choosing more near-by destinations or avoiding the trip altogether. The policy scenarios tend to reinforce the fuel price effect: in the business-as-usual scenarios A0 and B0 by fuel taxes and road pricing, in the technology investments scenarios A1 and B1 by additional costs of alternative vehicles and in the demand regulation scenarios A2, B2 and C2 by even higher fuel taxes and road user charges. The fuel savings through more energy-efficient cars and the acceleration of trains and buses in scenarios A1, B1 and C1 are not sufficient to offset these cost increases, nor do the fuel tax rebates in scenarios C0 and C1. The strongest distance-reducing effects are found in scenarios A2 and A3, B2 and B3 and C2 and C3 which also apply land use policies. Concentration of development at rail stations is very effective in attracting people to use public transport instead of the car and so reducing car-km travelled. Even more effective is mixed-use high-density development in inner cities as in Scenarios C2 and C3 which reduces car use to almost zero – a somewhat extreme reaction that will be discussed below.

The diagrams (Figures 5.3.5 to 5.3.7) underline the observation that fuel price increases have a major impact on travel behaviour. in all scenarios the proportions of walking and cycling and public transport trips go up and the proportion of car trips goes down compared with the Scenario A-1. As expected the magnitude of the impact is a function of the degree of the price increase, and in general the policies applied reinforce the price effect. If the policies are combined with land use policies as in Scenarios A2 and A3, B2 and B3 and C2 and C3, people can again make more trips by foot or bicycle, public transport use returns to levels used in the 1950s, and car travel to what it used to be in the 1970. Not surprisingly, door-to-door travel speed, which had continuously risen through increasing car use in the last decades (Figure 5.3.8) goes down by the shift to slower modes, despite some increase in car travel speeds due to reduced congestion.

In Scenarios C2 and C3 car use is reduced to less than ten percent of all trips. That may appear a rather extreme response of the model. However, in these two scenarios in 2030 a litre of petrol at the petrol stations costs 22 Euro fuel in today's money and almost 40 Euro including inflation. At the same time household incomes in the Dortmund metropolitan area grow by about ten percent less than in the Scenario A-1 (according to the SASI model, see Section 4.4). This makes it impossible for households to increase their travel budgets in order to maintain their present level of mobility, as it will be shown in Figure 5.3.18. In particular long-distance car commuters will have only two choices: to travel to work by public transport or to move more closely to their place of work – and this is even suggested by the two scenarios which provide extensive new housing construction on brownfield sites in the inner urban areas of the metropolitan area.

The distance-reducing effects of fuel price increases cal also be seen in Figures 5.3.9 and 5.3.10 showing average trip distances of all trips and car trips only, respectively. The reductions are even stronger than in Figures 5.3.3 and 5.3.4 because also less trips, in particular less car trips, are made. In scenarios A3, B3 and C3 average trip distances start to rise again after 2020 because faster trains and buses offer travel alternatives not available in Scenarios A2, B2 and C2. However, if one looks only at car trips (Figure 5.3.10), trip distances continue to go down.

Environment

With the assumed reductions in fuel consumption per car-km, car fuel consumption per capita per day and per car trip can be calculated (Figures 5.3.11 and 5.2.12). As to be expected, the same pattern as in the figures showing distances travelled and distance per trip (Figures 5.3.3-4 and 5.3.9-10) emerges. Again the major factor influencing fuel savings is fuel price. Within each of the three scenario groups with identical assumptions about fuel price, the demand regulation scenarios (A2, B2, C2) are more effective than the technology investments scenarios (A1, B1, C1); in other words, advances in fuel efficiency without restrictions on car use are not sufficient to achieve more sustainable urban transport. This is particular notable in Figure 5.3.12 showing car fuel consumption per car trip divided by average car occupancy. It can be seen that already in the Scenario A-1 average fuel consumption per car trip declines because of more energy-saving cars. However, significant further savings can only be achieved by policy combinations, i.e. policy packages containing both infrastructure and technology and demand regulation policies, as well as rigorous anti-sprawl land use policies (Lautso et al., 2004).

For the calculation of emissions by traffic, driving speed is a key factor (Figure 5.3.13). Unlike average trip speed averaged over all modes, which goes down as people shift to less expensive slower modes (Figure 5.3.8), car speeds go up as congestion is reduced because less cars are on the road – except in the scenarios in which speed limits are imposed. This leads to growing car speeds in the no-policy scenarios B-1 and C-1, while in the policy scenarios the decline in car speeds reflect the severity of the speed limits.

Figures 5.3.14 to 5.3.16 show the results of the calculation of emissions of greenhouse gases and air pollutants by transport based on traffic flows by vehicle type and speed predicted by the Dortmund model. Transport emissions are calculated using speed-related emission functions and information about the changing composition of the vehicle fleet.

CO_2 emission by transport has continuously grown during the past (Figure 5.3.14) because of the combined effect of growing transport volumes and the trend to larger, more fuel consuming cars which has more than offset the effect of decreasing fuel consumption per vehicle. CO_2 emission has currently reached its peak and slightly declines in the Scenario A-1. All scenarios have significant impacts on future CO_2 emissions, i.e. lead to strong reductions. The combination of infrastructure and technology with demand regulation policies (Scenarios A3, B3 and C3) leads to the largest reduction, but this effect is mainly due to demand regulation policies as can be seen by the almost identical CO_2 reduction of Scenarios A2, B2 and C2. Most of the scenarios result in CO_2 emission levels per capita that are below CO_2 emission in 1970.

The past development of NO_x emission (Figure 5.3.15) and PM emission (Figure 5.3.16) is notably different from that of CO_2. There was a strong increase in the emission of both pollutants between 1970 and about 1990. After 1990, enhanced emission standards led to a significant reduction in NO_x and PM emissions. Whereas there is no further reduction in NO_x emissions in the A-1 Scenario, PM emission will further decline through the more restrictive regulations for diesel cars. The reductions of NO_x and PM emissions through fuel cost increases and related policies are similar to those of CO_2.

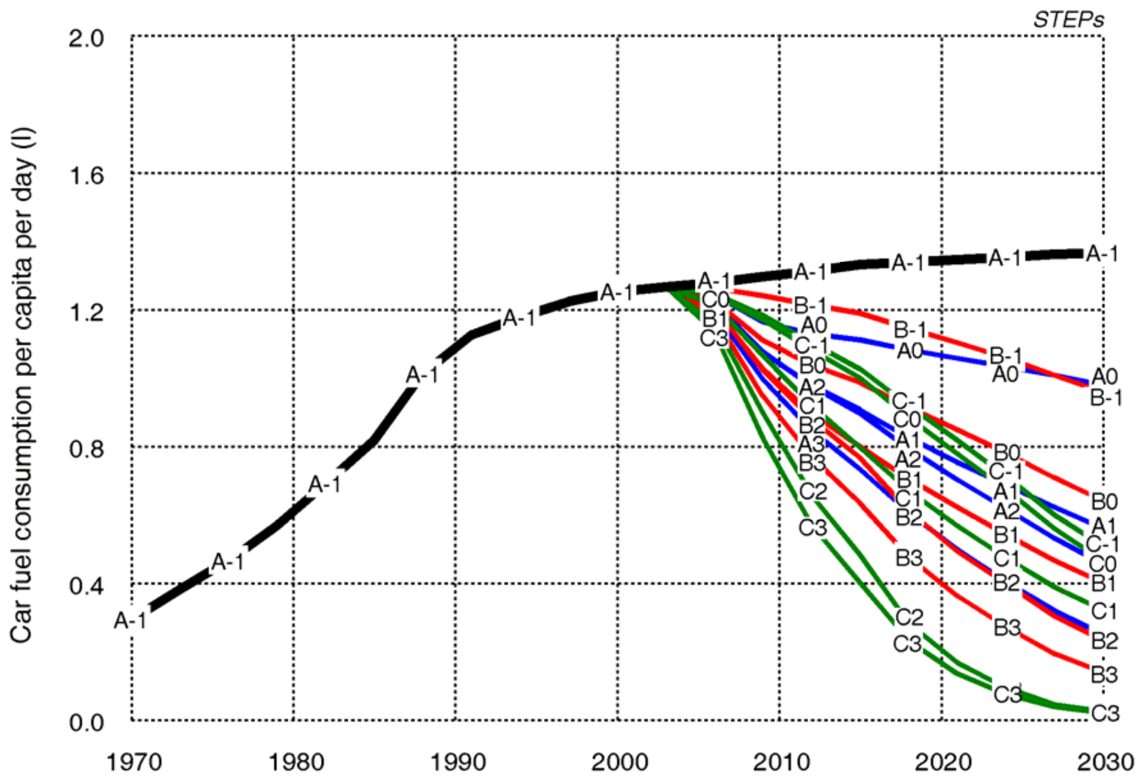


Figure 5.3.11 Dortmund model results: car fuel consumption per capita per day 1981-2030 (l)

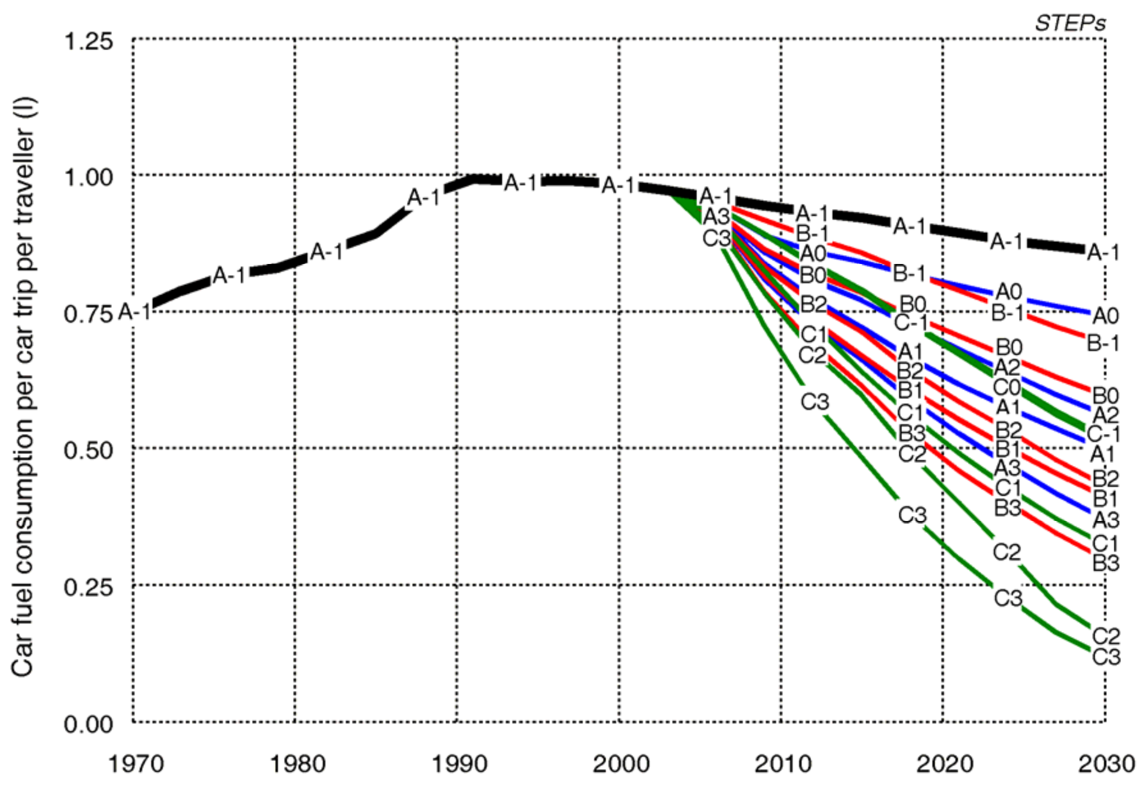


Figure 5.3.12 Dortmund model results: car fuel consumption per car trip per traveller 1981-2030 (g)

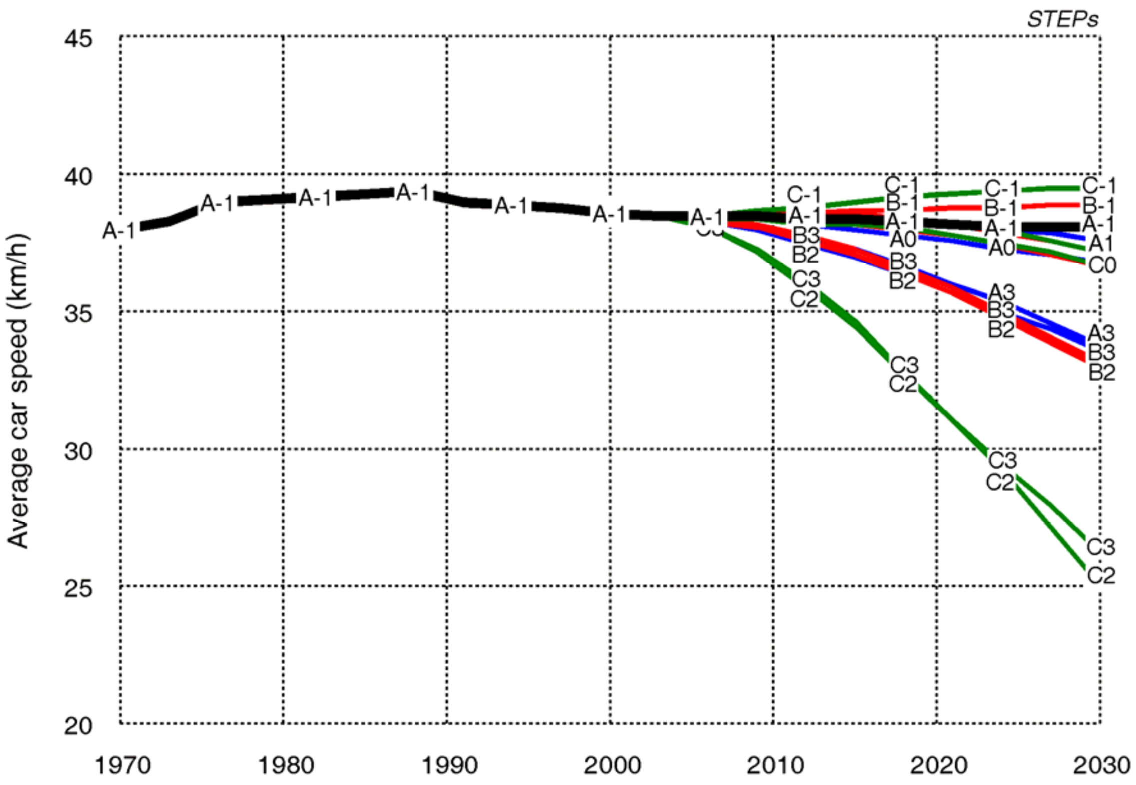


Figure 5.3.13 Dortmund model results: average car speed (km/h) 1981-2030

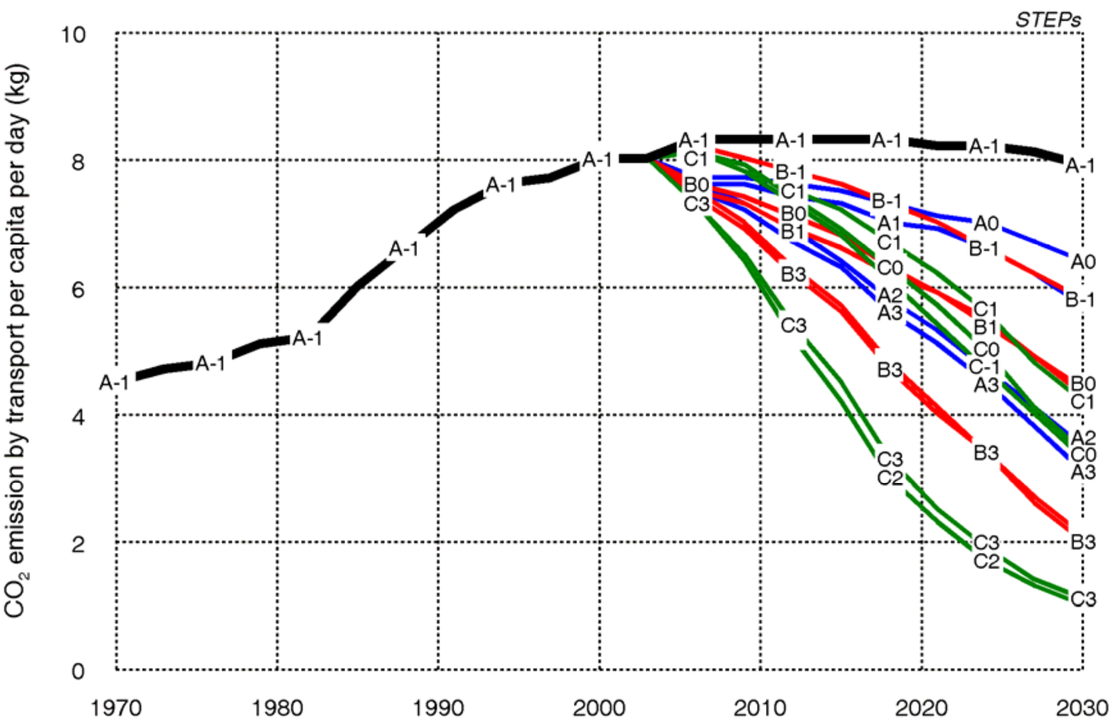


Figure 5.3.14 Dortmund model results: CO_2 emission by transport per capita per day 1981-2030

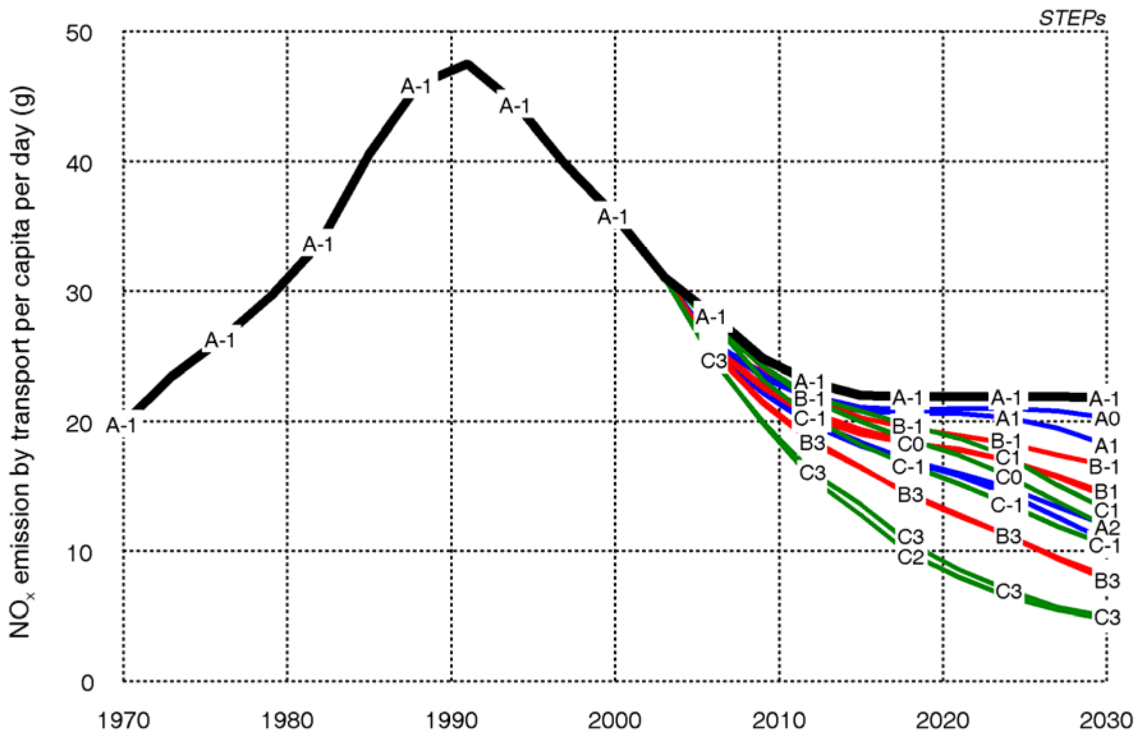


Figure 5.3.15 Dortmund model results: NO_x emission by transport per capita per day 1981-2030

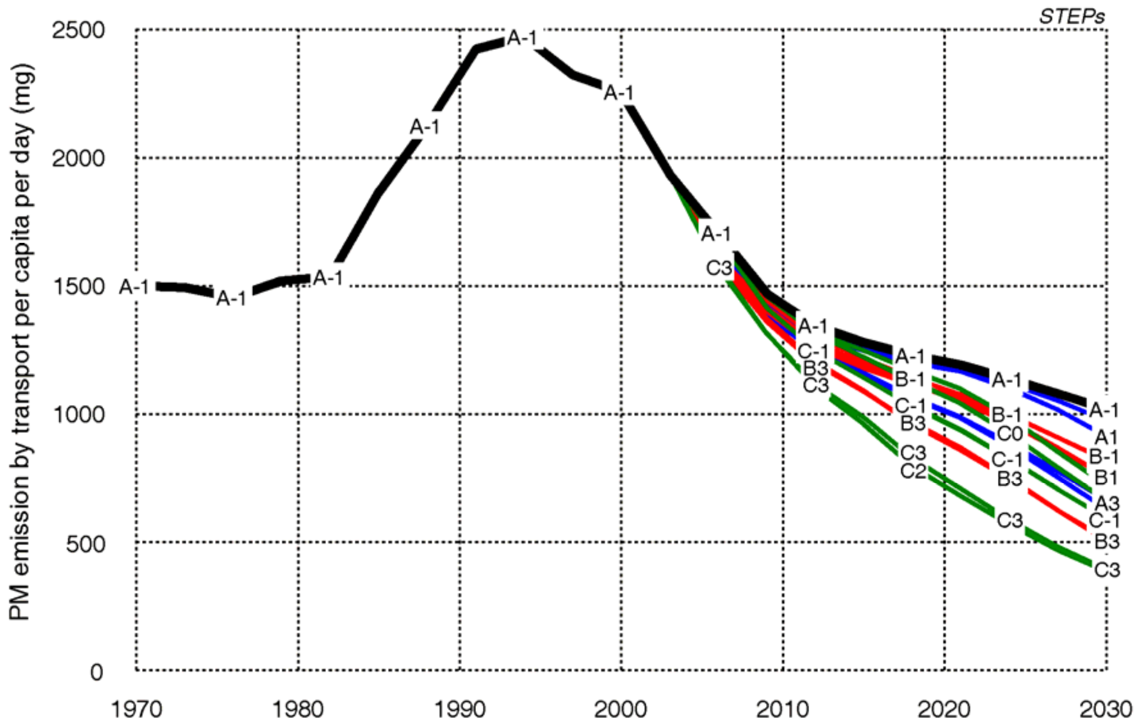


Figure 5.3.16 Dortmund model results: PM emission by transport per capita per day 1981-2030

Society

The fuel price increases and policies assumed in the scenarios have significant impacts also on the economic situation and quality of life of households.

One indicator of this is car ownership (Figure 5.3.17). In all scenarios car ownership is lower than in the Scenario A-1. However, this is not primarily due to rising fuel prices. In Scenario A-1 car ownership, which has almost tripled since 1970, continues to grow to more than 700 cars per 1,000 population. In the no-policy scenarios B-1 and C-1 it grows only slightly less, and even in the demand regulation scenarios A2, B2 and C2 car ownership remains at a level higher than today because these measures affect only the out-of pocket costs of car driving and not the costs of owning a car. In the technology investments scenarios A1, B1 and C1 (and consequently also in the integrated policy scenarios A3, B3 and C3) the higher costs of alternative vehicles are assumed to affect the cost of vehicles and so the cost of owning a car. The results is that in these scenarios car ownership goes down by about 40 percent to less than 450 cars per 1,000 population, the level of the late 1980s.

And even that reduction appears too moderate in the light of the decline in car use in these scenarios shown in Figures 5.3.11 and 5.3.12. The reason for this is that the car ownership submodel of the Dortmund model assumes that households will buy more cars if their travel budgets allow – because cars are used not only for daily travel but also for long-distance and business and holiday trips. This assumption is alright in 'normal' situations with cheap fuel but becomes unreasonable when long-distance car trips become even more unaffordable than short work trips or shopping trips by car. The car ownership submodel calibrated with data of the past was unable to cope with an extreme situation like this.

If daily travel becomes more expensive, people adjust their travel budgets upwards. Figure 5.3.18 shows monthly transport expenditures of households, including the costs of car ownership. It can be seen that travel expenditures have grown significantly since 1970 (more than incomes) and continue to grow until 2030. In all other scenarios households spend more on daily travel than in the Scenario A-1. However, the adjustments of travel budgets are relatively small compared to their long-term growth and much smaller than would have been necessary to maintain the present level of mobility. The reason is that households cannot expand their travel budgets beyond a certain limit in times when household incomes grow less (see the scenario descriptions in Section 5.3.2) and also housing becomes more expensive.

One of the few positive side-effects of increasing fuel prices is that with declining car traffic roads become safer. Figures 5.3.19 and 5.3.20 show the effects on the number of accidents and traffic deaths. The figures reflect the reductions in distances travelled by car shown in Figures 5.3.3-4 and 5.3.9-10. Already in the Scenario A-1 the number of accidents remains almost the stable despite significant growth in car-km travelled (Figure 5.3.3). The number of accidents decreases more than proportionally in all other scenarios because of lower speeds and better safety standards. The effect is more pronounced with respect to traffic deaths per year (Figure 5.3.20), where due to stricter safety standards for cars numbers have gone down already in the past and continue to go down even in the A-1 Scenario.

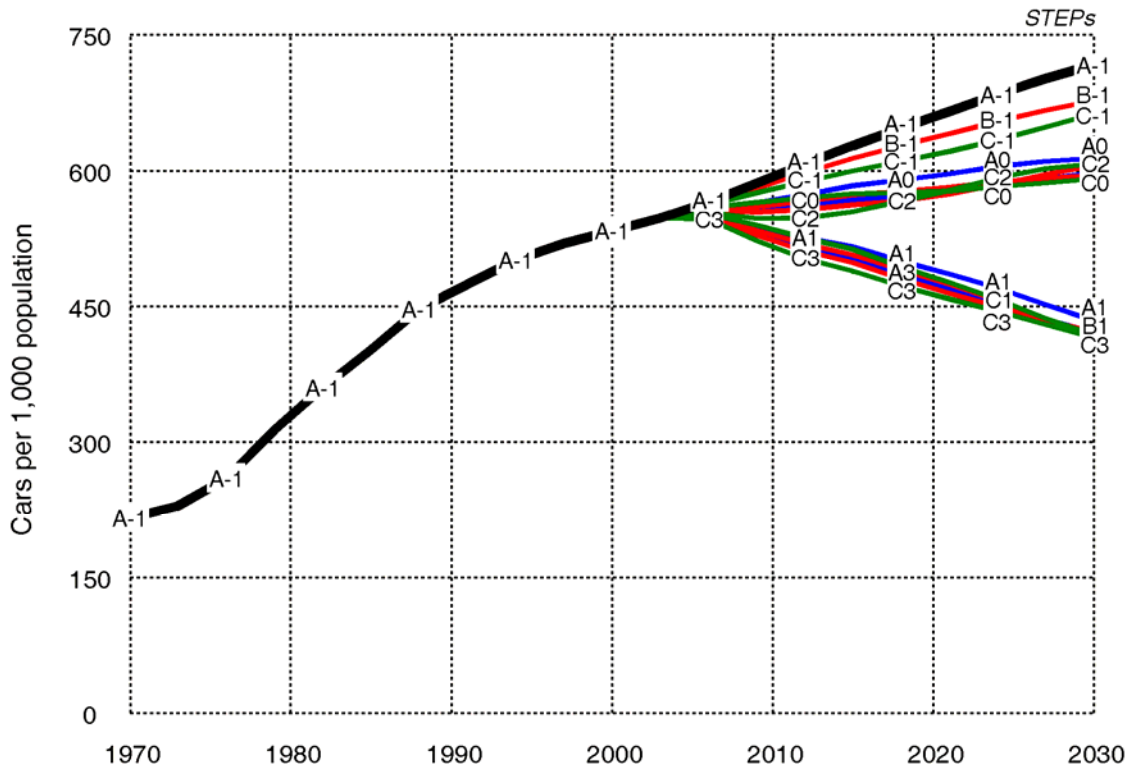


Figure 5.3.17 Dortmund model results: car ownership 1981-2030 (cars per 1,000 population)

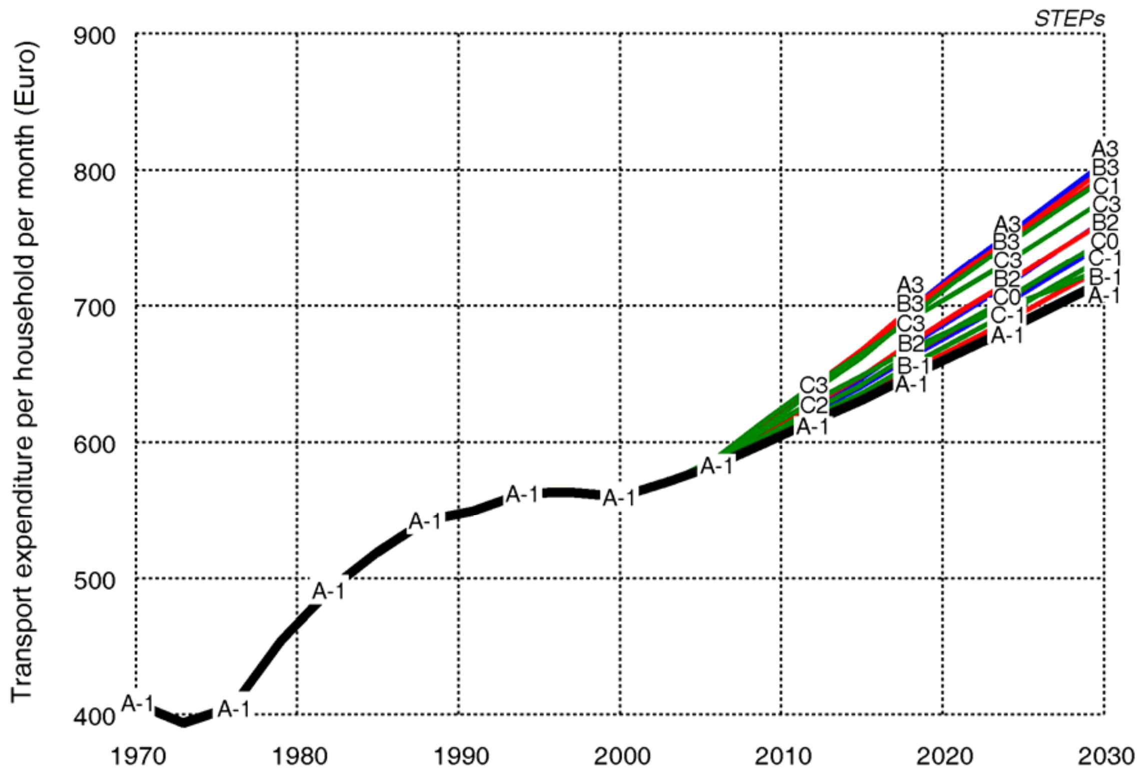


Figure 5.3.18 Dortmund model results: transport expenditure per household per month 1981-2030 (Euro)

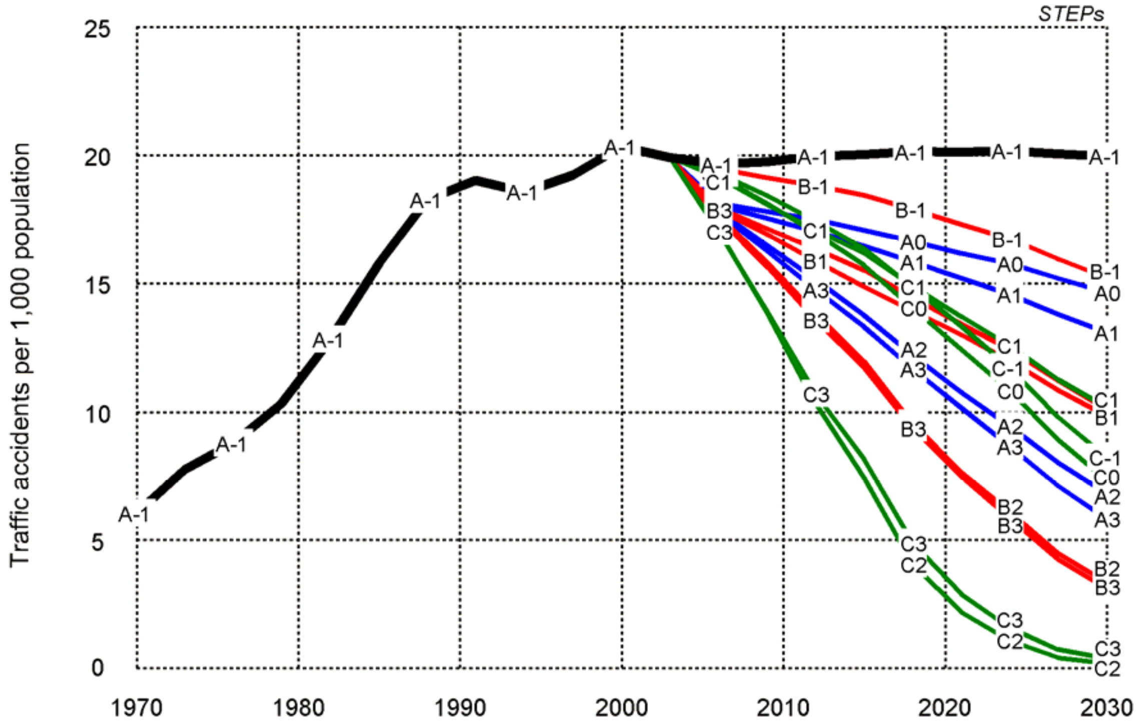


Figure 5.3.19 Dortmund model results: traffic accidents per 1,000 population per year 1981-2030

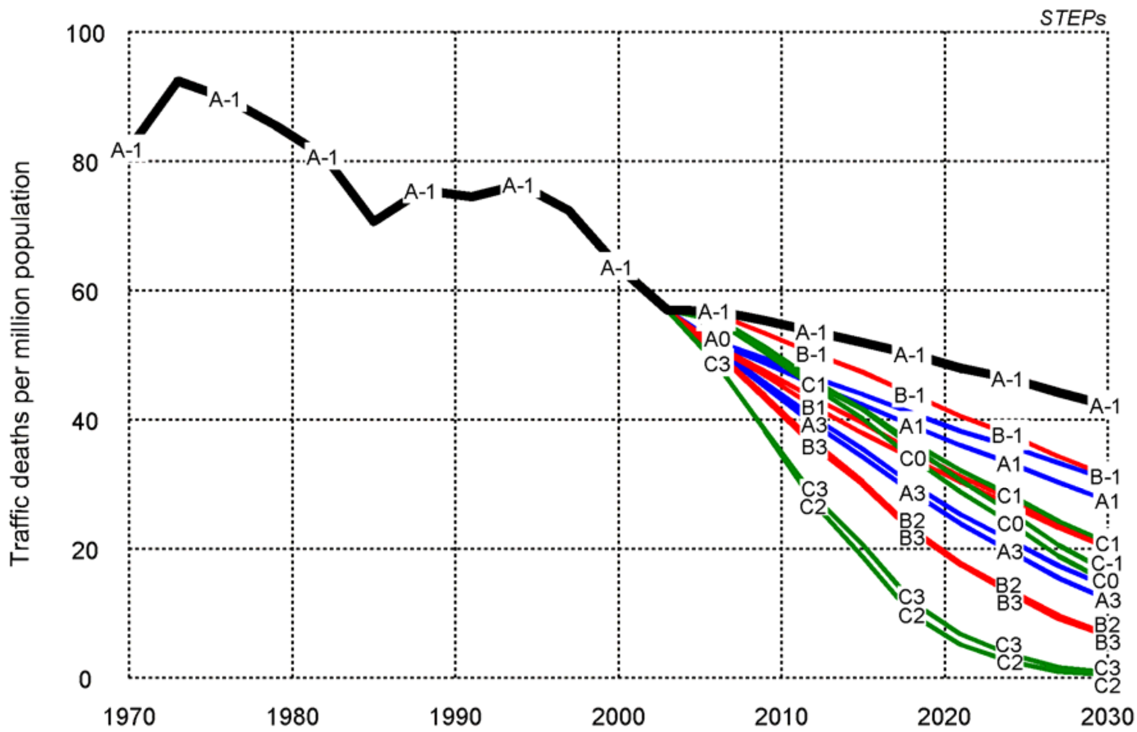


Figure 5.3.20 Dortmund model results: traffic deaths per million population per year 1981-2030

Accessibility

Accessibility is the product of an urban transport system. Accessibility indicators express the ease by which relevant destinations, such as work places, shops, high schools or the city centre can be reached from residential locations or, vice versa, how much market potential, e.g. household purchasing power, can be attracted to a potential retail location. Accessibility is therefore a key factor in location choice of developers, households and firms.

There are several ways to calculate accessibility indicators. The most commonly used is potential accessibility. Potential accessibility is defined as the total of destinations that can be reached from a location weighted by an inverse function of the travel time or travel cost needed to reach them, or both. Figure 5.3.21 shows the spatial distribution of potential accessibility in the Dortmund metropolitan area aggregated over all modes and several types of destinations (the component accessibility indicators are presented in Tables 5.5-6 and Figure 5.3.31 below). The 3D surface shows that accessibility is highest in the central areas of Dortmund and neighbouring Bochum and slopes down towards the outer suburbs at the periphery of the metropolitan area.

Figure 5.3.22 shows the development of the same aggregate accessibility over time. It can be seen that accessibility increased in the 1970s and 1980s due to massive improvements in transport infrastructure, but levelled off in the 1990s and even declines slightly until 2030 due to increasing road congestion in the Scenario A-1. Accessibility declines even faster in all other scenarios. This is mostly due to the shift from car travel to the slower modes of public transport and walking and cycling shown in Figures 5.3.5-7 and the resulting decline in average trip speeds shown in Figure 5.3.8. The decline in accessibility would be even larger without the massive shifts to more near-by destinations manifested in Figures 5.3.3-4 and 5.3.9-10. Again the strongest effects are associated with the cost increases in the demand regulation scenarios A2, B2 and C2 and consequently also the integrated policy scenarios A3, B3 and C3.

Figures 5.3.23 and 5.3.24 show the spatial distribution of the effects of the two integrated policy scenarios B3 and C3. The 3D surfaces show differences in accessibility between the two scenarios and the Scenario A-1 in 2030 in percent. The darkest 'valleys' indicate the areas where accessibility declines most; these are the outer suburbs and rural areas at the fringe of the metropolitan area which depend most on the car, whereas areas near rail stations are less affected.

The two figures differ because they represent different land use policies. Figure 5.3.23 at the top of the page shows less decline in accessibility as in Scenario B3 there is more decentralised development at commuter rail stations all over the metropolitan area, whereas Figure 5.3.24 at the bottom has larger and more contiguous areas of low accessibility because in Scenario C3 development is concentrated in three major centres only.

The difference between the two figures underlines the important role of land use planning in times of energy shortages or significant increases in fuel prices. This will be discussed in the following section.

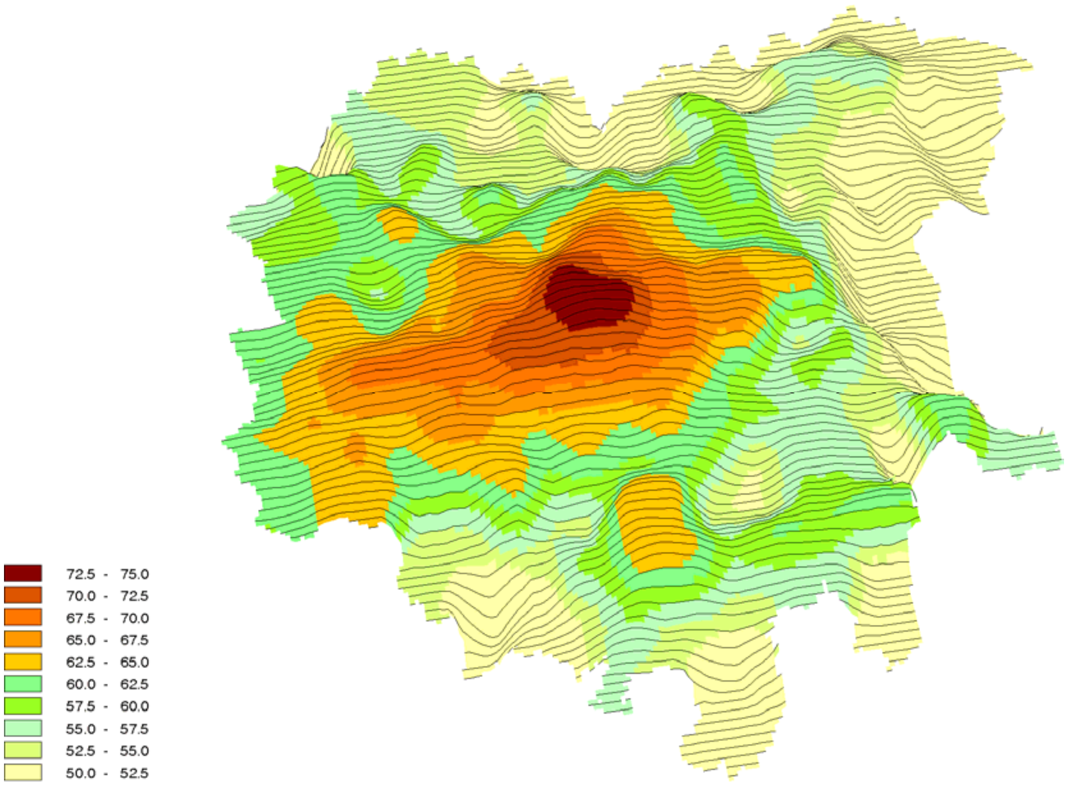


Figure 5.3.21 Dortmund model results: accessibility in Scenario A-1 2030 (0-100)

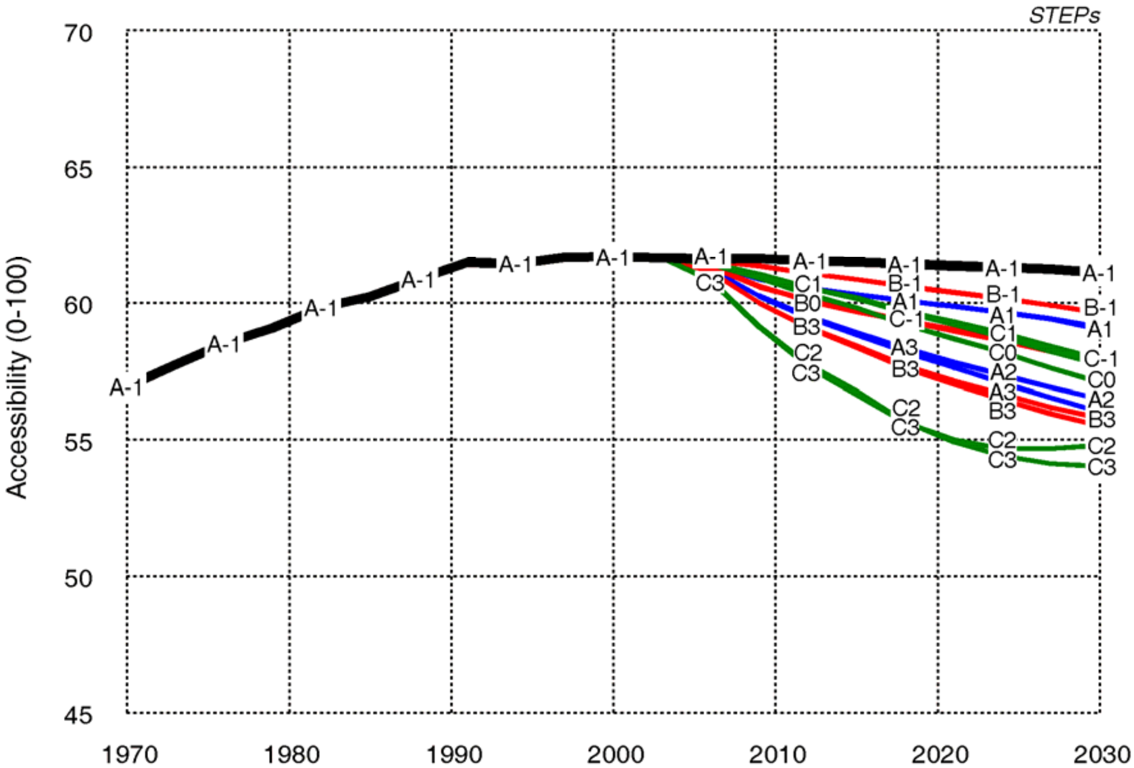


Figure 5.3.22 Dortmund model results: accessibility 2005-2030 (0-100)

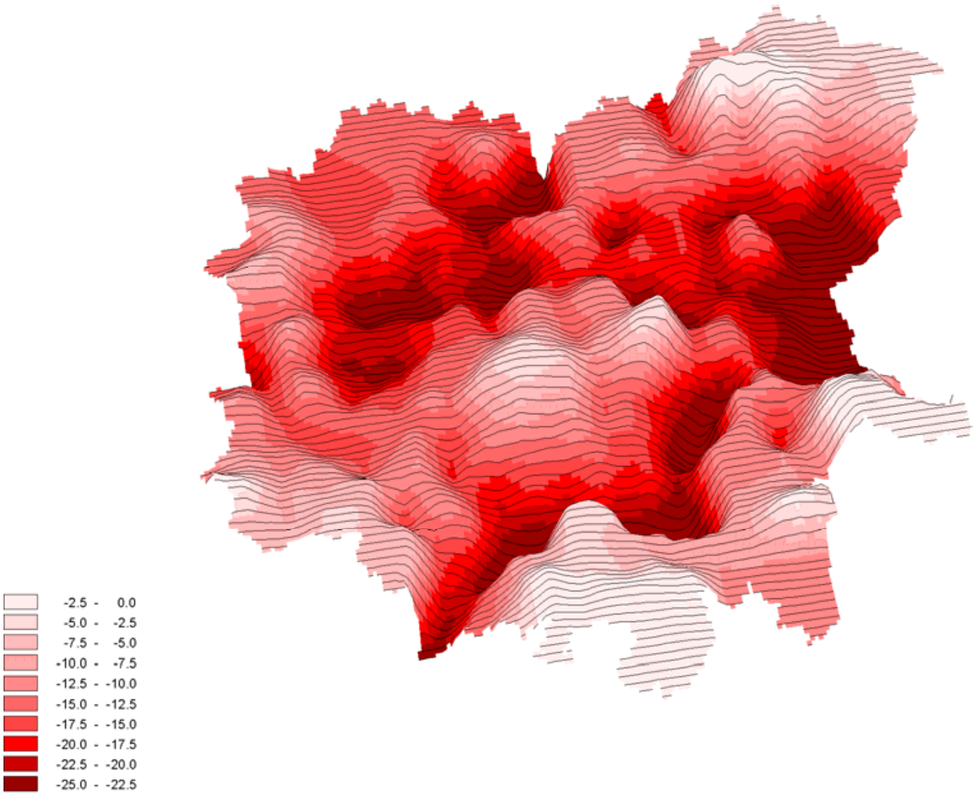


Figure 5.3.23 Dortmund model results: accessibility in Scenario B3 v. Scenario A-1 in 2030 (%)

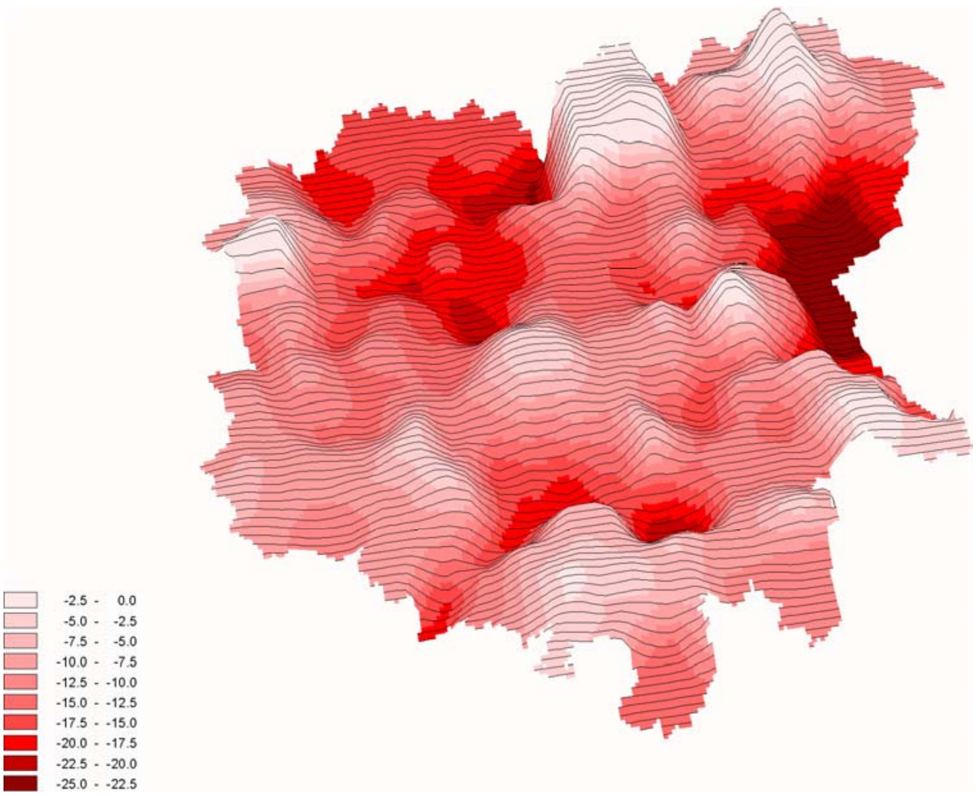


Figure 5.3.24 Dortmund model scenario results: accessibility in Scenario C3 v. Scenario A-1 in 2030 (%)

Land use

It is common knowledge among urban planners that the massive outflow of people to the suburbs in the last decades would not have been possible without the automobile and cheap fuel. In fact suburbanisation has gone hand in hand with growth of car ownership and decline of fuel prices in real terms. If, as in the scenarios examined in STEPs, fuel prices grow and car ownership goes down, will people leave the suburbs and return to the cities?

The simulations with the Dortmund model show that this cannot be expected without policy intervention. The investments of suburban households in home ownership are so large that even significant increases in the costs of car travel will induce them to give up their house and move back into a flat in the inner city – as long as they have alternatives, such as travelling by public transport or choosing a job nearer to their home. Only in extreme cases of long-distance commuting from rural areas in which there are neither acceptable public transport connections nor job alternatives, a move will be the only choice. The effects of the fuel price increase and associated policy scenarios on the distribution of population and employment in the urban area are therefore negligible except in the six scenarios in which land use policies are applied.

Figures 5.3.25 and 5.3.26 show the development of the shares of population and employment in three subregions of the Dortmund metropolitan area between 1970 and 2030 (see Figure 5.3.1): the central area, the inner suburbs and the outer suburbs in percent of the total of the three subregions. It can be seen that both population and employment in the central area have declined continuously since 1970 and are likely to continue to decline in the future – though employment will remain more centralised in the inner city, partly by displacing housing. The scenarios without land use planning policies (A0, A1, B0, B2, C0, C1) are not visible in the two diagrams because they differ only marginally from the A-1 Scenario (see Tables 5.3.4-5 and Figure 5.3.31). The remaining scenarios with land use policies differ from the A-1 Scenario: In Scenarios A2/A3 and B2/B3 the strategy of decentralised concentration leads to clustering of population and workplaces in all three subregions, whereas the compact city strategy applied in Scenarios C2/C3 results in massive shifts of both population and employment form the outer suburbs to the inner suburbs and the central area.

Figures 5.3.27-28 and 5.3.29-30 show the locations of the new concentrations of population and workplaces in the urban area resulting from the two land use strategies as differences in population compared with the A-1 Scenario in 2030. It is important to note that these massive shifts of population and workplaces were achieved by applying normal statutory land use planning instruments. However, these changes assume a degree of consensus and co-operation among core cities and suburban municipalities unimaginable in Germany today, where the current system of local taxes effectively forces municipalities to compete against one another for tax paying firms and households.

However, as the previous section has shown, regions with strong anti-sprawl land use planning perform better in terms of environmental quality and sustainability and are better prepared to cope with fuel shortages and high fuel prices.

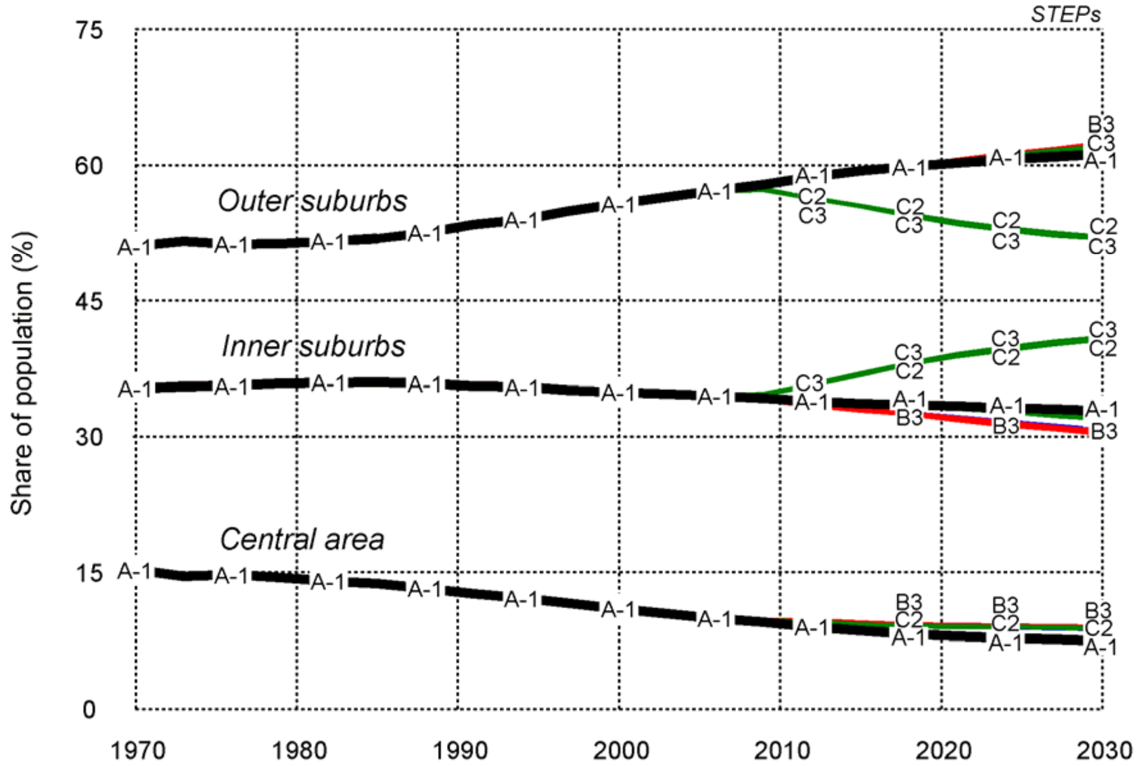


Figure 5.3.25 Dortmund model results: share of population in subregions 1970-2030 (%)

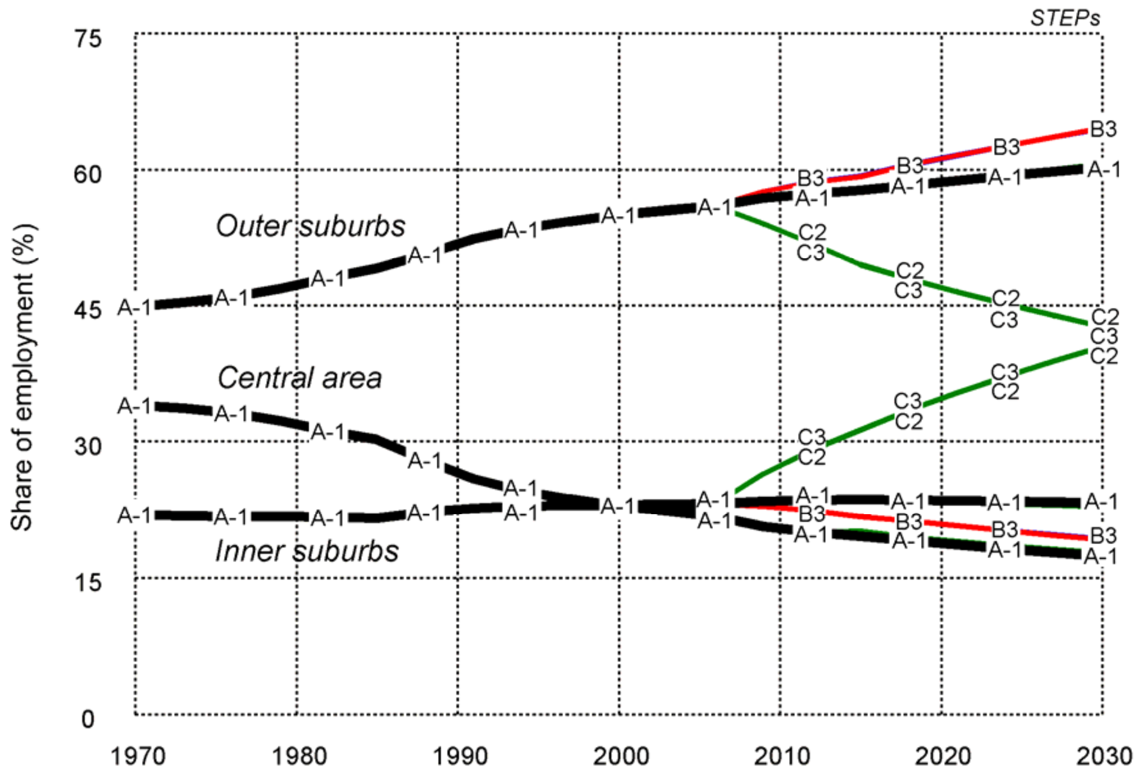


Figure 5.3.26 Dortmund model results: share of employment in subregions 1970-2030 (%)

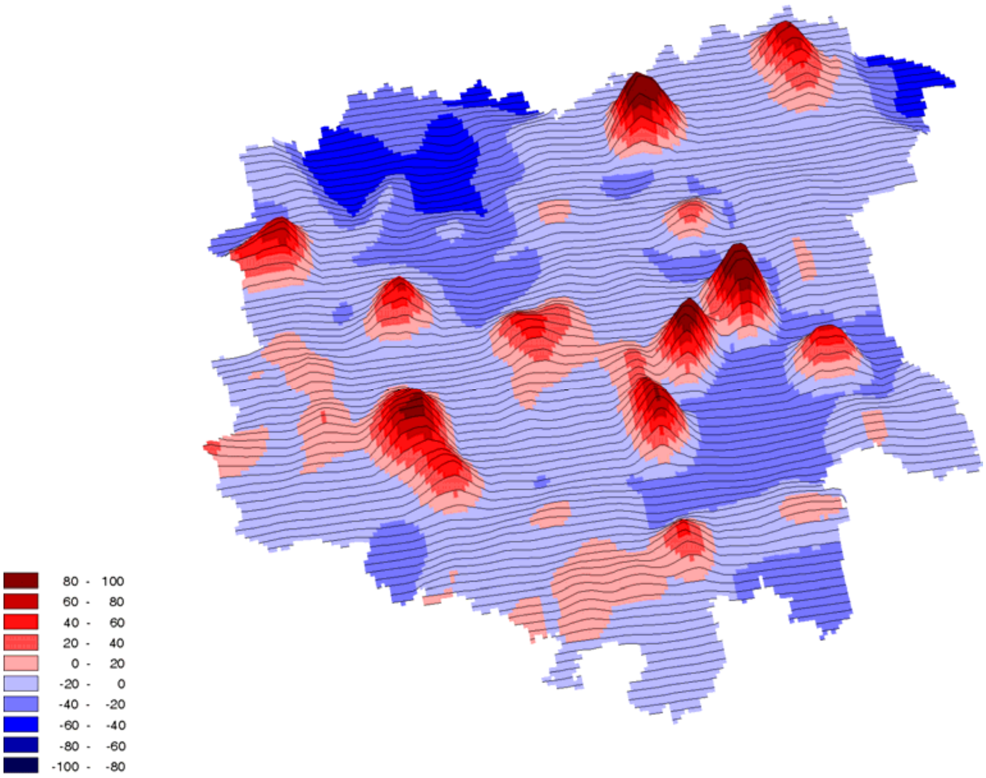


Figure 5.3.27 Dortmund model scenario results: population in Scenario B3 v. Scenario A-1 in 2030 (%)

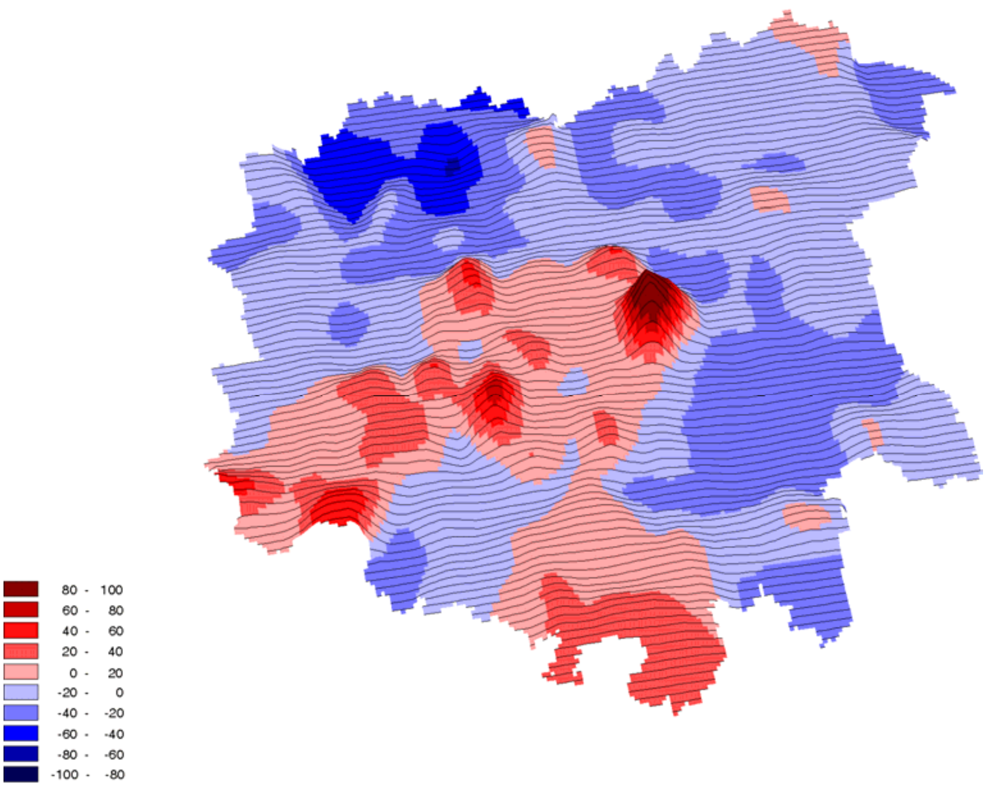


Figure 5.3.28 Dortmund model scenario results: population in Scenario C3 v. Scenario A-1 in 2030 (%)

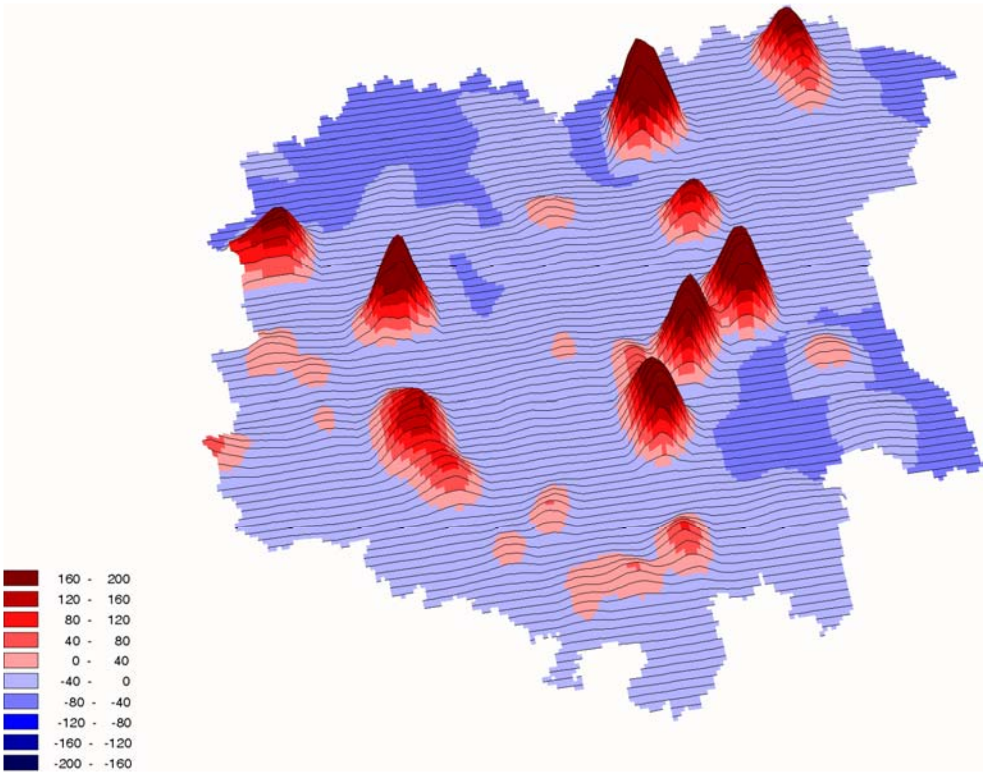


Figure 5.3.29 Dortmund model results: employment in Scenario B3 v. Scenario A-1 in 2030 (%)

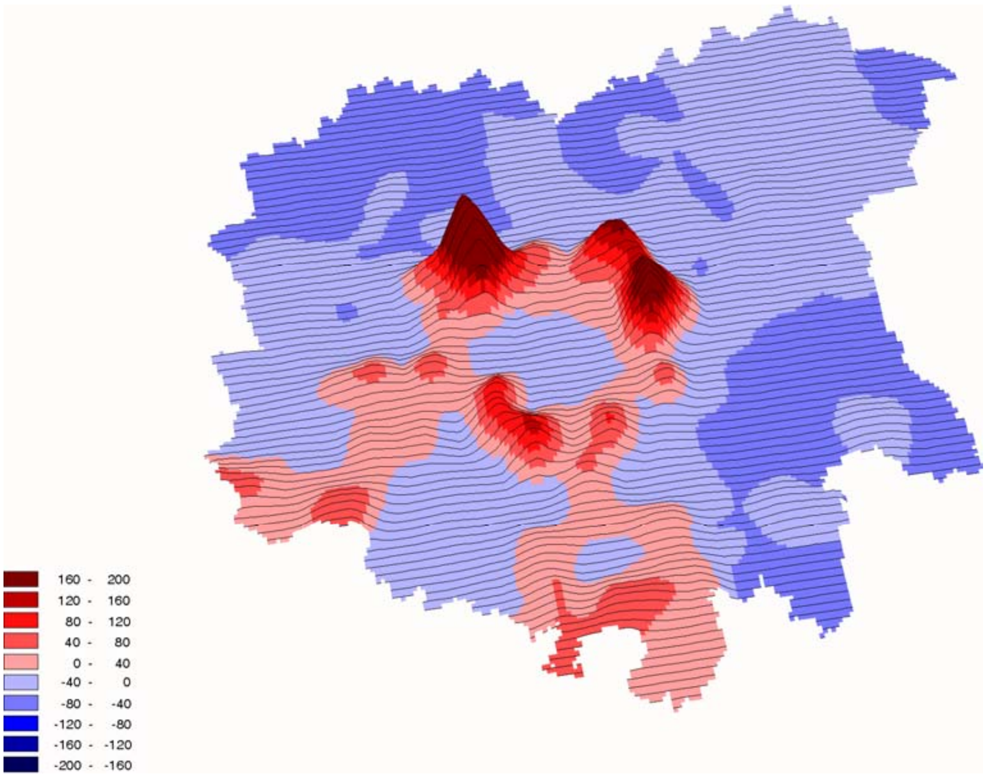


Figure 5.3.30 Dortmund model results: employment in Scenario C3 v. Scenario A-1 in 2030 (%)

Conclusions

Which main messages about the spatial impacts of increases in fuel costs and related policy responses can be taken from the results of the Dortmund model? In order to address this question, main results from the Dortmund model are summarised in Tables 5.3.4 to 5.3.6 and Figure 5.3.31. The tables contain key indicator values for the year 2005 and for all scenarios for the year 2030 in absolute values and as relative differences to Scenario A-1. Figure 5.3.31 presents the relative differences to Scenario A-1 of all key indicators for all scenarios in graphical form.

The combined scenario simulations with the SASI and Dortmund models have shown that the assumed fuel price increases and policy responses have a strong negative impact on the economy and daily mobility in the Dortmund metropolitan area. The magnitude of the negative impact depends on the rate of fuel cost increases. The transport-related policies do not improve the situation. Most of the policies, in particular those aiming at demand regulation, contain so much additional costs for car travellers that average accessibility in the policy scenarios is lower than in the corresponding no-policy scenarios with the same oil price growth assumption. The improvements in public transport are not strong enough to compensate the cost increases in car travel. This results in levels of accessibility not only lower than in the moderate A-1 Scenario but even lower than today.

These constraints in mobility lead to significant changes in daily travel behaviour. In all scenarios the long-term trend towards more and longer trips and more trips by car is stopped or even reversed. Average travel distances per capita return to the level of the 1990s, average travel distances by car to the level of the 1980s and before. There is a renaissance of walking and cycling trips, and the number of trips by public transport more than doubles or even triples – a challenge for public transport operators. The share of car trips declines to levels last experienced in the 1970s. As a consequence of these modal shifts, however, average trip speeds decline by 20 to 40 percent.

These changes in travel behaviour are not voluntary but forced responses to severe constraints and in most cases imply a substantial loss of quality of life. As ‘mandatory’ trips, such as work and school trips, can less easily be changed, the reductions in trips and trip distances mostly affects ‘voluntary’ trips, such as social or leisure trips, and every such trip not made means a friend not visited, a meeting not attended or a theatre performance or soccer match not seen. Rising costs of transport mean also financial stress for most households and families who sell their cars and still have to spend more on travel than before, although their income grows less and housing becomes more expensive.

The only positive side-effects of the reduction in traffic caused by rising fuel prices are its effect on the environment. Every car trip not made and every km the remaining trips are shorter means less greenhouse gases, less air pollution and less accidents. In addition, the efforts to develop more energy-efficient cars and alternative vehicles stimulated by the fuel price increases and related policies contribute to the positive environmental balance. From the point of view of achieving the Kyoto objectives, high fuel prices are the best possible prospect. However, the price paid for this success, both in terms of money and quality of life, is substantial, and ways to alleviate the hardships in these two dimensions have yet to be found.

Table 5.3.4 Dortmund model scenario results A-1 to A3

		2005	2030				
			A-1	A0	A1	A2	A3
Transport	Travel distance per capita per day (km)	23.6	28.5	23.6	22.4	21.2	21.2
			0.0%	*-16.7%*	*-21.1%*	*-25.2%*	*-25.4%*
	Travel distance by car per capita per day (km)	16.7	21.6	15.4	13.6	7.2	6.1
			0.0%	*-28.8%*	*-37.2%*	*-66.5%*	*-71.8%*
	Average trip distance (km)	10.8	11.6	10.4	11.1	9.5	10.7
			0.0%	*-9.9%*	*-3.7%*	*-17.9%*	*-7.8%*
	Average trip distance of car trips (km)	12.7	13.6	11.7	12.1	8.8	9.0
			0.0%	-14.1%	-11.0%	-35.5%	-33.9%
	Average trip speed (km/h)	23.2	24.5	21.8	22.9	17.5	19.2
			0.0%	*-11.0%*	*-6.6%*	*-28.6%*	*-21.6%*
	Average trip time (min)	27.8	28.2	28.5	29.0	32.2	33
			0.0%	+1.0%	+2.9%	+14.2%	+17.2%
	Share of walking and cycling trips (%)	28.7	25.6	30.7	31.5	41.5	40.3
			0.0%	*+19.8%*	*+23.1%*	*+62.0%*	*+57.4%*
	Share of public transport trips (%)	10.9	10.3	11.8	13.3	22.7	26.4
			0.0%	*+15.4%*	*+29.2%*	*+122%*	*+157%*
	Share of car trips (%)	60.3	64.1	57.5	55.2	35.8	33.3
			0.0%	*-10.4%*	*-13.9%*	*-44.2%*	*-48.0%*
Environment	Car fuel consumption per capita per day (l)	1.27	1.36	0.98	0.56	0.45	0.25
			0.0%	-28.3%	-59.0%	-66.6%	-81.7%
	Car fuel consumption per car trip per traveller (l)	0.96	0.86	0.74	0.50	0.56	0.37
			0.0%	*-13.6%*	*-42.1%*	*-34.7%*	*-57.0%*
	Average car speed (km/h)	38.4	38.0	36.7	37.5	33.5	33.7
			0.0%	*-3.4%*	*-1.2%*	*-11.8%*	*-11.3%*
	CO_2 emissions by transport per capita per day (kg)	8.18	7.92	6.39	5.73	3.50	3.10
			0.0%	*-19.4%*	*-27.7%*	*-55.8%*	*-60.8%*
	CO_2 emissions per person-km (g)	347	278	269	255	164	146
			0.0%	*-3.2%*	*-8.3%*	*40.9%*	*47.5%*
	NO_x emissions by transport per capita per day (g)	30.,0	21.7	20.2	18.1	11.9	10.7
			0.0%	-7.2%	-16.7%	-45.1%	-50.6%
	PM emissions by transport per capita per day (mg)	1,778	1,015	970	909	661	624
			0.0%	*-4.5%*	+10.4%	+34.9%	+38.6%
	Share of developed land (%)	34.5	39.8	39.7	39.7	35.9	35.9
			0.0%	*-0.1%*	*-0.1%*	*-9.8%*	*-9.8%*
	Share of open space (%)	65.4	60.1	60.2	60.2	64.0	64.0
			0.0%	*+0.1%*	*+0.1%*	*+6.5%*	*+6.5%*

Table 5.3.4 Dortmund model scenario results A-1 to A3 (continued)

		2005	2030				
			A-1	**A0**	**A1**	**A2**	**A3**
Society	Car ownership (cars per 1,000 population)	557	715	612	432	596	420
			0.0%	-14.4%	-39.5%	-16.6%	-41.3%
	Average trip costs (Euro)	1.12	1.23	1.51	1.29	1.49	1.26
			0.0%	+23.0%	+5.3%	+21.2%	+2.8%
	Transport expenditures per household per month (Euro)	578	717	744	801	761	804
			0.0%	+3.7%	+11.7%	+6.2%	+12.1%
	Public transport expenditures per hh. per month (Euro)	24.9	25.5	33.4	34.5	32.3	33.8
			0.0%	+30.8%	+35.1%	+26.5%	+32.2%
	Car expenditures per household per month (Euro)	553	691	710	767	729	770
			0.0%	+2.7%	+10.9%	+5.5%	+11.4%
	Traffic accidents per 1,000 population per year	19.7	19.9	14.6	13.0	6.8	5.8
			0.0%	*-26.7%*	*-34.5%*	*-66.0%*	*-70.9%*
	Traffic deaths per million population per year	56.6	42.0	30.5	27.3	14.0	12.0
			0.0%	*-27.3%*	*-35.0%*	*-66.7%*	*-71.4%*
	Traffic injuries per million population per year	3389	3334	2433	2176	1122	961
			0.0%	*-27.0%*	*-34.7%*	*-66.4%*	*-71.2%*
Accessibility	Accessibility of population (0-100)	61.6	61.7	61.9	61.7	60.2	59.5
			0.0%	*+0.2%*	*-0.9%*	*-1.4%*	*-2.9%*
	Accessibility of employment (0-100)	64.2	63.5	61.9	61.7	60.2	59.5
			0.0%	*-2.5%*	*-2.7%*	*-5.2%*	*-6.2%*
	Accessibility of shops (0-100)	64.8	64.3	63.0	63.1	60.6	60.1
			0.0%	*-1.9%*	*-1.8%*	*-5.7%*	*-6.6%*
	Accessibility of retail purchas-ing power (0-100)	65.5	65.0	63.5	63.7	61.1	60.6
			0.0%	*-2.3%*	*-2.0%*	*-6.0%*	*-6.7%*
	Accessibility of high schools (0-100)	64.1	63.1	61.4	61.3	59.2	58.7
			0.0%	*-2.7%*	*-2.8%*	*-6.1%*	*-7.0%*
	Accessibility of CBD (0-100)	49.2	48.7	42.6	42.8	36.6	37.1
			0.0%	*-12.5%*	*-12.1%*	*-24.9%*	*-23.9%*
Land use	Share of population in central area (%)	10.0	7.4	7.4	7.6	8.7	8.8
			0.0%	*-0.5%*	*+2.3%*	*17.5%*	*+18.9%*
	Share of population in outer suburbs (%)	56.7	61.0	61.2	61.1	61.9	61.8
			0.0%	*+0.3%*	*+0.1%*	*+1.4%*	*+1.3%*
	Share of employment in central area (%)	21.8	17.3	17.3	17.3	17.0	17.0
			0.0%	*+0.4%*	*+0.1%*	*-1.5%*	*-1.7%*
	Share of employment in outer suburbs (%)	55.6	60.0	60.2	60.2	64.3	64.3
			0.0%	*+0.2%*	*+0.2%*	*+7.0%*	*+7.1%*

Table 5.3.5 Dortmund model scenario results B-1 to B3

	Indicator	2005	2030				
			B-1	**B0**	**B1**	**B2**	**B3**
Transport	Travel distance per capita per day (km)	23.6	24.1	21.1	20.7	20.6	20.8
			-15.4%	*-25.9%*	*-27.4%*	*-27.7%*	*-26.9%*
	Travel distance by car per capita per day (km)	16.7	15.2	10.1	9.7	3.7	3.4
			-29.7%	-53.2%	-55.0%	-82.7%	-84.3%
	Average trip distance (km)	10.8	10.1	9.4	10.4	9.1	10.4
			-12.5%	-18.5%	-10.0%	-21.0%	-9.3%
	Average trip distance of car trips (km)	12.7	10.9	9.4	10.0	6.8	7.2
			-19.6%	-31.1%	-26.4%	-50.3%	-46.8%
	Average trip speed (km/h)	23.2	21.9	19.0	20.9	15.8	17.9
			-10.7%	-22.5%	-15.0%	-35.5%	-27.0%
	Average trip time (min)	27.8	27.6	29.5	29.7	34.4	34.9
			-2.1%	+5.0%	+5.5%	+22.1%	+23.8%
	Share of walking and cycling trips (%)	28.7	29.7	36.8	35.2	48.8	46.1
			+16.0%	+43.8%	+37.3%	+90.6%	+79.9%
	Share of public transport trips (%)	10.9	12.7	15.6	16.5	27.5	31.0
			+23.4%	+51.9%	+61.0%	+167%	+202%
	Share of car trips (%)	60.3	57.6	47.6	48.3	23.7	22.9
			-10.1%	-25.8%	-24.7%	-63.1%	-64.2%
Environment	Car fuel consumption per capita per day (l)	1.27	0.95	0.64	0.40	0.23	0.14
			-29.8%	-53.1%	-70.7%	-83.0%	-89.9%
	Car fuel consumption per car trip per traveller (l)	0.96	0.69	0.59	0.41	0.43	0.30
			-19.4%	*-30.5%*	*-52.2%*	*-49.9%*	*-65.5%*
	Average car speed (km/h)	38.4	38.8	36.6	37.1	32.9	33.1
			+2.1%	*-3.5%*	*-2.3%*	*-13.3%*	*-12.9%*
	CO_2 emissions by transport per capita per day (t)	8.18	5.80	4.39	4.30	2.14	2.05
			-26.8%	*-44.6%*	*-45.7%*	*73.0%*	*74.1%*
	CO_2 emissions per person-km (g)	347	240	208	207	103	98
			-13.5	*-25.2*	*-25.4*	*-62.6*	*-64.6*
	NO_x emissions by transport per capita per day (g)	30.0	16.5	14.4	14.1	8.0	7.7
			-24.2	*-33.6*	*-35.3*	*-63.2*	*-64.5*
	PM emissions by transport per capita per day (mg)	1,778	816	752	751	510	503
			-19.6	*-25.9*	-26.0	-49.8	-50.4
	Share of developed land (%)	34.5	39.8	39.7	39.7	35.9	35.9
			-0.1%	*-0.2%*	*-0.2%*	*-9.8%*	*-9.8%*
	Share of open space (%)	65.4	60.1	60.2	60.2	64	64
			+0.1%	*+0.2%*	*+0.1%*	*+6.5%*	*+6.5%*

Table 5.3.5 Dortmund model scenario results B-1 to B3 (continued)

		2005	2030				
			B-1	**B0**	**B1**	**B2**	**B3**
Society	Car ownership (cars per 1,000 population)	557	675	592	417	604	420
			-5.5%	*-17.1%*	*-41.7%*	*-15.5%*	*-41.2%*
	Average trip costs (Euro)	1.12	1.73	1.79	1.54	1.39	1.21
			+40.7%	*+46.2%*	*+25.2%*	*+13.2%*	*-1.4%*
	Transport expenditures per household per month (Euro)	578	727	747	794	761	799
			+1.4%	*+4.2%*	*+10.7%*	*+6.1%*	*+11.5%*
	Public transport expenditures per hh. per month (Euro)	24.9	30.5	41.9	41.2	38.5	38.8
			+19.6%	*+63.9%*	*+61.2%*	*+50.9%*	*+51.8%*
	Car expenditures per household per month (Euro)	553	696	705	753	722	760
			+0.7%	*+2.0%*	*+8.9%*	*+4.4%*	*+10.0%*
	Traffic accidents per 1,000 population per year	19.7	15.2	10.0	9.8	3.3	3.1
			-23.8%	*-49.5%*	*-50.8%*	*-83.4%*	*-84.5%*
	Traffic deaths per million population per year	56.6	31.1	20.4	20.0	6.7	6.3
			-26.1	*-51.4*	*-52.3*	*-84.0*	*-85.0*
	Traffic injuries per million population per year	3889	2499	1648	1613	543	507
			-25.0	*-50.5*	*-51.6*	*-83.7*	*-84.8*
Accessibility	Accessibility of population (0-100)	61.6	61.8	61.9	61.2	60.9	59.9
			+0.1%	*+0.3%*	*-0.9%*	*-1.4%*	*-3.0%*
	Accessibility of employment (0-100)	64.2	62.7	61.3	61.0	59.9	59.3
			-1.2%	*-3.3%*	*-3.8%*	*-5.6%*	*-6.6%*
	Accessibility of shops (0-100)	64.8	63.7	62.8	62.7	60.5	60.0
			-0.9%	*-2.4%*	*-2.5%*	*-5.9%*	*-6.8%*
	Accessibility of retail purchas-ing power (0-100)	65.5	64.1	63.1	63.1	61.0	60.4
			-1.3%	*-3.0%*	*-2.9%*	*-6.2%*	*-7.1%*
	Accessibility of high schools (0-100)	64.1	62.3	60.7	60.6	58.7	58.3
			-1.2%	*-3.8%*	*-3.9%*	*-6.9%*	*-7.6%*
	Accessibility of CBD (0-100)	49.2	42.7	36.8	37.8	33.4	35.0
			-12.4%	*-24.5%*	*-22.4%*	*-31.4%*	*-28.2%*
Land use	Share of population in central area (%)	10.0	7.4	7.4	7.4	8.8	8.9
			-0.4%	*+0.5%*	*+0.5%*	*+18.5%*	*+20.0%*
	Share of population in outer suburbs (%)	56.7	61.3	61.5	61.4	62.2	61.9
			+0.5%	*+0.8%*	*+0.5%*	*+1.8%*	*+1.3%*
	Share of employment in central area (%)	21.8	17.3	17.3	17,3	17.0	17.0
			+0.2%	*+0.5%*	*+0.3%*	*-1.7%*	*-1.7%*
	Share of employment in outer suburbs (%)	55.6	60.2	60.3	60.3	64.4	64.3
			+0.2%	*+0.5%*	*+0.4%*	*+7.2%*	*+7.1%*

Table 5.3.6 Dortmund model scenario results C-1 to C3

		2005	2030 C-1	2030 C0	2030 C1	2030 C2	2030 C3
Transport	Travel distance per capita per day (km)	23.6	21.1	20.1	20.8	18.7	18.7
			-25.9%	*-29.5%*	*-27.1%*	*-34.2%*	*-34.4%*
	Travel distance by car per capita per day (km)	16.7	8.1	7.4	10.1	0.4	0.7
			-62.4%	*-65.9%*	*-53.3%*	*-98.2%*	*-96.9%*
	Average trip distance (km)	10.8	9.0	9.0	10.4	8.3	9.5
			-22.5%	*-22.0%*	*-9.7%*	*-28.2%*	*-18.1%*
	Average trip distance of car trips (km)	12.7	8.1	8.2	10.2	2.4	3.7
			-40.4%	*-39.9%*	*-24.9%*	*-82.1%*	*-72.6%*
	Average trip speed (km/h)	23.2	17.7	17.3	21.0	13.7	15.6
			-27.9%	*-29.3%*	*-14.2%*	*-44.3%*	*-36.6%*
	Average trip time (min)	27.8	30.3	31.1	29.6	36.1	36.2
			+7.5%	*+10.1%*	*+5.0%*	*+28.0%*	*+28.4%*
	Share of walking and cycling trips (%)	28.7	39.6	41.7	34.6	62.8	59.2
			+54.5%	*+62.8%*	*+35.2%*	*+145%*	*+131%*
	Share of public transport trips (%)	10.9	18.6	18.4	16.1	29.5	31.7
			+81.7%	*+79.8%*	*+57.3%*	*+187%*	*+209%*
	Share of car trips (%)	60.3	41.8	39.8	49.2	7.8	9.1
			-34.8%	*-37.9%*	*-23.2%*	*-87.9%*	*-85.8%*
Environment	Car fuel consumption per capita per day (l)	1.27	0.51	0.46	0.32	0.02	0.02
			-62.8%	*-65.9%*	*-76.6%*	*-98.3%*	*-98.5%*
	Car fuel consumption per car trip per traveller (l)	0.96	0.51	0.52	0.32	0.16	0.12
			-40.1%	*-39.4%*	*-62.4%*	*-81.9%*	*-86.2%*
	Average car speed (km/h)	38.4	39.4	36.6	37.1	25.0	26.2
			+3.8%	*-3.6%*	*-2.2%*	*-34.1%*	*-31.1%*
	CO_2 emissions by transport per capita per day (t)	8.18	3.32	3.42	4.17	1.00	1.07
			-58.1	*-56.8*	*-47.3*	*87.4*	*86.5*
	CO_2 emissions per person-km (g)	347	157	170	201	53	57
			-43.5	-38.7	-27.3	-80.8	-79.4
	NO_x emissions by transport per capita per day (g)	30.0	10.4	11.8	13.1	4.7	4.9
			-52.3	-45.6	-39.6	-78.3	-77.4
	PM emissions by transport per capita per day (mg)	1,778	590	658	719	383	391
			-41.8	*-35.2*	-29.1	-62.3	-61.5
	Share of developed land (%)	34.5	39.7	39.7	39.7	35.6	35.6
			-0.2%	*-0.3%*	*-0.2%*	*-10.6%*	*-10.6%*
	Share of open space (%)	65.4	60.2	60.2	60.2	64.3	64.3
			+0.1%	*+0.2%*	*+0.2%*	*+7.0%*	*+7.0%*

Table 5.3.6 Dortmund model scenario results C-1 to C3 (continued)

		2005	2030				
			C-1	**C0**	**C1**	**C2**	**C3**
Society	Car ownership (cars per 1,000 population)	557	660	589	417	606	414
			-7.6%	*-17.6%*	*-41.7%*	*-15.2%*	*-42.1%*
	Average trip costs (Euro)	1.12	1.96	1.84	1.53	0.95	1.03
			+59.8%	*+50.0%*	*+24.2%*	*-22.5%*	*-15.8%*
	Transport expenditures per household per month (Euro)	578	734	746	792	727	777
			+2.4%	*+4.1%*	*+10.5%*	*+1.4%*	*+8.3%*
	Public transport expenditures per hh. per month (Euro)	24.9	42.1	47.9	40.4	59.6	56.8
			+64.9%	*+87.6%*	*+58.0%*	*+133%*	*+123%*
	Car expenditures per household per month (Euro)	553	692	699	751%	667	720
			+0.1%	*+1.1%*	*+8.7%*	*-3.5%*	*+4.1%*
	Traffic accidents per 1,000 population per year	19.7	8.2	7.3	10.1	0.2	0.4
			-58.9	*-63.4*	*-49.1*	*-99.2*	*-98.2*
	Traffic deaths per million population per year	56.6	16.3	14.7	20.8	0.3	0.7
			-61.2	*-65.1*	*-50.6*	*-99.2*	*-98.2*
	Traffic injuries per million population per year	3389	1328	1190	1670	27	60
			-60.2	*-64.3*	*-49.9*	*-99.2*	*-98.2*
Accessibility	Accessibility of population (0-100)	61.6	61.8	61.9	61.1	61.1	60.2
			+0.1%	*+0.2%*	*-1.0%*	*-1.1%*	*-2.5%*
	Accessibility of employment (0-100)	64.2	61.7	61.0	61.2	59.0	57.6
			-2.8%	*-4.0%*	*-3.6%*	*-7.0%*	*-9.2%*
	Accessibility of shops (0-100)	64.8	63.1	62.6	62.8	60.5	59.3
			-1.8%	*-2.7%*	*-2.4%*	*-5.9%*	*-7.8%*
	Accessibility of retail purchasing power (0-100)	65.6	63.5	62.9	63.2	61.3	60.0
			-2.4%	*-3.3%*	*-2.8%*	*-5.7%*	*-7.8%*
	Accessibility of high schools (0-100)	64.1	61.1	60.2	60.8	57.0	56.6
			-3.1%	*-4.5%*	*-3.6%*	*-9.6%*	*-10.3%*
	Accessibility of CBD (0-100)	49.2	34.9	33.8	38.3	29.6	30.2
			-28.3%	*-30.7%*	*-21.4%*	*-39.2%*	*-38.0%*
Land use	Share of population in central area (%)	10.0	7.3	7.5	7.5	8.8	8.7
			-1.1%	*+0.6%*	*+1.2%*	*+18.5%*	*+17.5%*
	Share of population in outer suburbs (%)	56.7	61.9	61.8	61.2	51.8	51.7
			+1.4%	*+1.3%*	*+0.2%*	*-15.1%*	*-15.3%*
	Share of employment in central area (%)	21.8	17.3	17.3	17.3	17.6	17.6
			+0.2%	*+0.5%*	*+0.3%*	*+2.1%*	*+2.0%*
	Share of employment in outer suburbs (%)	55.6	60.4	60.4	60.3	42.5	42.5
			+0.6%	*+0.6%*	*+0.4%*	*-29.2%*	*-29.3%*

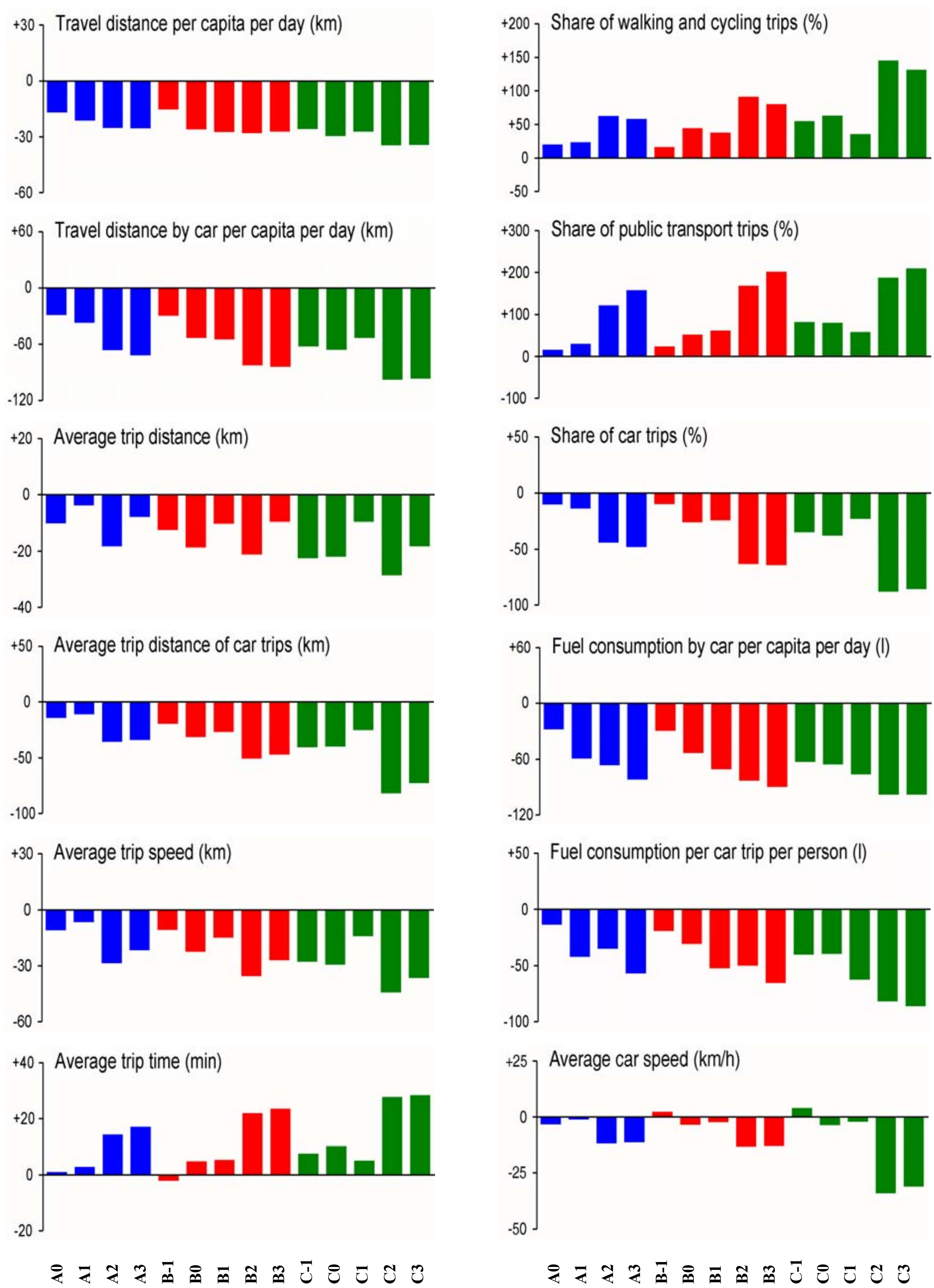


Figure 5.3.31 Dortmund model scenario results: differences to Scenario A-1 in 2030 (%)

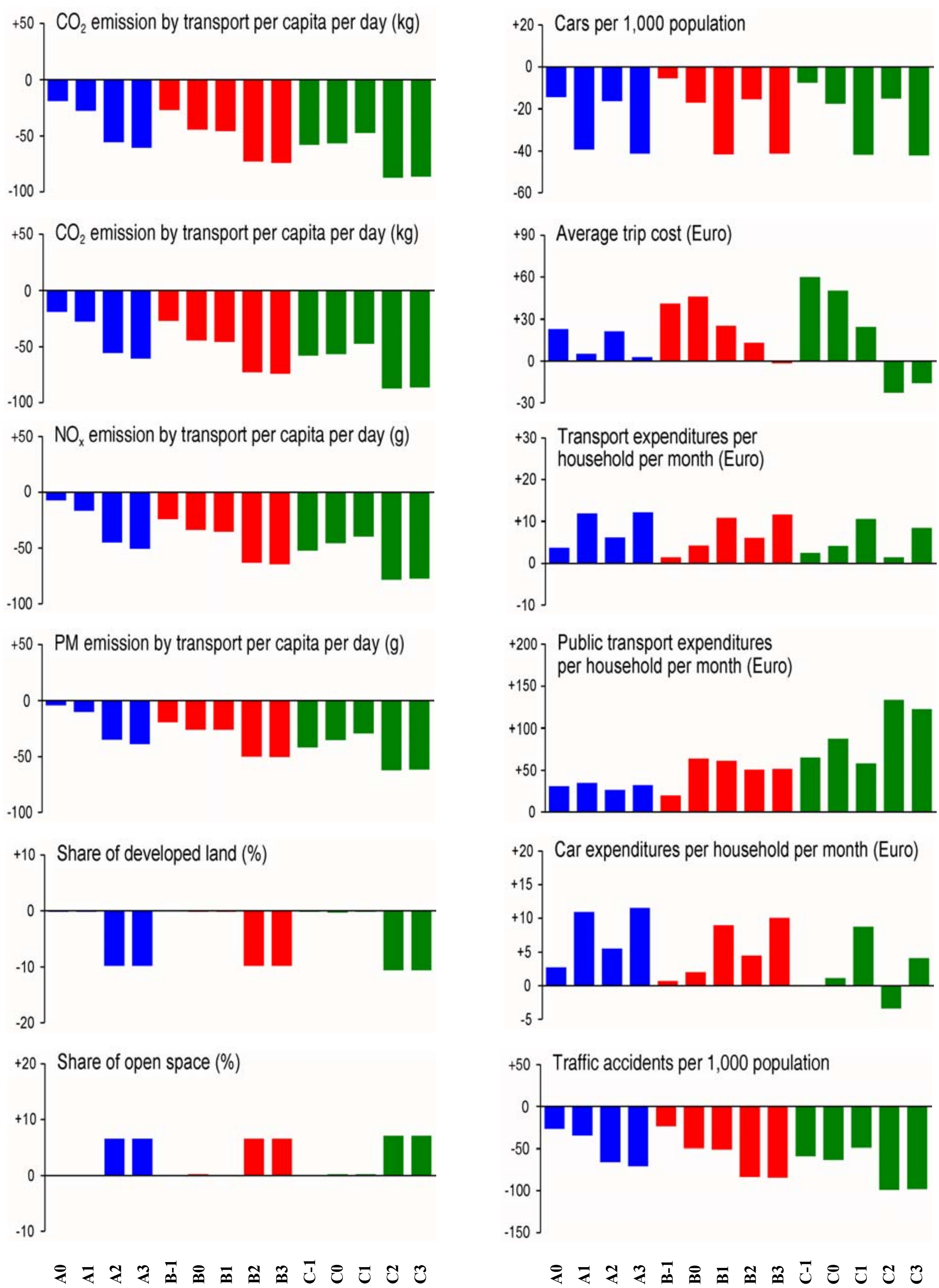


Figure 5.3.31 Dortmund model scenario results: differences to Scenario A-1 in 2030 (%) (continued)

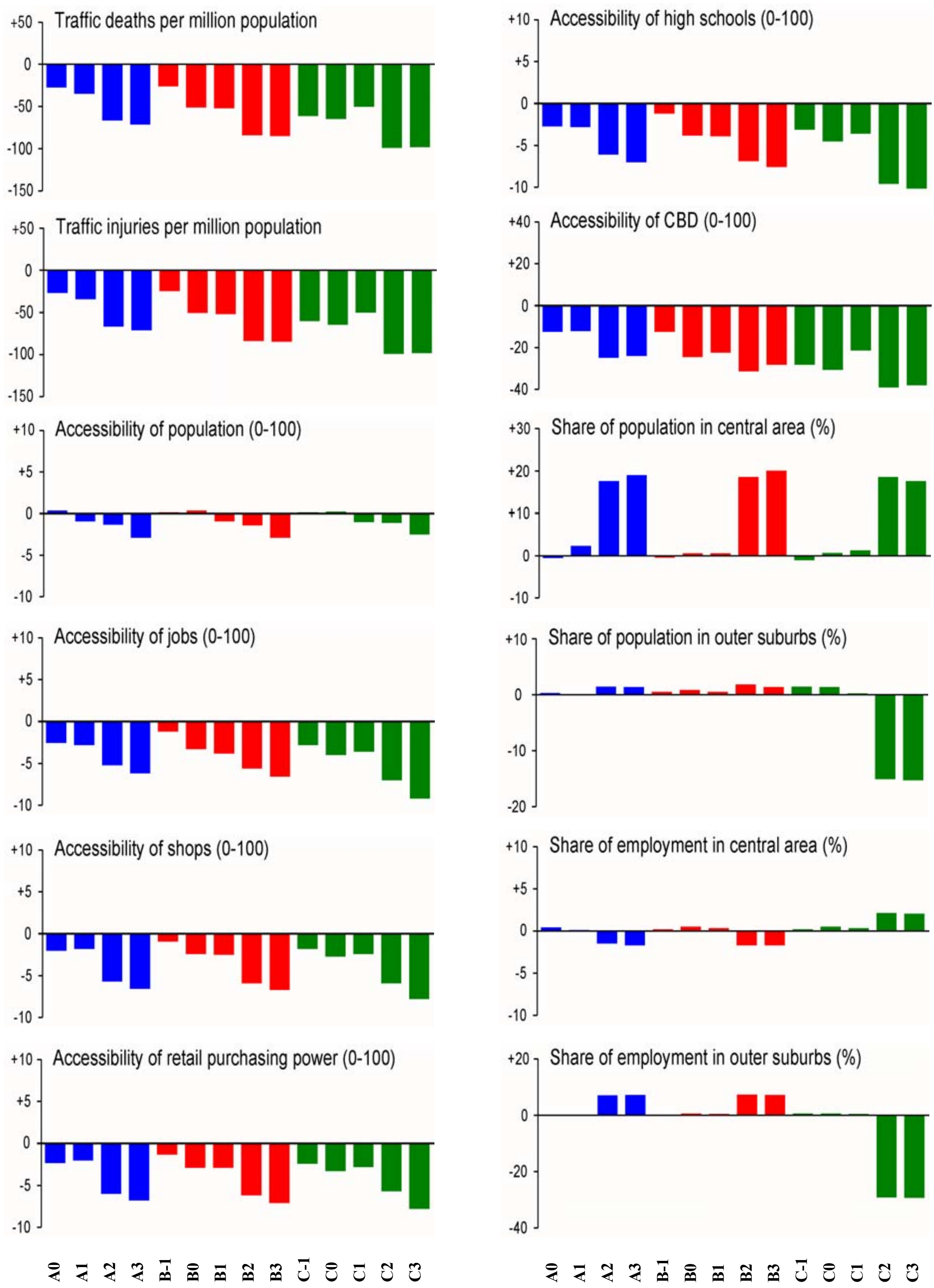


Figure 5.3.31 Dortmund model scenario results: differences to Scenario A-1 in 2030 (%) (continued).

Land use planning, if properly integrated and co-ordinated with transport planning might offer a way out this dilemma (Lautso et al., 2004). In a future with high fuel costs in which car driving is unaffordable for a large proportion of low and medium-income households, high-density mixed-use urban structures in which most daily mobility can occur on foot offer a higher quality of life than low-density suburbs at the fringe of metropolitan areas poorly served by public transport. In many cities in western Europe there are vast brownfield sites abandoned by closed-down manufacturing industries in prime locations close to city centres and railway stations. The land use policies included in six of the scenarios have demonstrated the important contribution land use policies can make to sustainable urban transport and preservation of open space – although a more detailed analysis would be necessary to show also their benefits in terms of quality of life.

However, integrated land use and transport strategies at the level of a whole metropolitan area require a high degree of consensus and co-operation between the core cities and the suburban municipalities. In many European countries, as for instance in Germany, a system of municipal taxes based on revenues from business and personal income taxes effectively compels suburban municipalities to compete against the core city and each other for tax-paying firms and household. There are only few countries in Europe with systems of revenue sharing and regional planning able to cope with this epochal challenge.

5.4 The Edinburgh model results

5.4.1 The Edinburgh model

SPM model is an integrated strategic and dynamic land-use and transport (LUTI) model. The basic underlying hypothesis of SPM is that settlements and activities within them are self organizing systems. Therefore SPM is based on the principles of systems dynamics (Sterman 2000) and synergetics (Haken 1983). The development of SPM was started in the year 2000. An early version is described in (Pfaffenbichler and Shepherd). This model was developed further and became its actual name within a PhD-thesis (Pfaffenbichler 2003). Recently the model was transformed to another software basis. The case study presented here is the first application of SPM in Vensim® (www.vensim.com).

SPM assumes that land-use is part of a dynamic system that is influenced by transport infrastructure rather than being constant. As a consequence SPM can be divided into two main sub-models: the land-use model and the transport model. The interaction process is implemented through time-lagged feedback loops between the two sub-models covering a period of 30 years. Two person groups, one with and one without access to a private car are considered in the transport model. The transport model is broken down by commuting and non-commuting trips, including travel by non-motorized modes. Car speed in the SPM transport sub-model is volume and capacity dependent and hence not constant. The land-use model considers residential and workplace location preferences based on accessibility, available land, average costs and amount of land with high recreational value. Decisions in the land-use sub-model are based on random utility theory. The output of the transport model are accessibility measures by mode for each zone while the land-use model yields workplace and residential location preferences per zone. The case study presented here uses a simplified land use part defining land use developments in accordance with the scenarios described in section 5.4.2.

To date the model SPM has been applied to the following six European case study cities Edinburgh, Helsinki, Leeds, Madrid, Oslo, Stockholm and Vienna. Within the ongoing project SPARKLE (Sustainability Planning for Asian cities making use of Research, Know-how and Lessons from Europe) SPM is adapted and applied to the Asian cities Ubon Ratchasthani, Thailand and Da Nang, Vietnam (Emberger et al. 2005). To test the SPM model an extensive back casting exercise was carried out with data of the city Vienna (Pfaffenbichler 2003). A fuller description of the basic Edinburgh SPM model is given in deliverable 4.1.

5.4.2 Implementation of scenarios in the Edinburgh model

The policy variable assumptions were derived in WP3 from an analysis of current and future policy trends and are detailed in table 5.4.1 below.

The Edinburgh model SPM has taken the resulting fleet composition and emission factors from the POLES/ASTRA runs for each scenario. As can be seen from the following analysis the resulting fleet composition differs from the suggested fleet shares (from WP3) and responds not only to the technology investments assumptions but also to a lesser degree to the other policy and scenario variables such as fuel price and car ownership costs. For simplicity we have also assumed that the fleet composition for A-1 and B-1 are the same as in A0 and B0 respectively. The fleet shares are taken from the POLES/ASTRA runs for the given scenario. The resulting composition takes into account changes in costs of car ownership, energy use assumptions and improved emissions as detailed in the last rows of Table 5.4.1. These impacts are introduced into the SPM model directly by inputting the fleet composition over time along with associated emissions and fuel consumption models which also vary over time.

Under the demand regulation scenarios A2/B2 there is a strict control on new developments and a compact city policy is adopted whereby all developments outside the urban area are forbidden and all new developments are assumed to be possible within the urban area – assuming greater use of brownfield developments (see Figure 5.4.1).

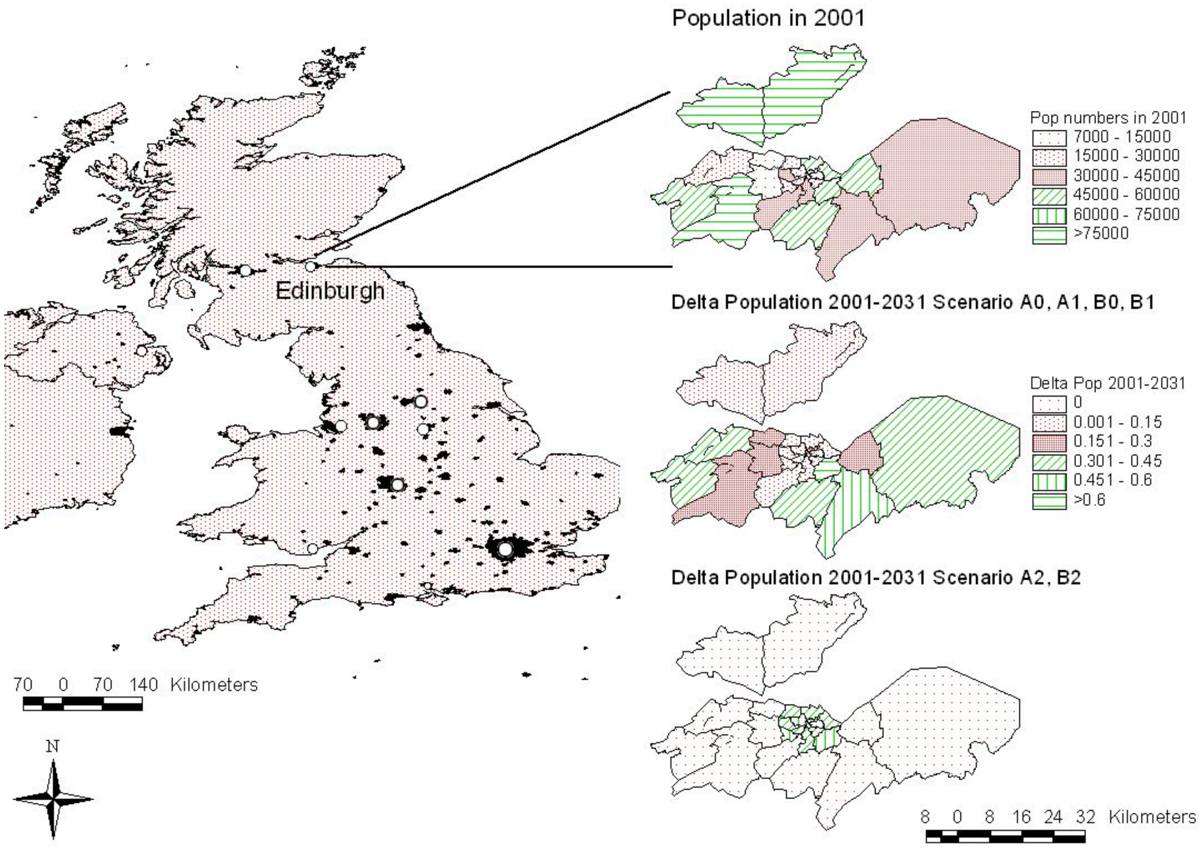


Figure 5.4.1 Land use scenarios population

Table 5.4.1 Overview of scenario variables

Policy/Scenario variable	Business as usual (A0/B0)	Technology Investments (A1/B1)	Demand Regulation (A2/B2)
Fuel resource cost	A0 +1% p.a.	As A0	As A0
	B0 + 4% p.a.	As B0	As B0
Fuel tax	Petrol +0.7% p.a. Diesel +1.5% p.a.	As A0/B0	Petrol +4.7% p.a. Diesel +4.7% p.a.
Public transport speeds	+0.3% p.a.	+1.1% p.a. (peak) As A0/B0 (off-peak)	As A0/B0
Public transport fares	+0.8% p.a.	As A0/B0	-1.7% p.a.
Road pricing –Double cordon	N/A	N/A	€2 rising to €5 by year 30
Telework	No change	As A0/B0	+0.3% p.a. work trips saved
Land use controls on new developments	As in structure plan	As A0/B0	Compact city: New developments split 30/70/0 (CBD/urban/extra urban)
Fleet shares derived from POLES/ASTRA (Year 2030)	A0 : 86/8.2/0.6/0.1/4.8[a]	A1 : 69/17/0.1/0/13.8	A2 : 86/9/0.5/0.1/5.4
	B0 : 74/13.5/0.3/0.3/11.6	B1 : 51/20/0.1/0/28.6	B2 : 76/13.4/0.4/0.2/10.2
Car ownership growth rate[b]	A0 : 1.20% p.a.	A1 : 1.21% p.a.	A2 : 1.02% p.a.
	B0 : 1.12% p.a.	B1 : 1.15% p.a.	B2 : 0.76% p.a.
Cost of car ownership[c]	Check input to POLES/ASTRA	+3% p.a. Check?	As A0/B0
Energy use[c]	Petrol -0.5% p.a. per km Diesel -1.0% p.a. per km	Petrol -2.0% p.a. per km Diesel -3.0% p.a. per km	As A0/B0
Emission factors[c]	-8.1% p.a. (check POLES description - class assumptions?)	-16% p.a. (check POLES description - ?)	As A0/B0

a) share of conventional/hybrid/CNG/electric/hydrogen
b) The car ownership growth rate is based on UK TEMPRO projections for A0 and the relative changes in ownership rates from POLES/ASTRA are applied to the other scenarios.
c) The assumptions on costs of car ownership, energy use and emission factors were input to POLES/ASTRA - the fleet composition by class was then used as input to SPM which affected not only composition but also fuel consumption rates and emission factors (see below).

5.4.3 Main results from the Edinburgh model

This section present the results of the model runs by looking at the impact on demand, environmental outputs, costs to society and accessibility.

Car fleet

Figure 5.4.2 to Figure 5.4.5 show the development of Petrol, Diesel, Hybrid and Fuel Cell fleets as a percentage of the whole fleet by each scenario. Electric and CNG categories are not shown as these represent less than one percent of the fleet. In the following we note that the fleet composition for scenarios A-1 and B-1 are the same as A0 and B0 respectively.

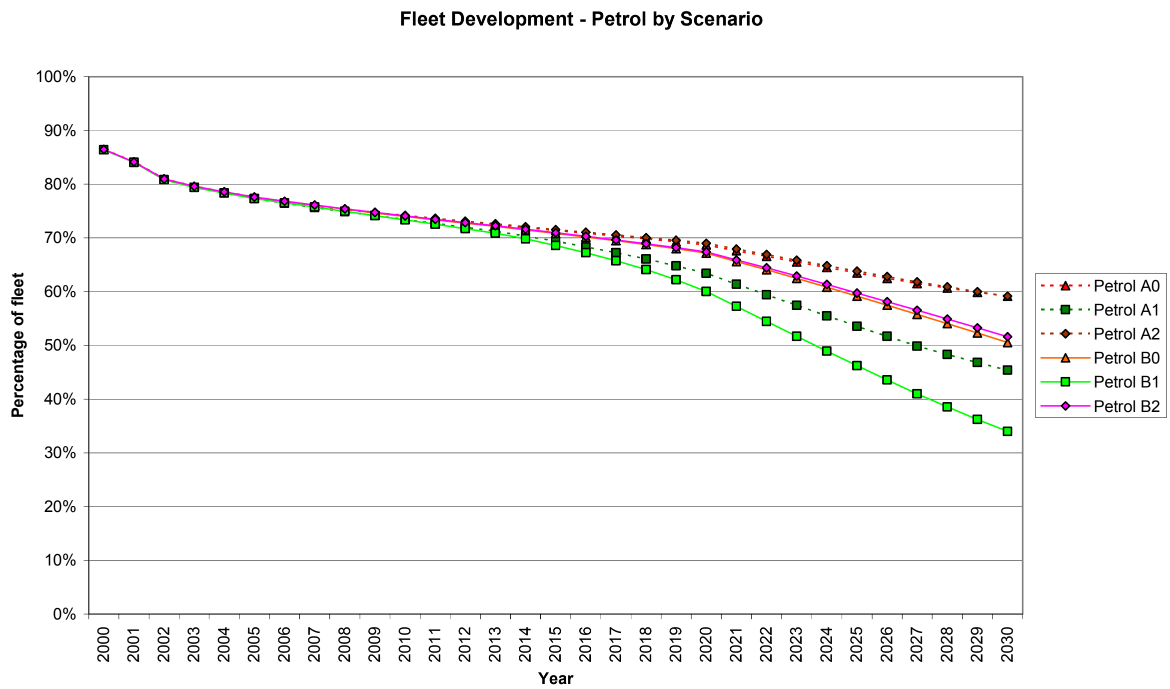


Figure 5.4.2 Development petrol vehicle fleet by scenario

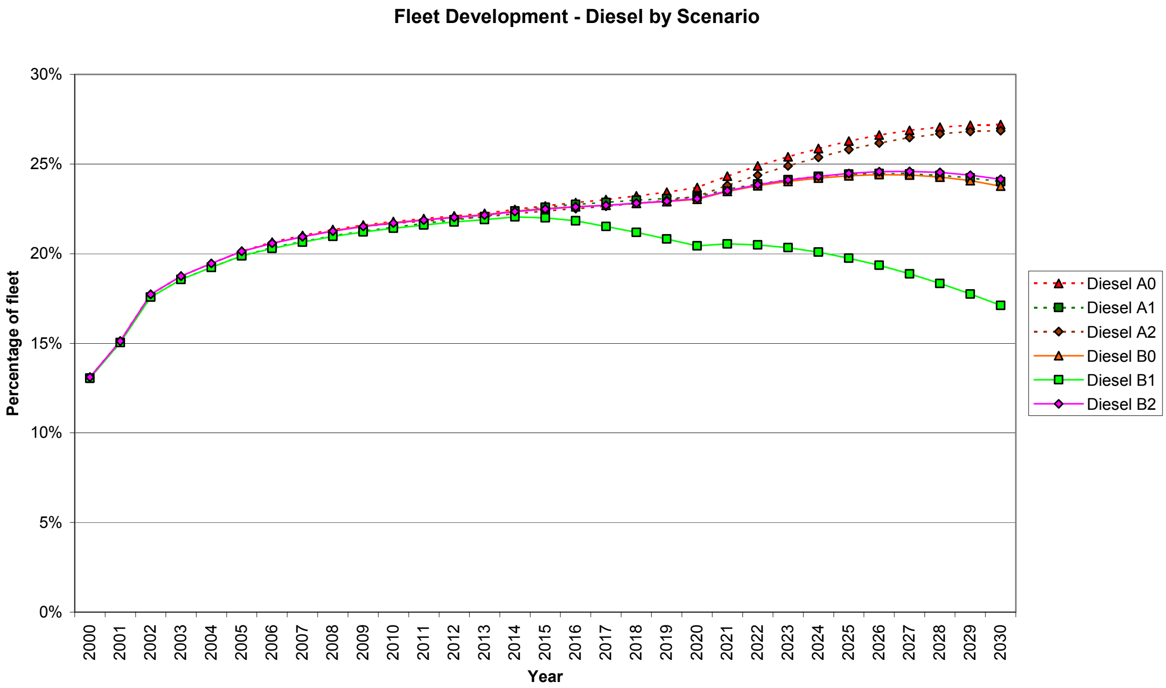


Figure 5.4.3 Development diesel vehicle fleet by scenario

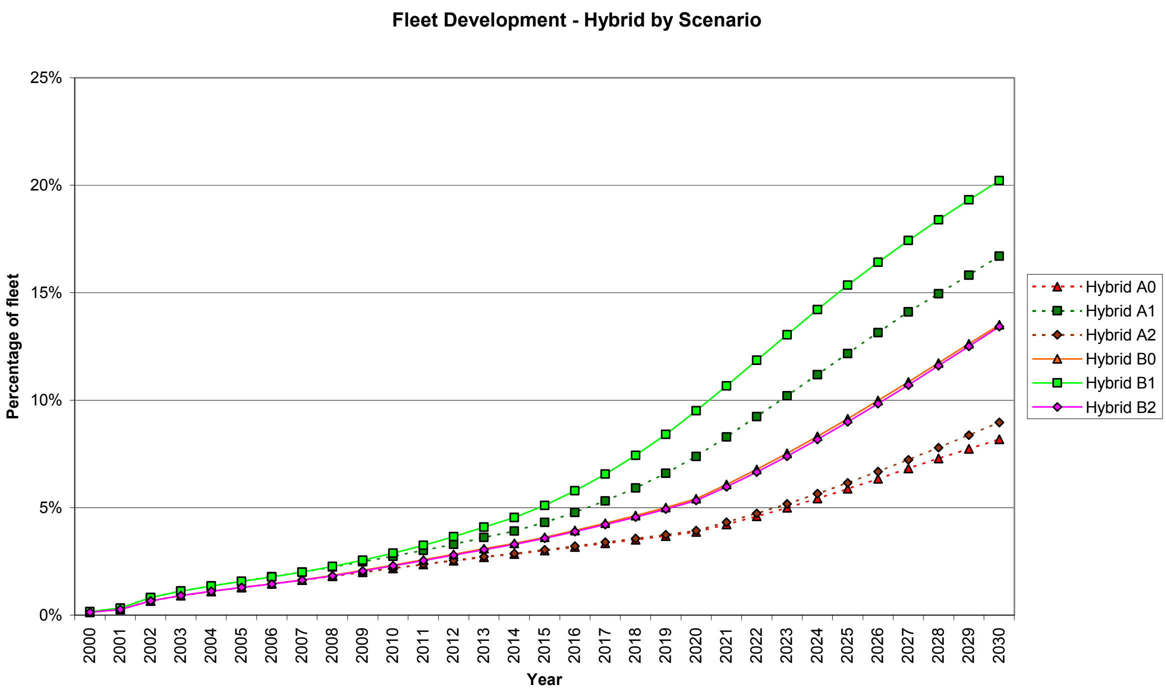


Figure 5.4.4 Development hybrid vehicle fleet by scenario

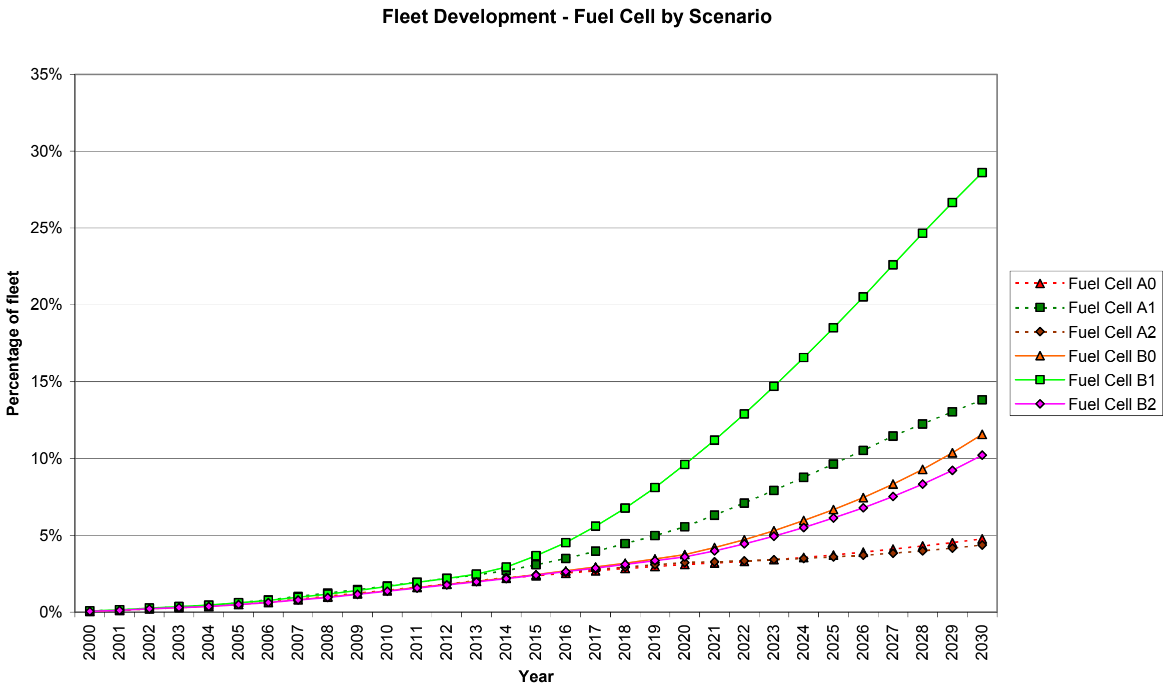


Figure 5.4.5 Development fuel cell vehicle fleet by scenario

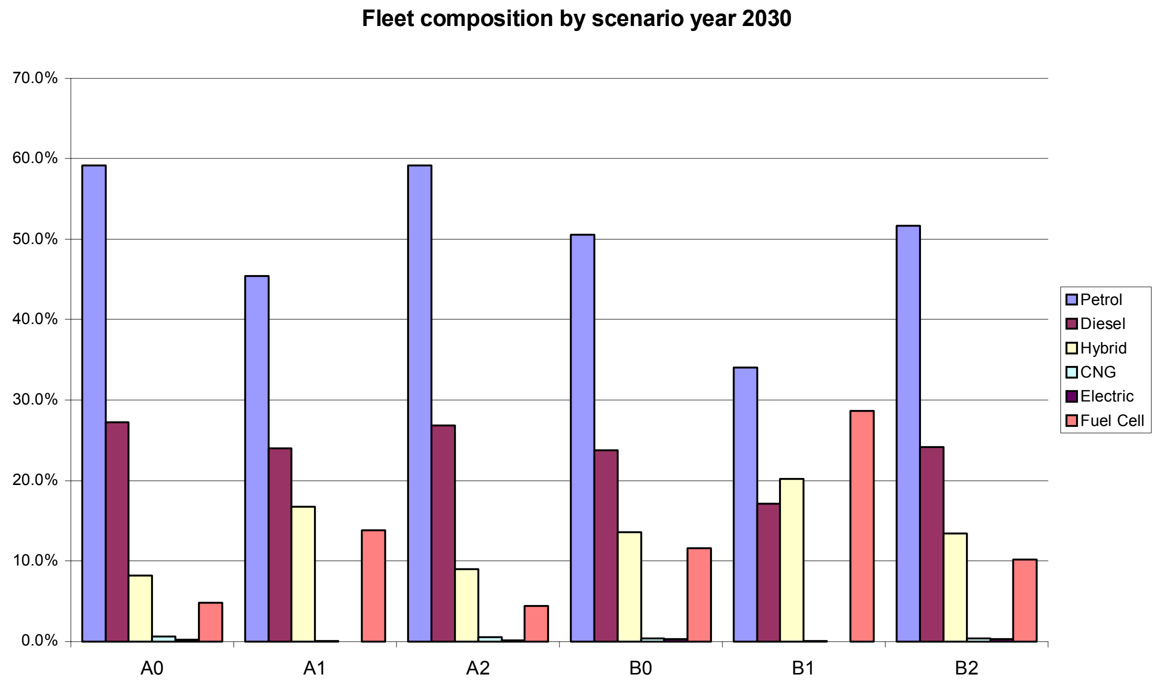


Figure 5.4.6 Fleet composition by scenario in the year 2030

Figure 5.4.6 shows the proportion of each fuel type in the year 2030 by scenario. It can be seen that the technology investments scenarios A1 and B1 increase the share of Hybrid and Hydrogen (fuel cell) technologies significantly. The demand regulation scenario A2 results in only small changes in fleet composition. Furthermore the B scenarios which have higher fuel prices promote a further shift away from conventional fuels in the business as usual scenario with similar but more exaggerated shifts for the technology investments scenario and as before only small shifts for the regulation scenario.

Demand

Table 5.4.2 shows the total demand for passenger-kms and car passenger-kms for all eight scenarios. Here we compare the based value in year 2005 with the values in year 2030 in both absolute terms and as an index value using 2005 as the base=100. Figure 5.4.7 shows the trajectories for car-passenger-kms over the 30 year evaluation period. Over 25 years the total demand increases by around 15-16% for all scenarios except A2/B2 – the demand regulation scenarios where growth is limited to around 2%.

Similarly, the demand for car use increases by more than 20% except under demand regulation where car use is reduced by around 5-7% below 2005 levels. The differences between the A and B scenarios is only slight as is the difference between the -1, 0 and 1 scenarios.

Table 5.4.2 Passenger demand impacts

	2005	2030							
		A-1	**A0**	**A1**	**A2**	**B-1**	**B0**	**B1**	**B2**
Total passenger km (Million per year)	17.3	19.9	20.0	20.2	17.7	19.8	19.9	20.2	17.7
Index	100.0	114.8	115.4	116.7	102.4	114.6	115.1	116.6	102.0
Total car pass km (Million per year)	13.3	16.0	16.1	16.3	12.7	15.8	15.9	16.3	12.4
Index	100.0	120.8	121.5	123.1	95.3	119.3	120.0	122.5	93.5

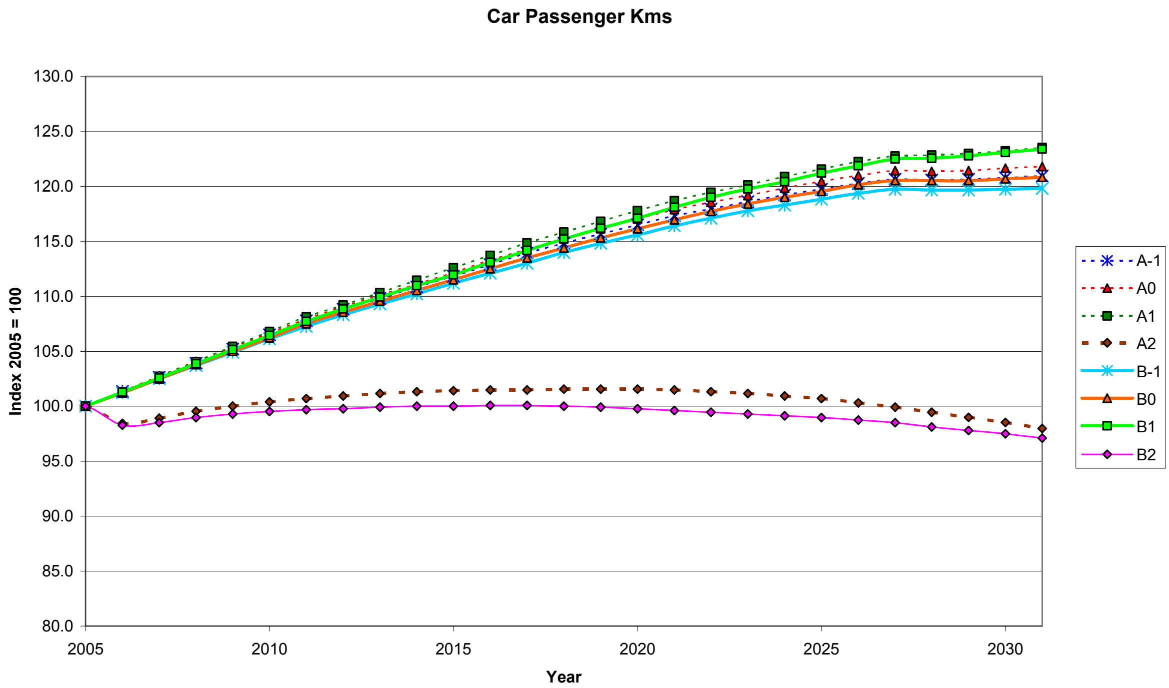


Figure 5.4.7 Car Passenger-km Index over time

Mode share

Table 5.4.3 and Table 5.4.4 show the mode shares for trips and trip-kms. Figures 5.4.8 and 5.4.9 shows the mode share trajectories by scenario over the 30 year evaluation period for car and public transport. As expected the impact on mode share can be viewed in pairs of scenarios. Obviously the demand regulation scenarios A2/B2 have the greatest impact on car use due to the significant increases in costs for car use compared to other scenarios. Similarly A-1/A0/A1 and B-1/B0/B1 are grouped together and the relative changes are small within these groupings as expected.

Table 5.4.3 Mode share (Trips) for year 2005 and year 2030 by scenario

Mode	**2005**	**2030**							
		A-1	**A0**	**A1**	**A2**	**B-1**	**B0**	**B1**	**B2**
Car	58.6%	64.3%	64.1%	64.4%	51.5%	63.4%	63.3%	64.0%	50.4%
Bus	15.1%	13.0%	12.7%	12.7%	17.2%	13.3%	13.1%	12.9%	17.8%
Slow	26.3%	22.8%	23.2%	22.9%	31.3%	23.2%	23.6%	23.1%	31.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 5.4.4 Mode share (kms) for year 2005 and year 2030 by scenario

Mode	2005	2030							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Car	76.5%	80.4%	80.5%	80.7%	71.1%	79.6%	79.7%	80.3%	70.0%
Bus	19.2%	16.1%	15.9%	15.8%	23.6%	16.8%	16.6%	16.2%	24.5%
Slow	4.3%	3.5%	3.6%	3.5%	5.3%	3.6%	3.7%	3.6%	5.4%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

In the business as usual case A0 there is a trend to more car use in both the peak and off-peak. This trend is the same for B0 – the increase in resource cost of fuel has little impact on mode shares. The technology investments scenarios A1/B1 do not impact on mode share – if anything the more fuel efficient fleet encourages more car use in the off-peak period. The demand regulation scenarios A2/B2 as expected have a significant impact on mode shares reversing the trend for increased car use and increasing the shares for both public transport and slow modes.

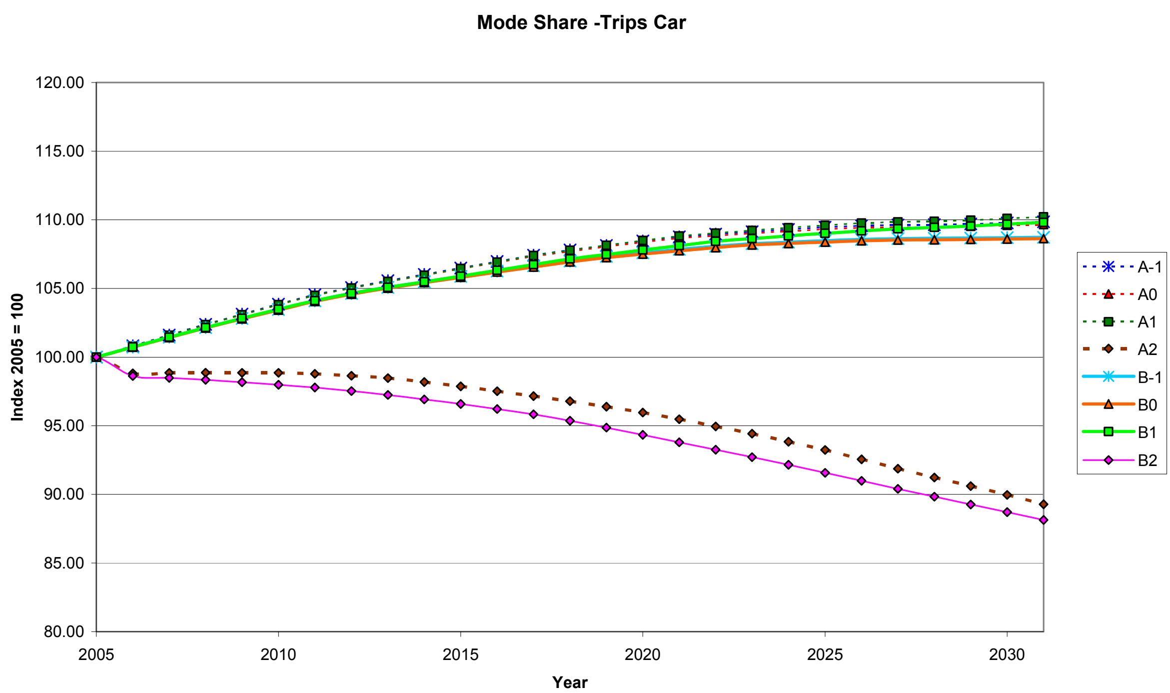


Figure 5.4.8 Trip Mode share trajectories for car

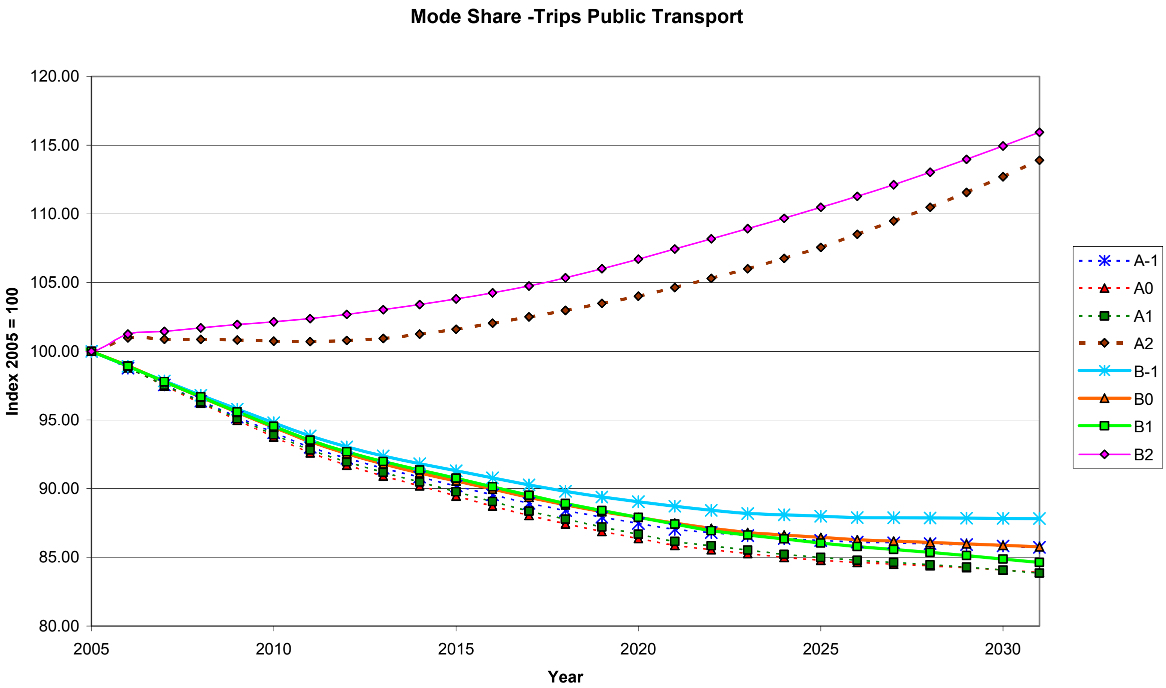


Figure 5.4.9 Trip Mode share trajectories for public transport.

Average speeds

Table 5.4.5 shows the average speeds for public transport and car trips by time period. These are door-to-door speeds and include all access, egress, waiting and parking search times. Public transport speeds are increased as part of the policy for A1/B1 whereas for A2/B2 both car and PT speeds are increased as a result of reduced congestion due to the shift away from car use. This results in car speeds being more in line with current conditions by year 30 under the demand regulation policy.

Without policies the trend is for car and PT speeds to be reduced over time, quite significantly in the peak and less so in the off peak. This is due to the increased demand over the next 25 years. The reduction is lower for PT users as part of the network is insulated against congestion (being either rail or bus lanes). Within the technology investments scenarios A1/B1 the increased speed for public transport in the peak results in similar speeds as for car use – the fact that there is little mode shift is explained by the reduced costs for car and increased costs for public transport under this scenario as shown below. Under the demand regulation scenarios A2/B2 speeds are actually increased slightly compared to 2005. These speed gains come at a cost to the users though whereas the public transport users benefit from the reduced congestion levels (mainly bus based system) along with reduced fares[12]. The average speeds per trip in the off-peak period remain fairly constant despite increased costs under A2/B2 – this reflects the lower levels of congestion in the off-peak period.

[12] Note no operator response is modelled so there will be some increase in crowding without further increases in services

Table 5.4.5 Average speed

Average Speed (km/h)	2005	2030							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Car Peak	26.7	20.4	20.3	20.3	27.0	20.8	20.7	20.5	27.5
PT Peak	20.6	17.5	18.3	20.7	21.4	17.8	18.6	20.9	21.6
Car Off Peak	36.9	36.0	35.9	35.9	33.8	35.9	35.8	35.9	33.9
PT Off Peak	21.6	20.9	21.9	21.9	20.9	21.0	22.0	21.9	21.0

Average Speed Index	2005	2030							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Car Peak	100.0	76.2	76.0	76.0	101.0	77.9	77.5	76.8	102.8
PT Peak	100.0	84.7	88.6	100.3	103.8	86.1	90.0	101.2	104.9
Car Off Peak	100.0	97.7	97.4	97.4	91.6	97.4	97.1	97.3	91.9
PT Off Peak	100.0	96.7	101.6	101.3	96.7	97.1	102.0	101.6	97.2

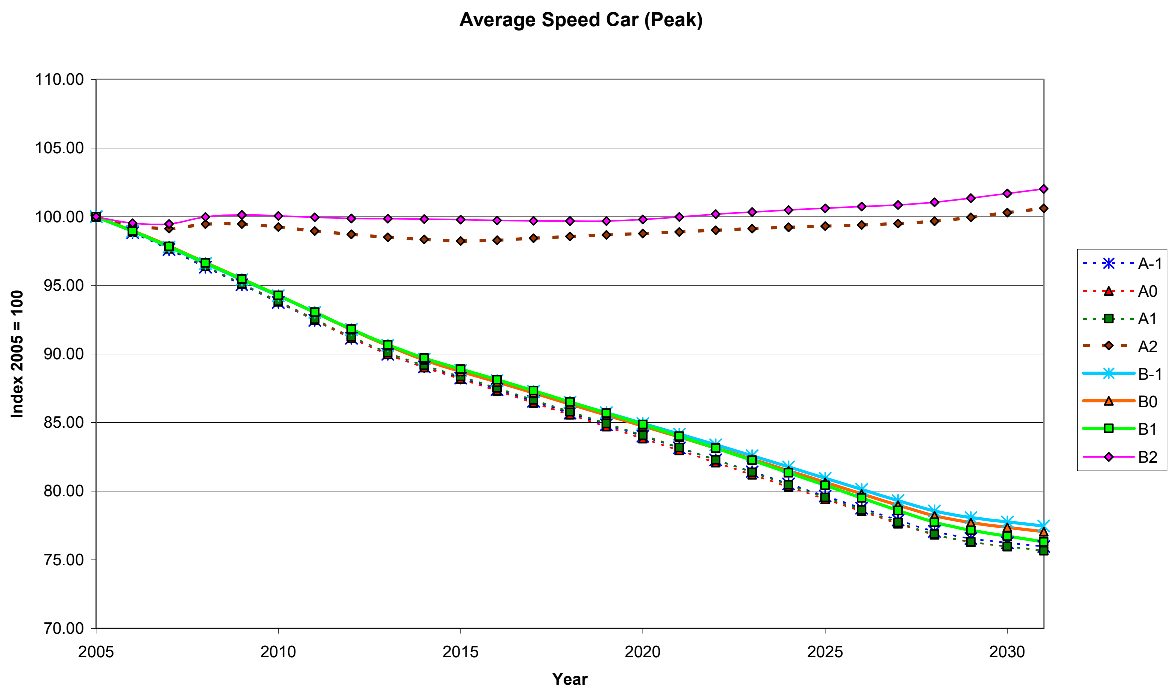


Figure 5.4.10 Average car speed peak period

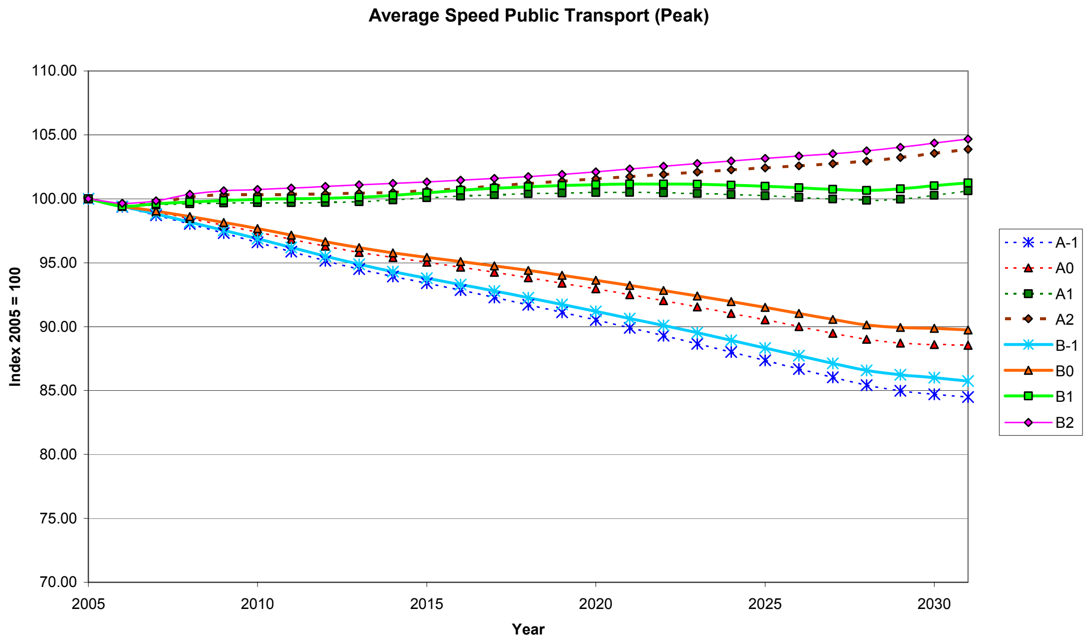


Figure 5.4.11 Average speed public transport peak period

Average trip lengths

Table 5.4.6 shows the average trip lengths by PT and car users for year 2005 and year 2030. In general trip lengths are increasing over time for both car and PT use. This is due to the additional developments in the outer zones and increased car ownership levels. The B0 scenario has a small impact on average car trip lengths reducing them by less than 1% compared to A0 in 2030. The technology investments scenarios have little impact – if anything average trip lengths increase slightly. As expected the demand regulation scenarios have the greatest impact on trip length reducing car trip lengths by around 10% in both A and B scenarios. They also reduce PT and slow mode average trip lengths by similar amounts which suggests that the land use controls may play a significant role in this reduction in average trip lengths (more research with and without land use controls would be required to confirm the cause of the reduction).

Table 5.4.6 Average trip lengths.

Average Trip Lengths	2005	2030							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Public Transport	13.7	14.2	14.3	14.3	12.8	14.3	14.3	14.3	12.7
PT Index	100.0	104.3	104.5	104.7	93.8	104.5	104.7	104.7	93.4
Car	14.2	14.6	14.6	14.6	13.1	14.5	14.4	14.6	13.0
Car Index	100.0	102.7	102.3	102.8	91.8	101.8	101.5	102.4	91.4

Energy

Table 5.4.7 and figure 5.4.12 shows the energy use in tonnes of oil equivalent, energy use per million trips and trajectories over time for total energy used. Without any policies there is a reduction in energy used of 16% in the A-1 scenario and 19% in the B-1 scenario due to the improved fleet which reduces energy used per trip by 21% and 24.5% respectively.

The technology investments scenarios decrease total energy used compared to A0/B0 in year 30 by 16% and 22% respectively. The demand regulation scenarios decrease total energy use by 4.5% and 3.9% for A2/B2 respectively whilst the induced shift away from car use and shorter trip lengths due to compact land use means a greater reduction in energy used per trip. In terms of energy indicators the technology investment policies are more effective than the demand regulation policies.

Table 5.4.7 Energy use

Energy Use	2005	2030							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Total Energy toe/year	428	359	359	304	344	348	348	276	335
Index	100.0	84.0	84.0	71.1	80.4	81.3	81.3	64.4	78.2
Energy per trip (toe/million trips)	0.39	0.31	0.31	0.26	0.27	0.30	0.29	0.23	0.26
Index	100.0	78.7	77.7	65.5	67.7	75.5	74.6	59.0	65.3

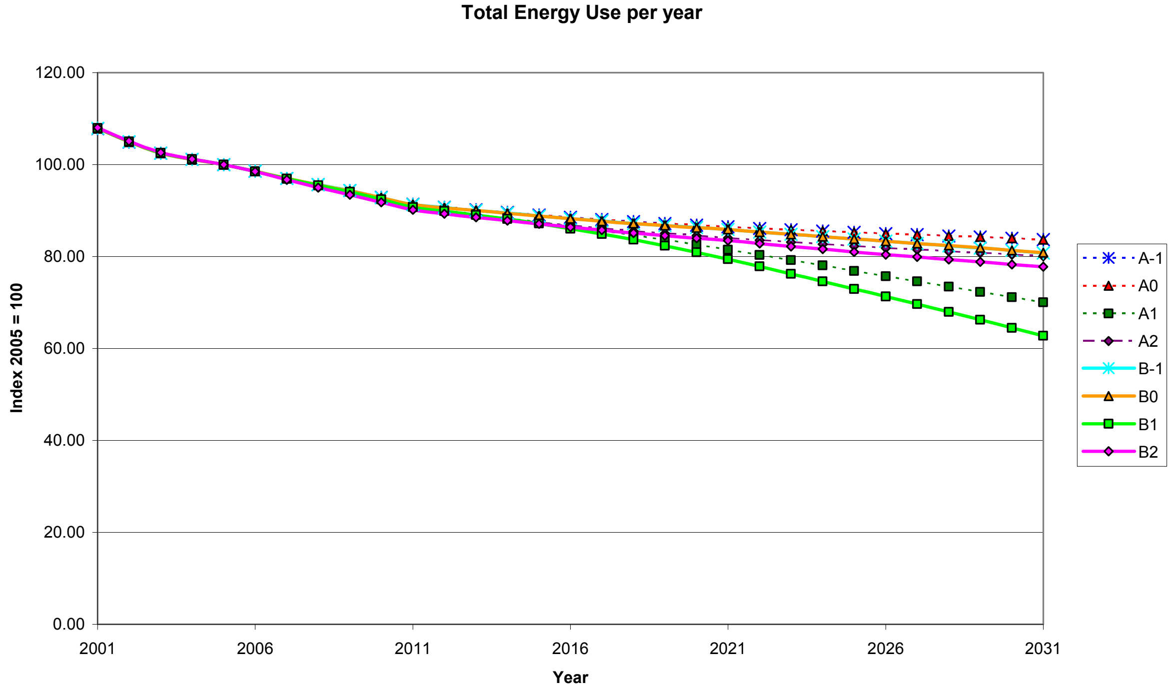


Figure 5.4.12 Changes in total energy use per scenario

Emissions

CO_2 produced per person km is reduced despite the increase in car use in the A-1 case by around 14% over the 25 year period. This is due to improved technologies and the shift from conventional vehicles. Demand regulation and technology investments scenarios both reduce CO_2 per person-km even further, the technology policies being more effective on a per km basis. In terms of total CO_2 produced, the demand regulation scenario outperforms the technology investments scenario for both A and B scenarios reducing the total well to wheel emissions by 23% and 27% compared to 2005 levels respectively.

NO_X emissions are reduced by around two-thirds in A-1 and B-1. This is due to technological improvements which are already in the pipeline. It then becomes a question of how much further NO_X can be reduced by year 30. Accelerating the investment in technology under scenario B1 reduces NO_X by 27.7% compared to B0 in year 30 – which is due to the high proportion of Hydrogen powered vehicles in use by 2030.

The trajectories for PM (figure 5.4.14) all show a marked decline around year 2011 due to the introduction of EURO V standards. PMs are reduced by 55-60% in the A-1 cases despite increased car-kms. Further reductions are possible with investment in technology and/or by demand regulation. These reductions are really the icing on the cake as there is significant progress being made in the A0 case.

Table 5.4.8 Emissions of CO_2, NO_X and PMs.

	2005	2030							
		A-1	A0	A1	A2	B-1	B0	B1	B2
CO2 WW tons/year	1,102,829	1,090,347	1,094,622	942,220	847,864	1,042,521	1,047,666	848,504	809,828
Index	**100.0**	**98.9**	**99.3**	**85.4**	**76.9**	**94.5**	**95.0**	**76.9**	**73.4**
Co2/person km (g/km)	95.8	82.8	82.6	70.3	71.4	79.3	79.2	63.3	68.4
Index	**100.0**	**86.4**	**86.2**	**73.3**	**74.5**	**82.7**	**82.6**	**66.0**	**71.4**
Total NOx Pump-Wheel (tons/year)	2628	935	938	771	727	826	829	613	650
Index	**100.0**	**35.6**	**35.7**	**29.3**	**27.7**	**31.4**	**31.5**	**23.3**	**24.7**
Total PM Pump-Wheel (tons/year)	123	55	55	46	42	48	49	36	37
Index	**100.0**	**44.9**	**45.1**	**37.2**	**34.2**	**39.5**	**39.7**	**29.4**	**30.5**

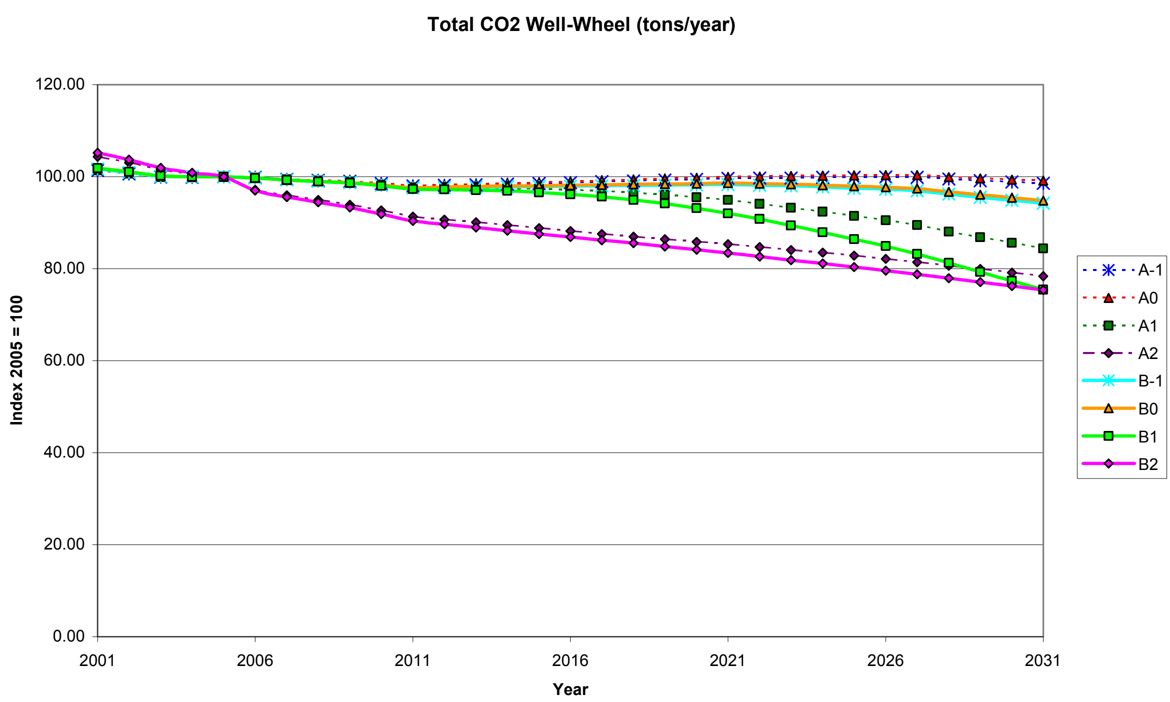


Figure 5.4.13 CO2 Well to Wheel – trajectories per scenario

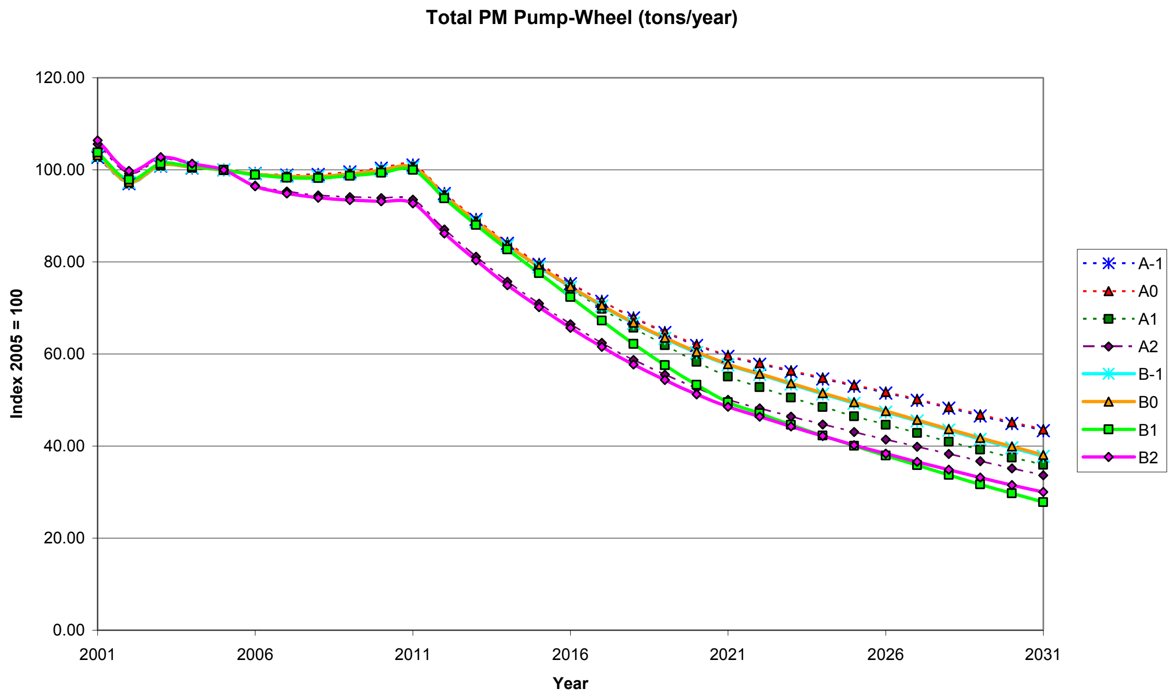


Figure 5.4.14 PM Pump to wheel trajectories per scenario

Noise and accidents

Noise costs increase by 11% in the A0 case but can be reduced to below current levels under the demand regulation scenarios A2/B2. Similarly accident levels increase by 12% under the business-as-usual and technology investments scenarios but are reduced below current levels by the demand regulation policies A2/B2. This relatively large reduction is solely due to the reduction in car use caused by the demand regulation and land use policies.

Table 5.4.9 Noise and Accidents

	2005	2030							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Total Noise cost	0.98	1.09	1.09	1.11	0.93	1.08	1.09	1.11	0.92
Index	100.0	111.1	111.6	113.3	94.7	110.4	111.0	113.1	93.4
Accidents per year	1791	2005	2014	2044	1691	1992	2002	2040	1666
Index	100.0	111.9	112.5	114.1	94.4	111.2	111.8	113.9	93.0

Cost per trip and per km by mode

Table 5.4.10 shows the average costs per trip by mode for year 2005 and year 2030. The lower costs for car use in A-1/A1 are due to the increased fuel efficiency and a move towards alternative fuels. This results in lower costs per km in year 30 than in year 5 under A1 cancelling out any tax and oil price increases. The effect is more marked for the peak which suggests the efficiency gains are speed dependent and so the congested peak benefits more than the un-congested off-peak.

The regulation scenarios A2/B2 increase costs for car use by 80-90%. Basically these changes in costs per trip help explain the mode shifts above. Note the much cheaper car cost in the off-peak compared to peak for all scenarios – this is due in part to cheaper parking charges but also due to lower fuel consumption in the less congested conditions. The public transport costs are also reduced significantly by year 30 with the fare reduction policy in A2/B2 compared to the increases in A0/A1/B0/B1.

Table 5.4.10 Average costs per trip

Cost Per Trip (€)	2005	2030							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Car Peak	2.7	2.6	2.8	2.6	4.9	3.0	3.2	2.8	5.2
PT Peak	2.5	2.6	3.1	3.1	1.6	2.6	3.1	3.1	1.6
Car Off Peak	1.1	1.0	1.1	1.0	2.0	1.2	1.3	1.1	2.1
PT Off Peak	2.0	2.0	2.3	2.3	1.2	2.0	2.4	2.4	1.2
Index Car Peak	100.0	95.7	104.3	95.3	180.6	110.8	118.6	102.4	189.4
Index PT Peak	100.0	101.9	122.8	122.0	63.7	102.0	122.9	122.0	63.6
Index Car Off Peak	100.0	95.8	104.0	96.3	188.8	111.4	119.0	103.8	198.3
Index PT Off Peak	100.0	99.0	119.1	119.1	62.3	99.3	119.5	119.2	62.2

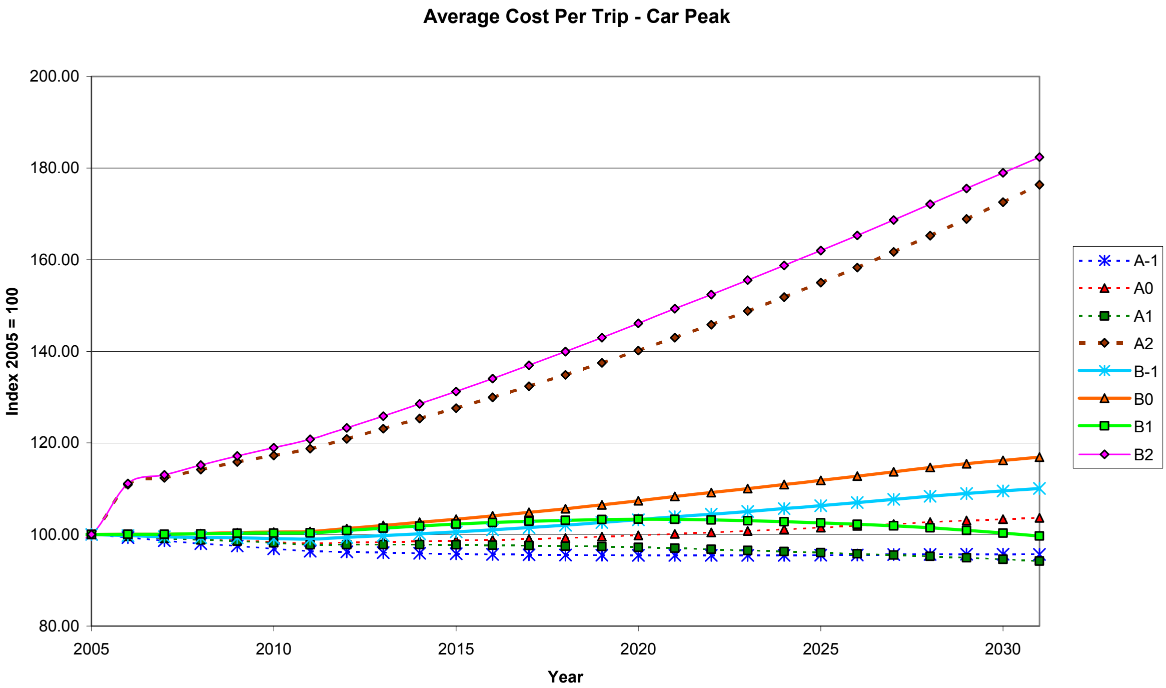


Figure 5.4.15 Trajectories per scenario : Average cost per trip for car in the peak period.

Revenue from charges on car use

Table 5.4.11 shows the changes in fuel tax revenues and road user charging revenues for each scenario. Revenue is obviously affected by the growth in fuel taxes and the VAT element which depends on resource cost and fuel duty levels. It is also dependent on overall demand and the shift to other modes and to alternate vehicles. A-1 and B-1 sees fuel tax revenues decrease by 5% and 13% respectively due to increased fuel costs without any other policies in place. This is the most significant impact of the no-policy scenarios. The business as usual scenarios see revenues increase by 23% and 12% over the 25 year period. The demand regulation scenarios A2/B2 stand out as they increase the tax revenue significantly – both more than double the tax take compared to the A0 case. Note A2 increases the revenue take more than in B2 as the proportion of tax to pump price is higher. Conversely the technology investments scenarios and B0 result in a reduction in fuel tax revenues compared to A0. For A1 this is due to the more efficient fleet and lower taxes assumed on alternative vehicles. In B0/B1 there is the combined effect of more fuel efficient fleet, higher prices for fuel reducing demand and the shift to alternative vehicles.

Revenue from road charging

All scenarios collect tolls from the Forth Road Bridge. Only scenarios A2/B2 include the road pricing cordons around Edinburgh. These generate an additional €150m in the opening year with a charge of €2 rising to an additional €400m per year with a charge of €5. There are only small differences between A2 and B2.

Table 5.4.11 Fuel tax revenue year 1 and year 30

Fuel Tax and Road charging revenues	2005	2030							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Revenue Fuel Tax	268.6	256.0	330.7	273.2	711.4	233.8	301.6	221.2	652.8
Index	100.0	95.3	123.1	101.7	264.8	87.0	112.3	82.4	243.0
Revenue Road charge	54.8	60.6	60.9	61.7	461.2	60.1	60.5	61.5	452.3
Index	100.0	110.5	111.1	112.5	841.4	109.7	110.3	112.2	825.2

Accessibility to workplaces

Accessibility here is meant as the aggregated accessibility to workplaces by car, public transport and slow modes. Appendix A contains figures of changes in accessibility to workplaces between year 2005 and 2030 for all eight scenarios in turn. As most scenarios give similar results in terms of accessibility we concentrate within this section on the significant differences brought about by the demand regulation scenarios A2 and B2 described earlier. Figures 5.4.16 and 5.4.17 show these differences between A2 and A-1 and B2 and B-1 respectively. From these figures we can see that the development controls which do not allow any new developments in the outer areas increase accessibility via increased speeds in these areas. In contrast the inner zones suffer a reduction in speed due to increased densities and hence a reduction in accessibility up to 15% relative to the base scenarios.

Note that differences in residents and employment are scenario based for the Edinburgh study and these really only vary for the A2 and B2 scenarios as described in section 5.4.3.

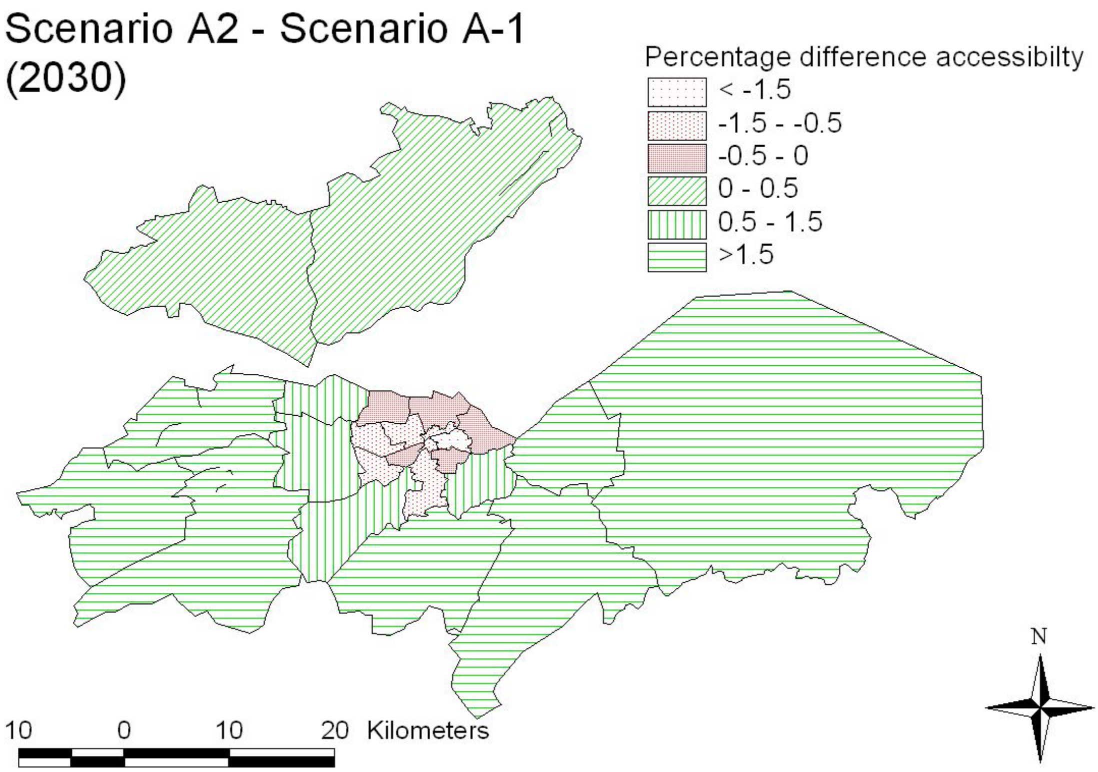


Figure 5.4.16 Relative difference in accessibility to workplaces (A2-A-1)

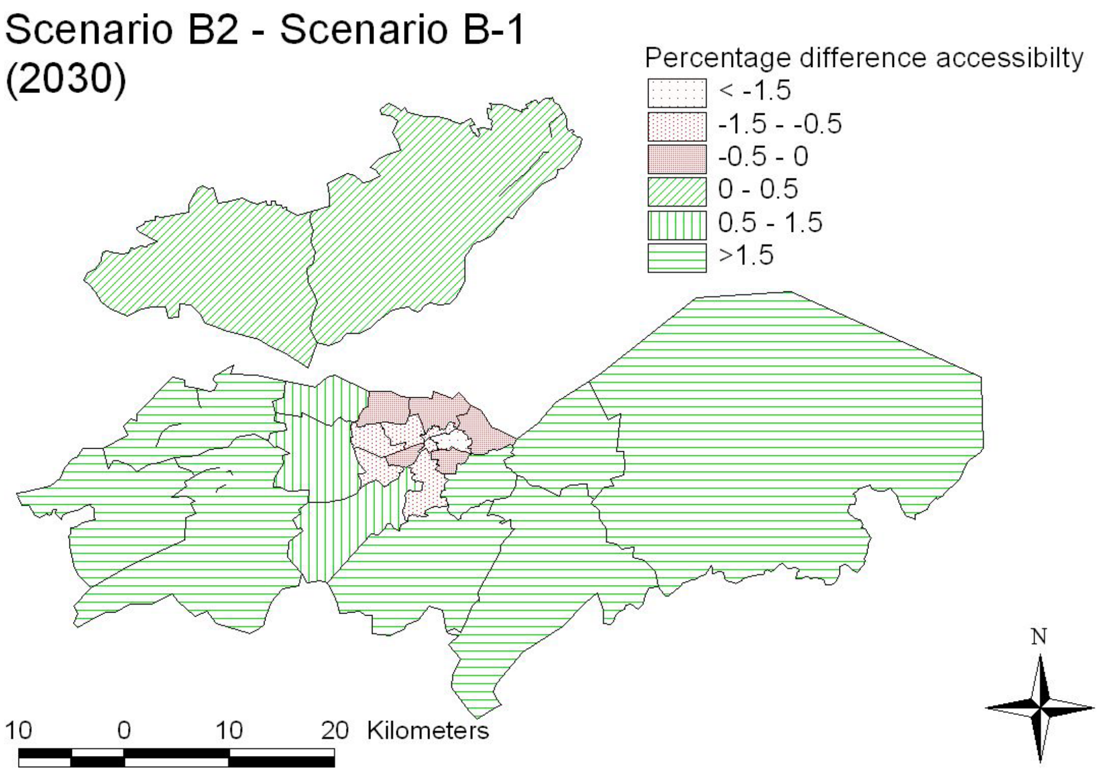


Figure 5.4.17 Relative difference in accessibility to workplaces (B2-B-1)

5.5 The Helsinki model results

5.5.1 The Helsinki model

The geographical scope of the model is the Region around Helsinki within about 100 km radius (pendel region, 1 657 000 inhabitants in 2000). The study area covers the Helsinki Metropolitan Region (946 000 inhabitants) and is divided into 53 +42 = 95 land use zones and transport zones. Five external zones are also considered.

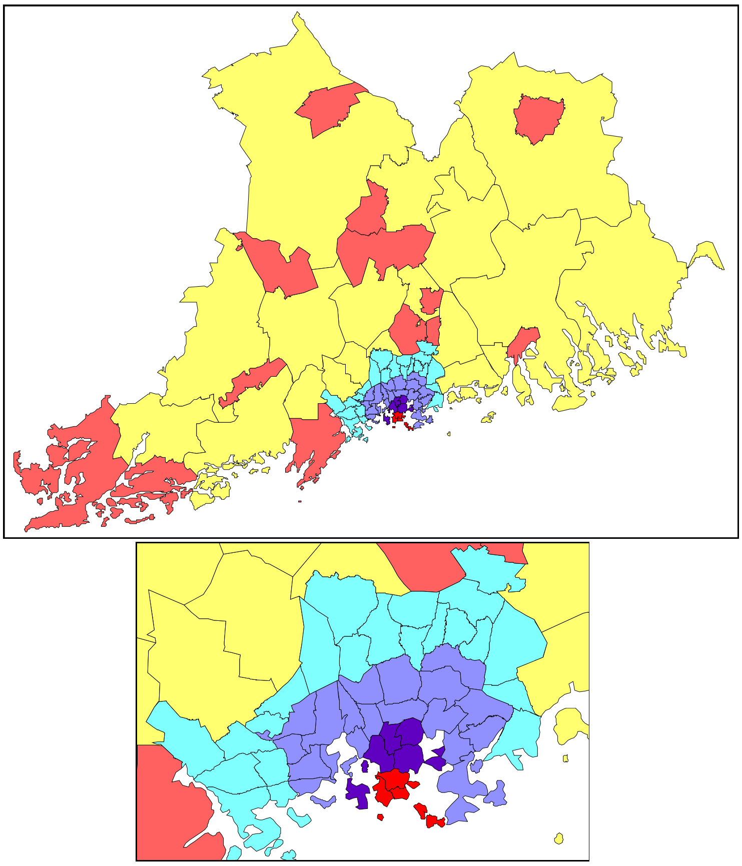


Figure 5.5.1 The Helsinki model zoning system, the model area and the study area

The Helsinki model area is actually a large region that includes both urban and rural areas. At the heart of the region lies Helsinki, the capital of Finland, surrounded by three smaller cities. Together they form the Helsinki Metropolitan Area (HMA). Additionally, included in the model area is a relatively large surrounding region with smaller cities and towns lying within the Metropolitan Area's commutershed. The total land area is 13 827 km2 of which the metropolitan region is 743 km2.

The Helsinki model was originally built in early 90s and has since then been regularly updated and expanded. It currently corresponds with the Helsinki Metropolitan Area Transport Master Plan. The model was last updated in 2003 – 2004 for the assessment of the Transport Master Plan.

The base year of the model is 2000 and it produces forecasts for the years 2005, 2010, 2015 and 2020.

The Helsinki model was built using the MEPLAN software and it belongs to the group of the integrated land-use/transport models. For that reasons, two main modules can be recognised: a land use model and a transport model. An interface module provides the required connections between the two main modules in both directions. For further details see D4.1 or the South Tyrol model description in section 5.6.

The Helsinki Metropolitan Area Council has prepared a long-term transport plan for the year 2020. This plan and the projects included in the plan forms the basis for the development of infrastructure and is assumed to be the same in all scenarios.

It is important to understand – when analysing the results – that the population of the model area is rapidly increasing due to immigration from 1.720.000 inhabitants in 2005 to 1.954.000 inhabitants in 2020.

The figures below illustrate the growth of population and employment in different superzones or rings around Helsinki city centre. The superzones are illustrated on the map in Figure 5.5.2.

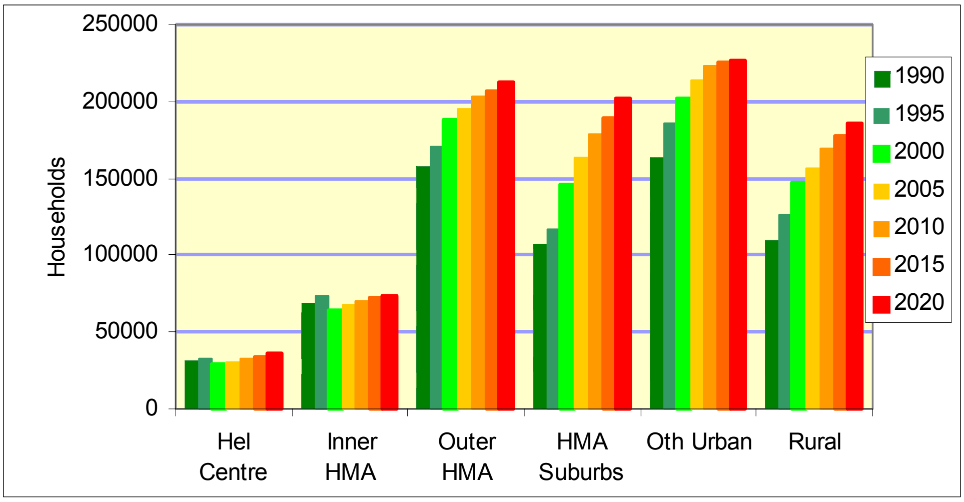


Figure 5.5.2 Growth of population in different superzones

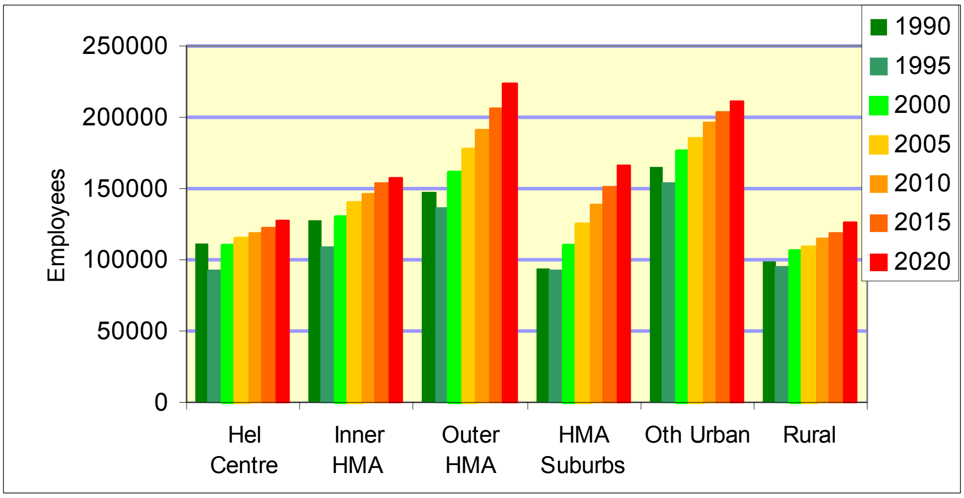


Figure 5.5.3 Growth of employment in different superzones

5.5.2 Implementation of the scenarios in the Helsinki model

Helsinki model tests have been defined based on the D3 definitions and the output of the ASTRA and POLES runs. The scenarios have been implemented through direct input parameter changes in the model according to the definitions. The feedback effects of the annual changes of the parameters have not been considered (e.g. reduction of fuel consumption due to higher price). Therefore the actual outcomes usually differ from the definitions (as the demand model has e.g. price elasticity).

The defined car ownership changes have been reached by changing the constants of the model. The improvement of public transport service has been implemented in the runs by decreasing the time spent for a trip on that mode with a coefficient. Car and lorry speed reduction policy has been applied to the metropolitan area only as defined in D3 by reducing the speed limits. The pricing system is a distance related system that reduces the additional cost by one third in each of the three concentric rings around the city centre. The price is relative to the behavioural vehicle operating costs. The logistics policies have been implemented with coefficients reducing the congestion effect and distance ‘artificially’ in the assignment phase of the model. All energy policies are a direct application of the coefficients in the ASTRA/POLES data.

Fuel price is part of the vehicle operation cost (VOC) function for car and freight road transport according to the standard practise used in the Finnish CBA. As described above, the given changes in consumption by the ASTRA/POLES information is used instead of changing of fuel consumption per kilometre (e.g. due to congestion). The person traffic behavioural VOC in the Helsinki model consist of the resource costs part (€/litre) and excise tax part of the fuel in addition to the VAT (i.e. the weighted average pump price of petrol and diesel). We assume that the VAT is included in the resource cost part in the ASTRA/POLES data and it is therefore extracted from the values for different years before they are applied to the VOC functions of the model. Goods traffic behaviour is based on all vehicle costs excluding VAT. The operating cost increase due to the alternative technology (as defined in the scenario definitions) are assumed to affect the whole VOC of the fleet (as it would be rather illogical to assume production cost changes for fuels e.g. due to the development of electric cars).

The fixed emission factors for Finland provided by ASTRA/POLES results for an average vehicle of the car fleet and the fuel price (comprehensive of pure fuel cost and fuel taxes) have been used for each technology and road type pair. The division of the fleet into different technologies also follows the ASTRA/POLES definitions for Finland. Vehicle efficiency development has not been used because of the model structure as we apply directly the ASTRA/POLES assumptions.

The scenario inputs are summarised in the table 5.5.1 below. Land use changes in scenario A-1 are explained above. Land use changes in other scenarios are scenario outputs and therefore not presented in the table. Land use changes in different scenarios are illustrated in figure 5.5.20.

Table 5.5.1 Scenario inputs for Helsinki

	Measure	Indicator	Annual change (%)		
			A0/B0	A1/B1	A2/B2
Socio-economic	Pure Fuel Price	Car Cost (petrol)	0.8% / 4.9%	0.6% / 4.7%	0.6% / 4.7%
		Car Cost (diesel)	0.9% / 5%	0.7% / 4.8%	0.6% / 4.8%
	Car sharing etc.	Cars per 1000 inhabitants	0.98 %	0.96 %	-0.50 %
	Fuel tax	Petrol (€/l)	0.58 %	0.58 %	5.68 %
		Diesel	1.61 %	1.61 %	5.68 %
		Kerosene			
	Travel cost due to tax increases	Cost per km	-0.3 %	0.7% / 0.1%	4% / 4.3%
		Air cost per km			
	Telework	Work trips			
Travel	European rail	European rail speed			
	Regional rail	Regional rail time	-0.40 %	-1.70 %	as A0
	Public transport	Public transport time	-0.30 %	-1.10 %	as A0
	Traffic calming	Car speed in HMA	-0.40 %	as A0	-1.00 %
	Road pricing	€ per car-km	2.00 %	as A0	6.00 %
	Public transport cost	Bus cost per km	0.80 %	as A0	-1.70 %
		Train cost per km	0.80 %	as A0	-1.70 %
Freight	Traffic calming	Lorry speed in cities	-0.40 %	as A0	-1.00 %
	Road pricing	€ per veh-km	2.00 %	as A0	6.00 %
	City logistics	Distance in cities	-0.20 %	-0.50 %	as A0
		Load factor in cities	0.80 %	2.40 %	as A0
	Rail freight	Rail freight speed			
		Rail freight cost			
Energy	Energy use car	Petrol per km	-0.9% / -1.1%	-0.7% / -1.6%	-1.2% / -1.4%
		Diesel per km	2.7% / 2.4%	2.6% / 2.1%	2.3% / 2.0%
	Alternative vehicles	Emissions per km	-1.2% / -1.4%	-1.8% / -2.2%	-1.2% / -1.2%
		Car fleet	POLES car fleet	POLES car fleet	POLES car fleet
		Car/GV resource cost per km	0.80 %	3.00 %	as A0
	Energy use rail	Energy per km	-0.80 %	-5.00 %	as A0
	Energy use ship	Energy per km			

HMA = Helsinki Metropolitan Area

(yellow)	ASTRA/POLES input, model output for information
(grey)	Not used/scenario parameter in Helsinki Model

5.5.3 Main results from the Helsinki model

This paragraph describes the main results concerning the simulation of the STEPs scenarios with the Helsinki model. Results are presented and commented below for five main areas: transport demand, environment, society, economy and land use.

Transport demand

Figure 5.5.4 illustrates the growth of passenger kilometres, which varies between 33% (B0) and 54% (A1) between 2020 and 2005 whereas the population growth during the same period is only about 14%. A0 and B0 are on lower level whereas A1 and A2 and B1 and B2 are on higher level than the corresponding no-policy trends A-1 and B-1. B scenarios with higher fuel prices are always lower than the A scenarios. The reasons for mileage growth is in the urban sprawl trend and increased use of public transport in many scenarios.

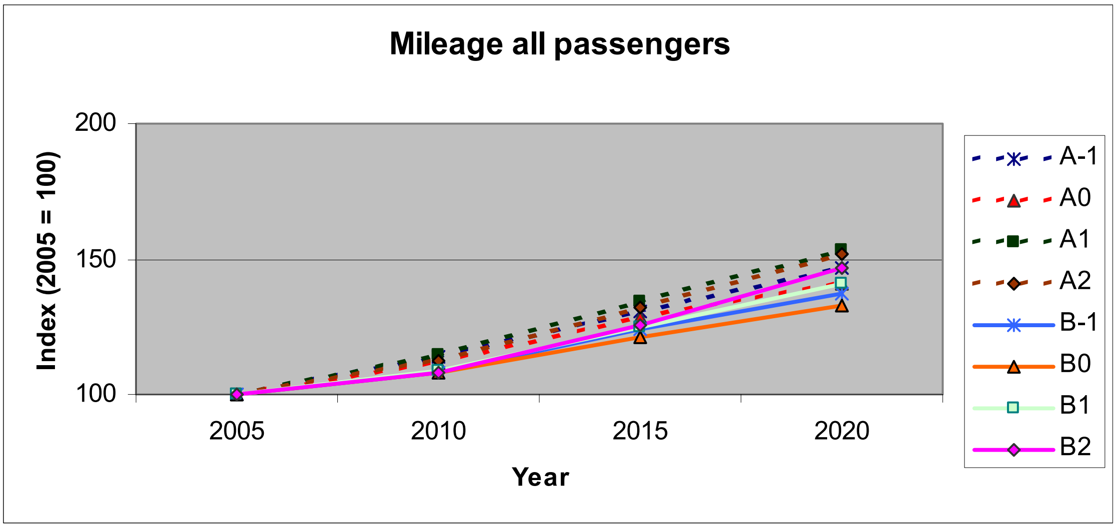


Figure 5.5.4 Total mileage index in the eight scenarios

The private car kilometre index is illustrated in Figure 5.5.5.

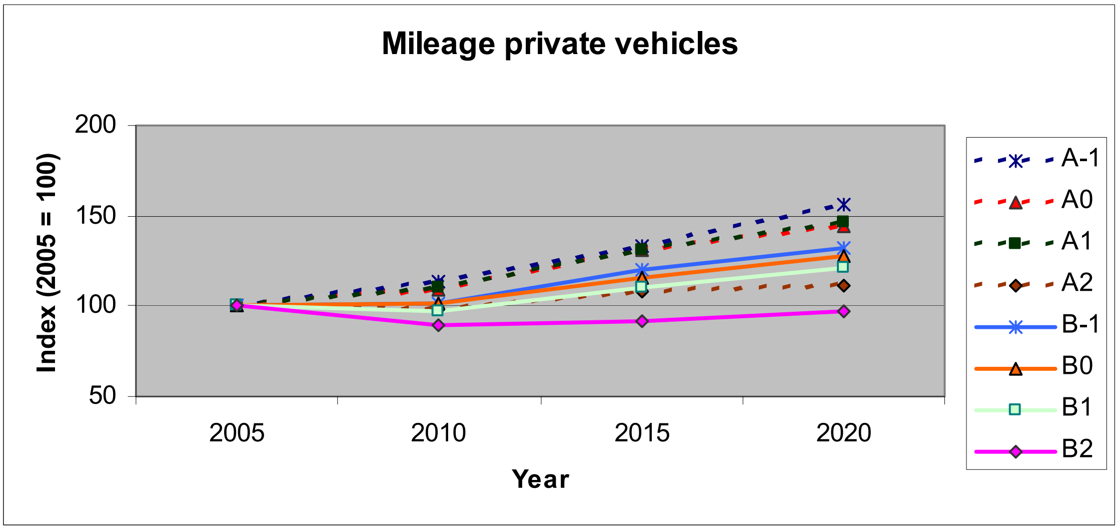


Figure 5.5.5 Total private vehicles mileage index in the eight scenarios

All scenarios produce less car kilometres than the no-policy case A-1 but only the Scenario B2 maintains or slightly reduces the current absolute level of car kilometres and the number of car kilometres/inhabitant is clearly reduced. The demand regulation scenarios are significantly better in reducing car kilometres than the technology investments scenarios.

The increase of goods vehicle kilometres varies between 19-29% (Figure 5.5.6), which is in all cases more than the population growth. All scenarios reduce freight compared with the no-policy case A-1. The demand regulation scenarios are more efficient than the technology investments scenarios in reducing goods transports.

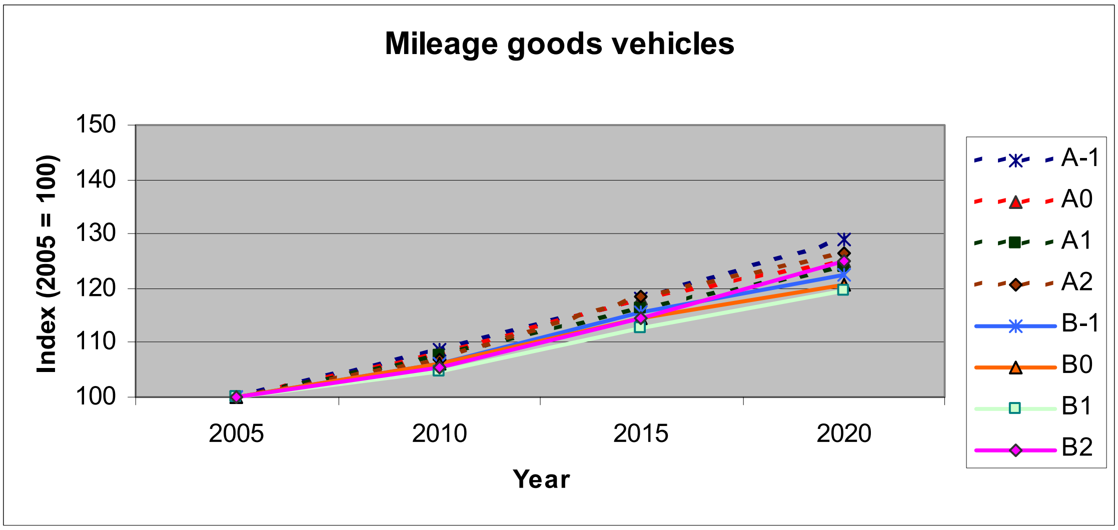


Figure 5.5.6 Mileage index for goods vehicles in the eight scenarios

Change of modal shares for public transport and private cars are illustrated in Figure 5.5.7 and Figure 5.5.8.

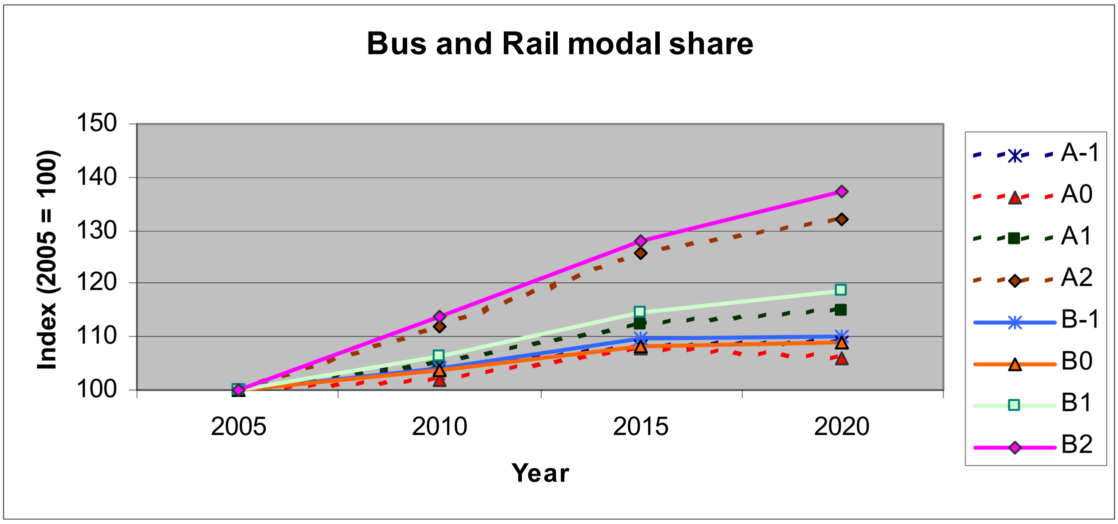


Figure 5.5.7 Modal share development for public transport

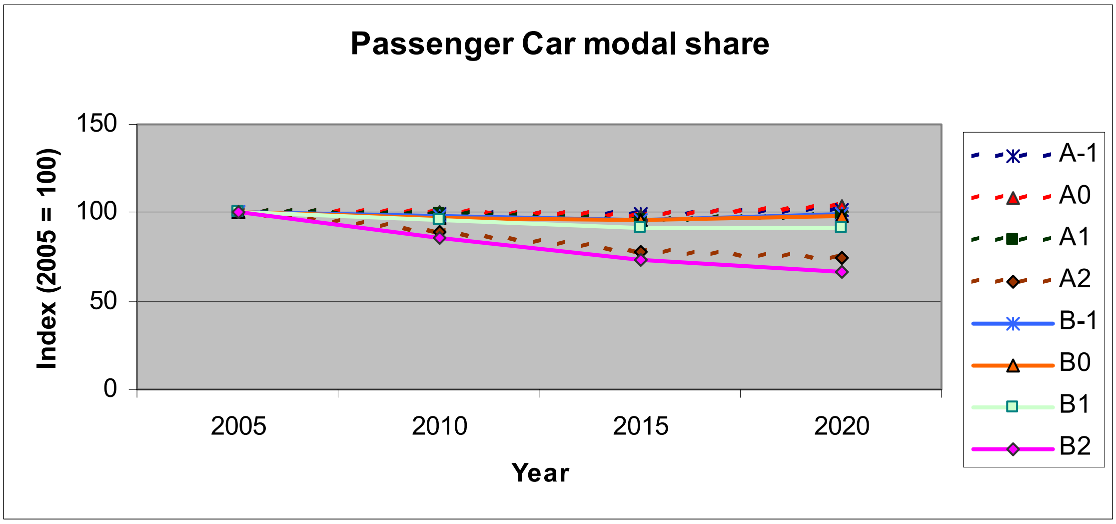


Figure 5.5.8 Modal share development for private cars

The modal shares are also presented in the table below.

Table 5.5.2 Passenger modal shares at 2020 in the eight scenarios

Mode	2005	2020							
		A-1	**A0**	**A1**	**A2**	**B-1**	**B0**	**B1**	**B2**
Slow	13.9%	8.9%	9.7%	8.4%	7.3%	9.1%	10.0%	8.6%	7.5%
Public	49.6%	51.8%	51.1%	53.5%	61.1%	52.4%	51.7%	55.2%	62.7%
Car	36.5%	39.4%	39.3%	38.0%	31.6%	38.5%	38.3%	36.2%	29.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The demand regulation scenarios B2 and A2 are efficient in reducing the private car modal share and correspondingly in increasing the public transport modal share. Part of the shift is also explained by slow modes users who change to use public transport. The public transport modal share is maintained or increased in all scenarios.

The average speeds of public transport and private cars are illustrated in the figures and the table below.

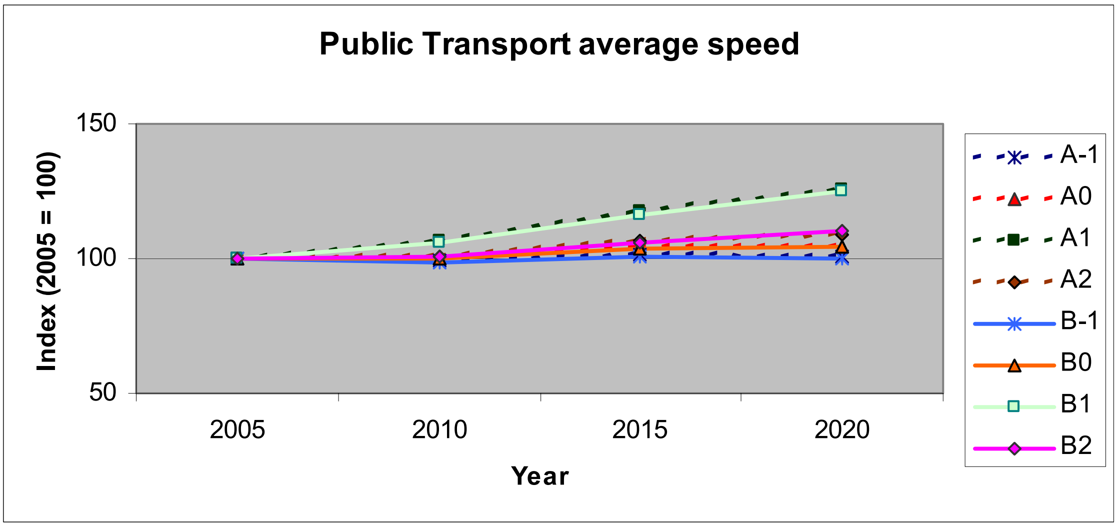


Figure 5.5.9 Index for Public Transport speeds

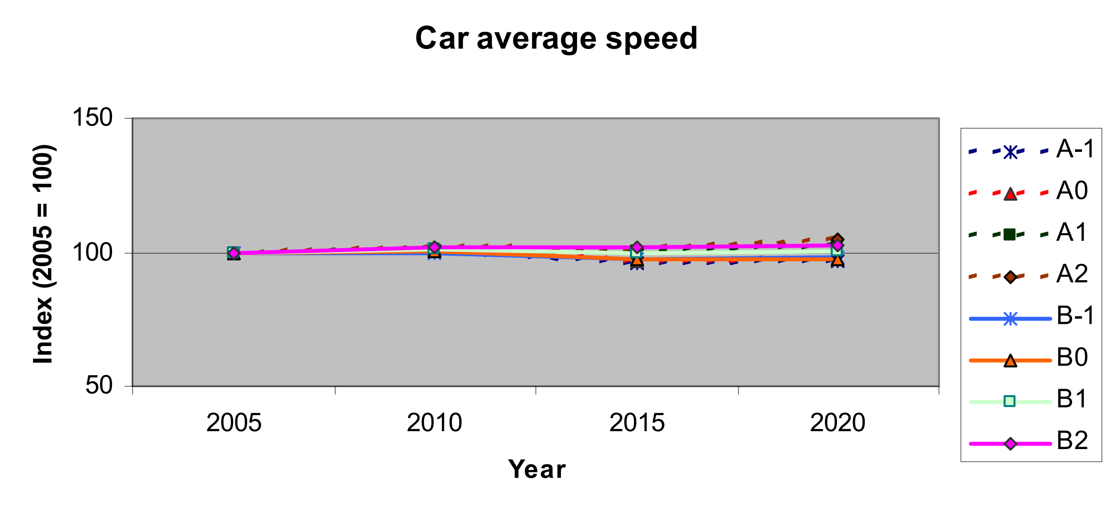


Figure 5.5.10 Index for car speeds

Table 5.5.3 Average speed of passenger modes at 2020in the eight scenarios [1] (km/h)

Mode	2005	2020							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Bus	18.4	18.4	19.2	21.8	19.4	18.3	19.1	21.7	19.4
Train	25.8	26.2	27.1	32.2	29.0	25.9	27.1	33.6	29.4
Car	53.7	52.0	52.3	54.1	55.8	52.8	52.3	54.1	54.7

Car speeds increase most in scenarios A2 and B2 due to less congestion. The lower increase in B2 compared with A2 is explained by the land use effects: in B2 people live in more central areas than in A2. The public transport speeds are maintained or increased in all scenarios.

Travel distances for public transport and private cars are illustrated in the figures and table below.

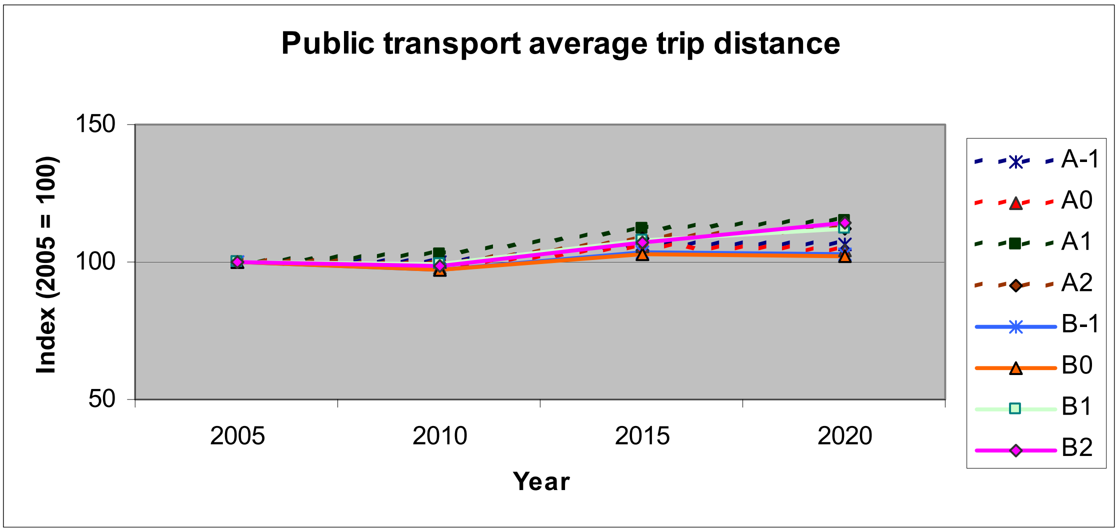


Figure 5.5.11 Public transport average travel distance index

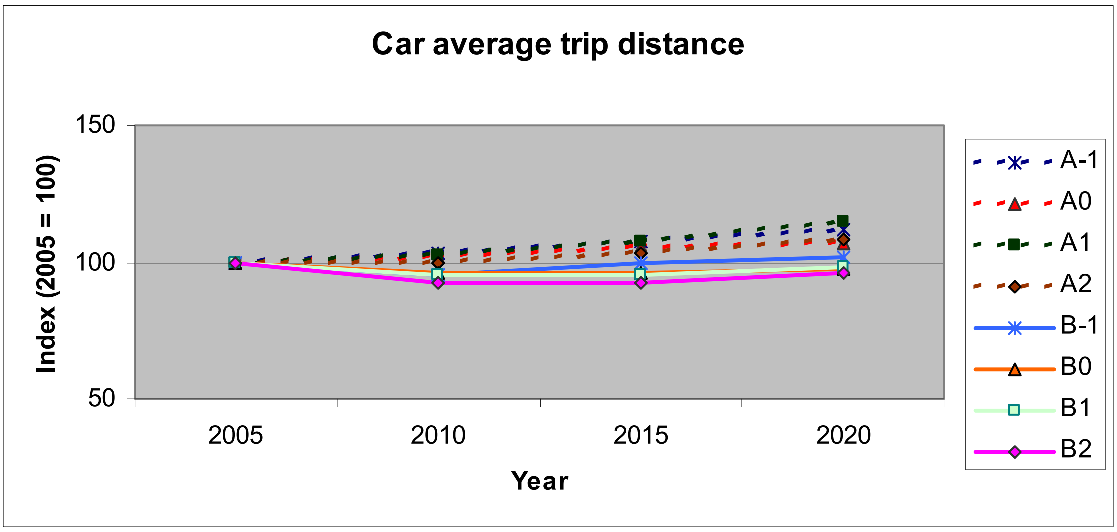


Figure 5.5.12 Private car average travel distance index

Table 5.5.4 Average distance of passenger modes in 2020 in the eight scenarios [1] (km)

Mode	2005	2020							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Slow	2.69	2.65	2.65	2.64	2.69	2.65	2.65	2.64	2.68
Public	12.32	13.09	12.81	13.30	13.89	12.65	12.58	13.79	14.16
Car	14.43	16.13	15.46	15.89	15.79	14.65	14.02	14.13	13.98
All trips	11.75	13.36	12.87	13.39	13.67	12.50	12.14	12.96	13.24

Average travel distances for both cars and public transport tend to increase due to the city sprawl effect. The average trip distances for cars are best maintained in the B scenarios under the high oil price growth.

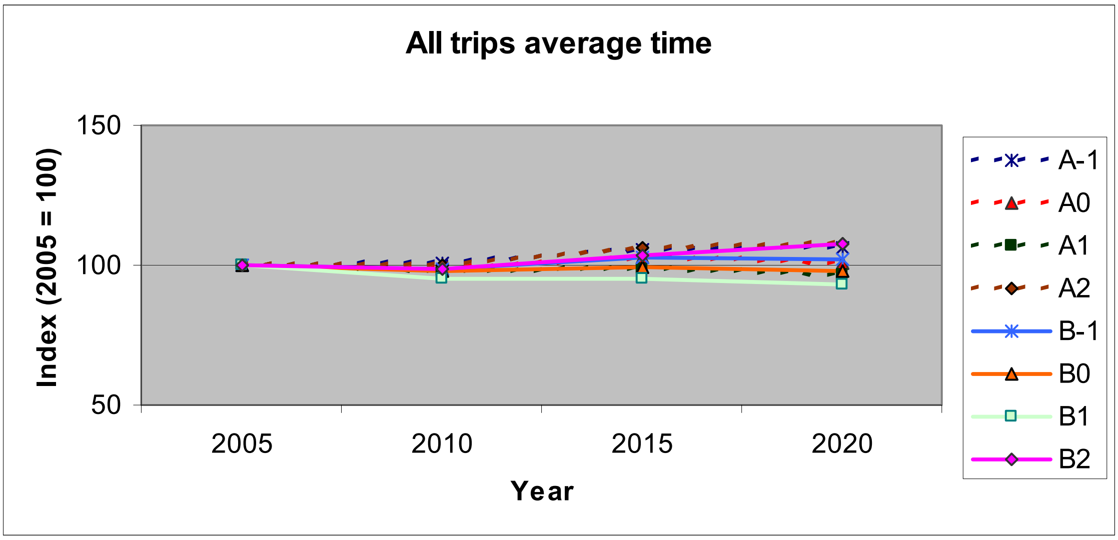


Figure 5.5.13 Average travel time index for all trips

The figure shows that the average travel time index for all trips can be reduced in scenarios B0, B1 and A1. However, increased fuel price and regulation policies in B2 then start to affect the total trip times by increasing them due to further increased use of public transport.

Environment

The Helsinki model produces forecasts for CO2, CO, NOx and PM. The emissions are presented as indices of the total emissions.

The CO_2 emissions are growing in each scenario but the growth/inhabitant is less or at the same level than the population growth scenarios A2 and all B scenarios. The demand regulation scenarios are more efficient in reducing CO_2 emissions than the technology investments scenarios.

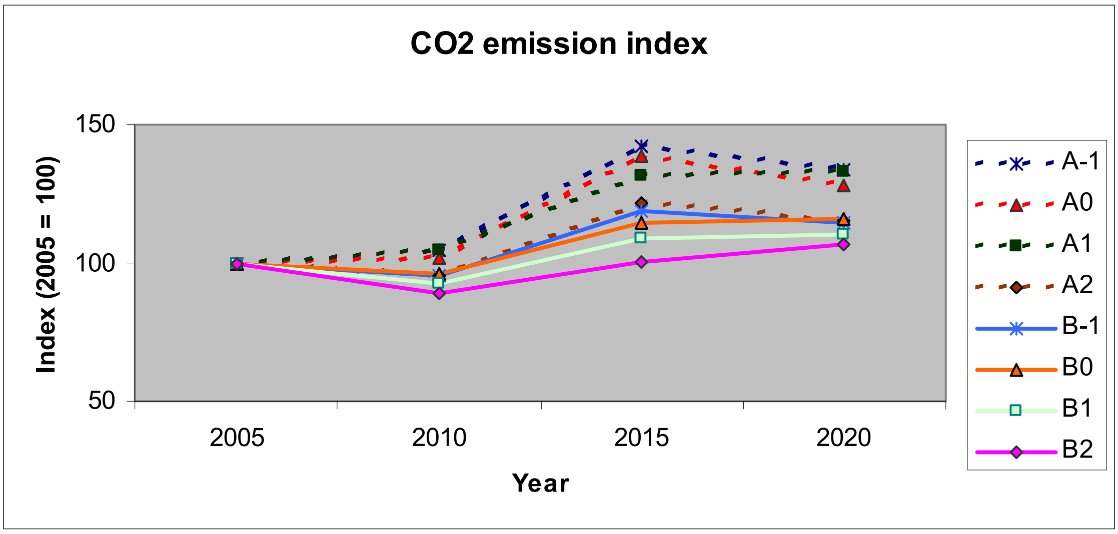


Figure 5.5.14 Total CO2 emission index

CO emissions are significantly reduced in all scenarios especially in the period 2005 – 2010. As for CO_2 emissions the scenarios associated with demand regulation policies are the most efficient ones. A similar development can be seen in NOx emissions that are reduced by around 75% by the year 2020 in all scenarios.

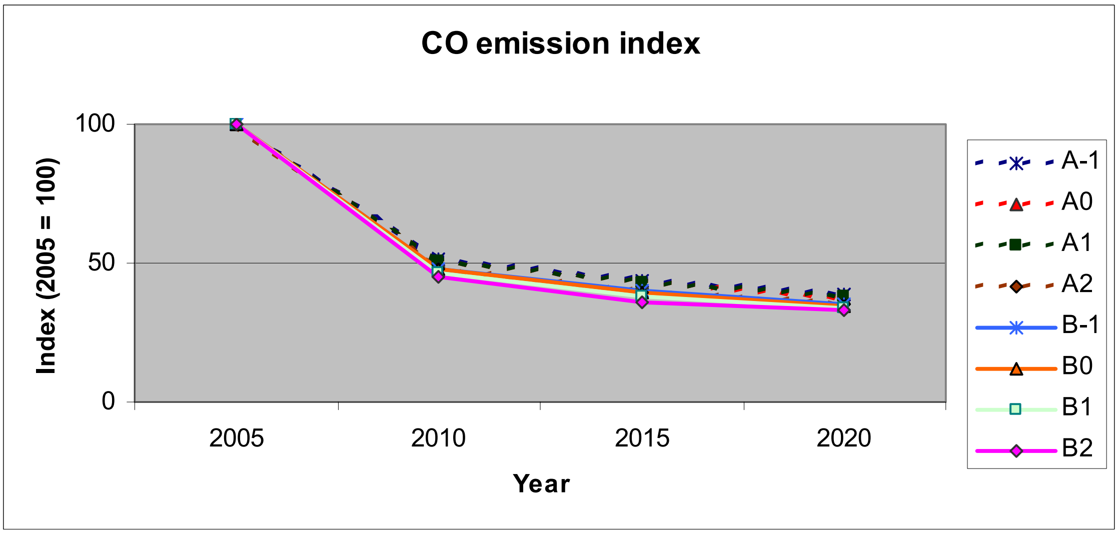


Figure 5.5.15 CO emission index

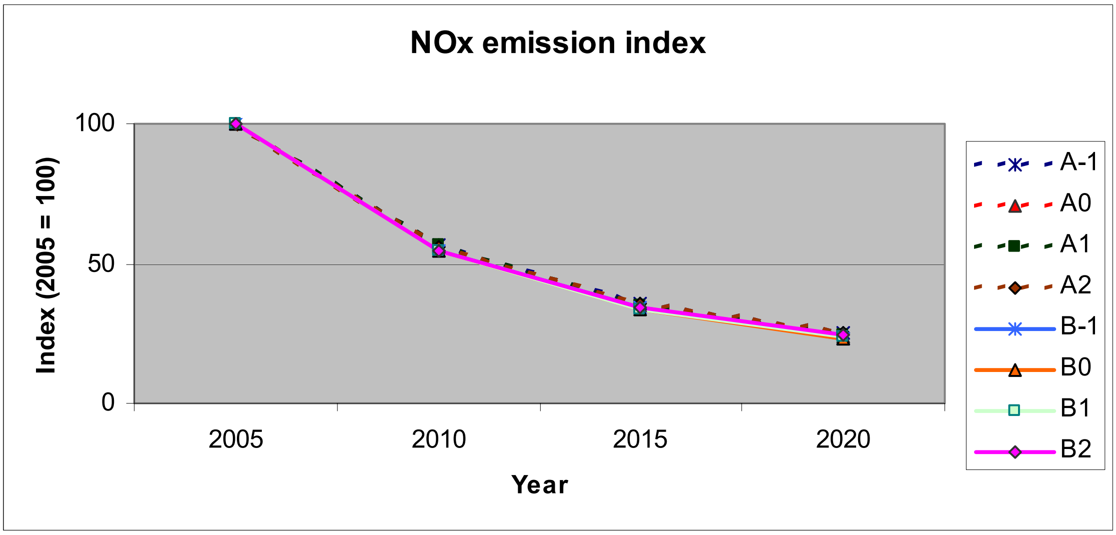


Figure 5.5.16 NOx emission index

The PM emissions are reduced by 30 –35% in all scenarios by the year 2020, as shown in Figure 5.5.17. The reduction is at maximum level in the year 2015 after which a slight increase starts.

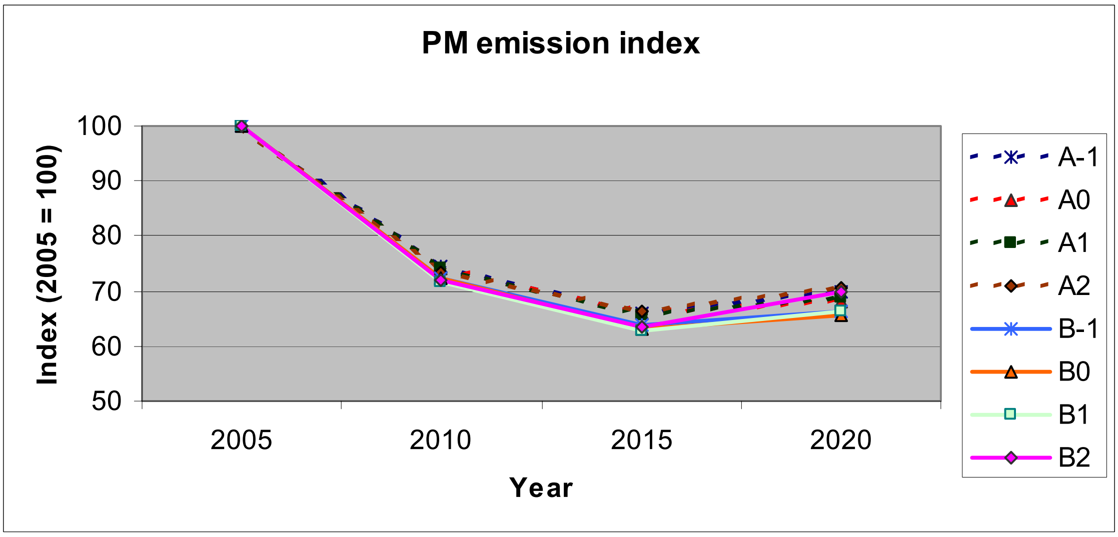


Figure 5.5.17 PM emission index

Society

Figure 5.5.18 and Figure 5.5.19 show the number of fatalities and accidents in all scenarios. The growth of fatalities and accidents is significantly higher than the population growth in all scenarios except B2. Especially high number of fatalities and accidents take place in scenarios A-1, A0 and A1. The demand regulation scenarios are more efficient in reducing the accidents than the technology investments scenarios.

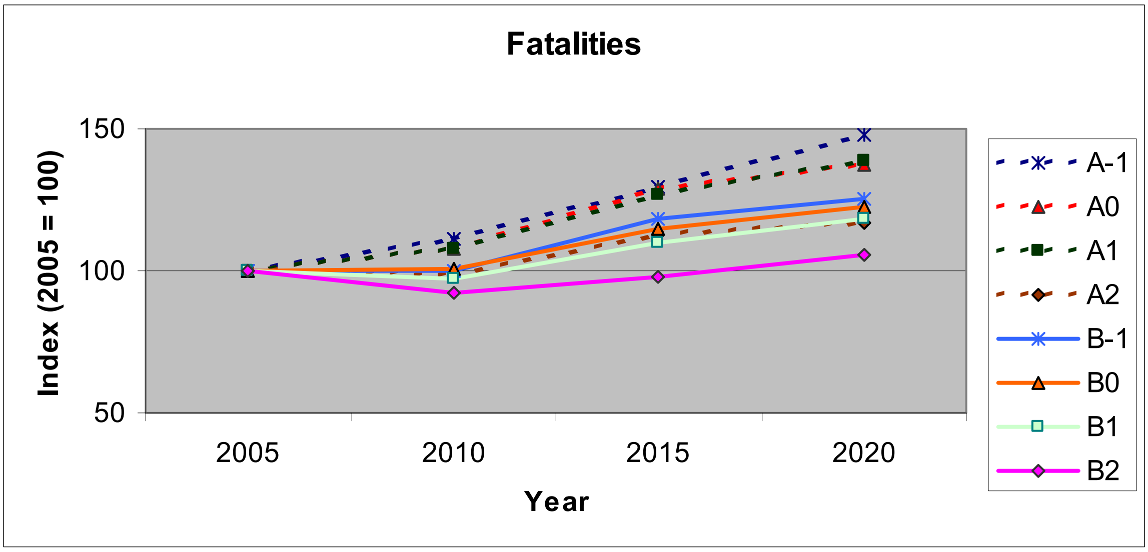


Figure 5.5.18 Fatalies index

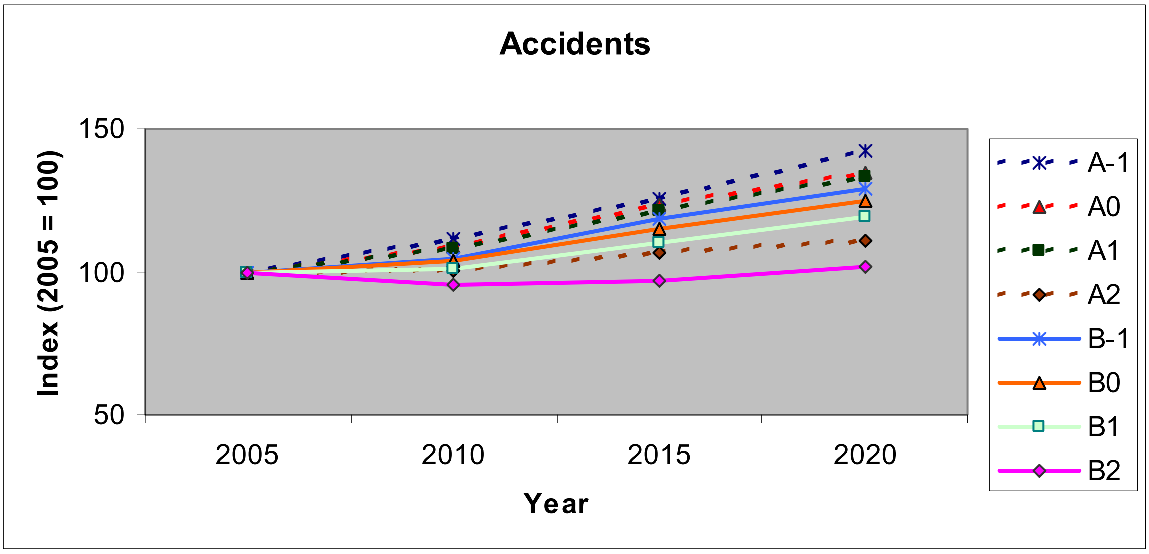


Figure 5.5.19 Accident index

Economy

A socio-economic calculation has been made for all scenarios. The elements of the calculation include Transport user benefits, Government revenues, Operators revenues and savings in externalities. The base against which the comparisons have been made is scenario A-1. All benefits have been discounted to the year 2005 and also expressed as net benefits/capita/annum. Policy implementation costs have not been estimated. The results are shown in table 5.5.5.

Table 5.5.5 Economic comparison of the scenarios against scenario A-1

	A0	**A1**	**A2**	**B-1**	**B0**	**B1**	**B2**
Transport user benefits	-1607	2750	-3626	-2315	-4656	-1435	-6934
Government revenues	2486	1147	15291	898	3605	3242	16003
Operators net revenues	1527	2565	-1600	-354	1332	3016	-1430
Savings in externalities	613	1406	2226	1480	1781	2328	3309
Total benefits	3020	7868	12292	-291	2063	7151	10947
Sum/capita	62	162	253	-6	42	147	225

Both the technology investments and the demand regulation scenarios produce clear socio-economic benefits. Best benefits are reached in demand regulation scenarios, especially combined with low oil price growth assumption (A2).

Land use

The figure below illustrates the land use changes (households and employees) in scenarios A0, A1 and A2 compared with the scenario A-1.

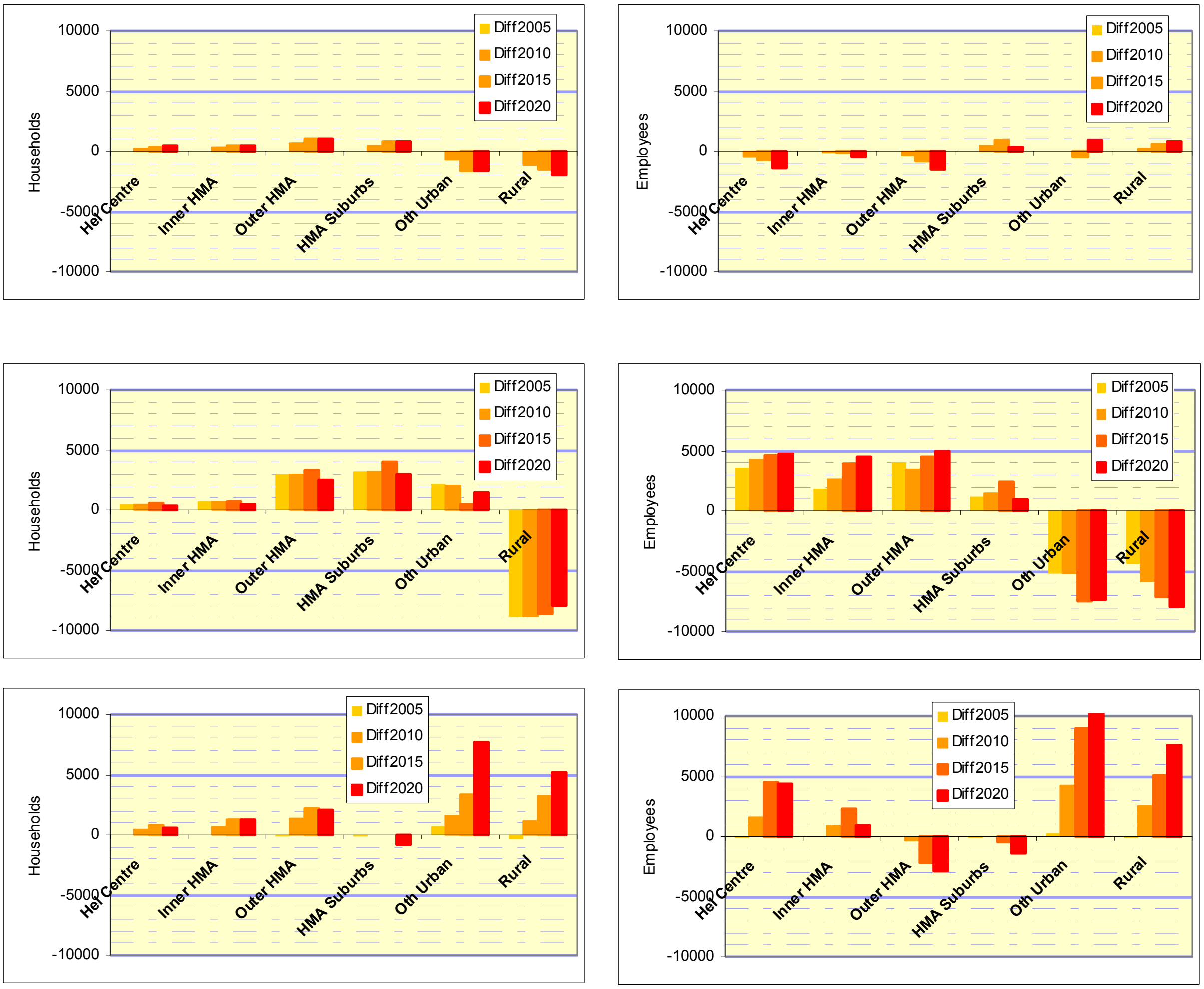


Figure 5.5.20 Land use changes in Scenarios A0, A1 and A2

The land use changes in Scenario A0 compared with scenario A-1 are very small.

It is interesting to note that under the low oil price growth assumption the technology investments scenario and the demand regulation scenario work in opposite directions. In the technology investments scenario (A1) the role of the Helsinki Metropolitan Area (HMA) is emphasised whereas in the demand regulation scenario (A2) the growth of the satellite cities (with good rail connections to the Helsinki city centre) surrounding the HMA is emphasised. Combination of the both scenarios would probably produce a balanced growth pattern.

5.6 The South Tyrol model results

5.6.1 The South Tyrol model

The South Tyrol model is a land-use and transport model covering the region corresponding to the Italian province 'Alto Adige'. While in other local models used in STEPs the study zone is a metropolitan area, in the South Tyrol model a larger region with a low average population density and several small or medium towns is considered. The study area is divided into 98 zones for land use and transport (see figure 5.6.1 below). Six external zones are also considered.

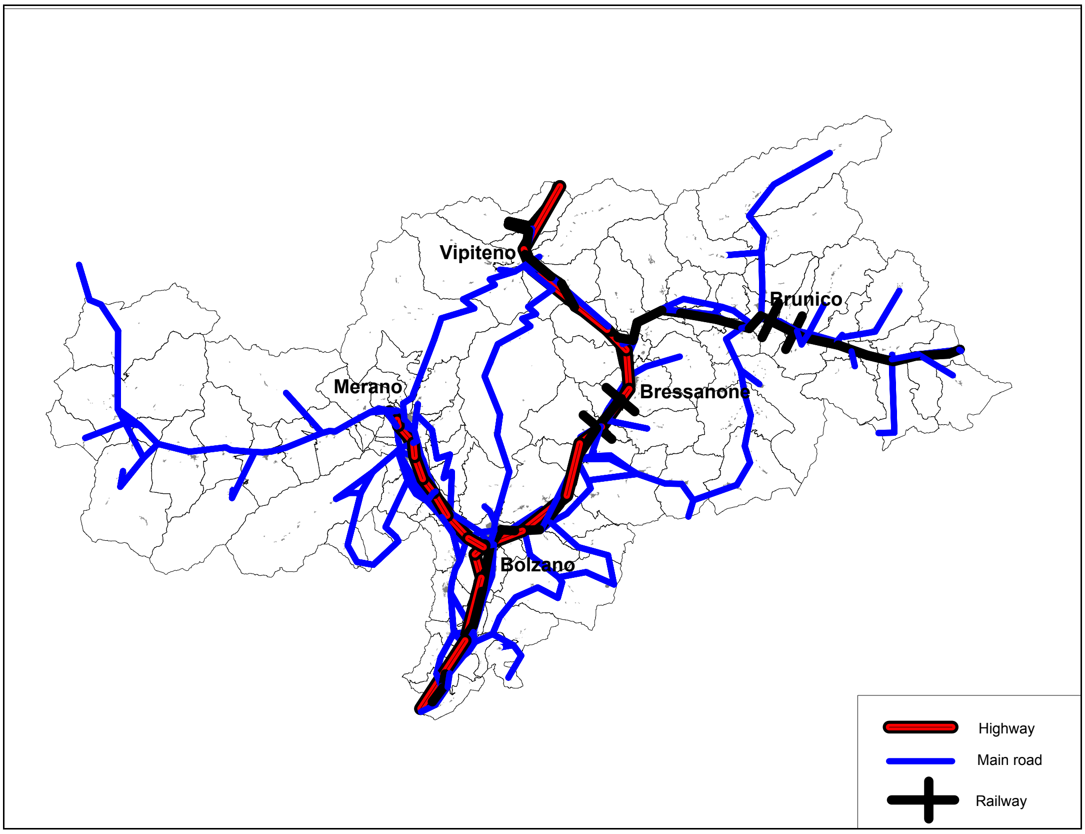


Figure 5.6.1 The South Tyrol model zoning system

The base year of the model is 1999 and the model produces forecasts for years 2007, 2014 and 2020.

The South Tyrol model was built using the Meplan software and belongs to the group of the integrated land-use/transport models. For that reasons, two main modules can be recognised: a land use model and a transport model. An interface module provides the required connections between the two main modules in both directions.

In the land model, the local economy structure is represented by an input-output matrix, where the interacting factors are segmented into four groups. The first group includes twelve economics sectors ranging from agriculture to foodstuff production to tourism. A specific sector is used to compute value added. The second group concerns population groups which include both residents and tourists. As third sector, floorspace is modelled according to its destination (e.g. residential floorspace, agricultural land, etc.). The last group of factors are used as attractors for trips generated in the area.

The integration of land-use and transport in the model framework allows not only to compute endogenously the trips matrices but also to simulate feedbacks from the transport system to land use (see Figure 5.6.2). More specifically, changes of locations may be induced by variations of transport costs and accessibility which are the effect of increasing congestion, new infrastructures, additional services and so on. Effects on land-use are lagged (i.e. changes on the transport side at the year t are reflected on land use only at time t+n) to take into account that re-location choices need some time to be put in practice.
The mobility of individuals is determined by the interaction between economic sectors and the population groups. Passenger trips are divided into four main trip purposes: Working, Education, Tourism, and Other Purposes.

The interaction between the economic sectors gives rise to a matrix of economic trades which is converted into freight traffic flows by means of volume-to-value ratios. Three freight transport flows are modelled: bulk, general cargo and container.
The transport model deals with the modal split and assignment of trips. Four passenger modes are allowed on the network: car, bus, coaches and train. Three modes are available for freight: heavy truck, light truck and rail.

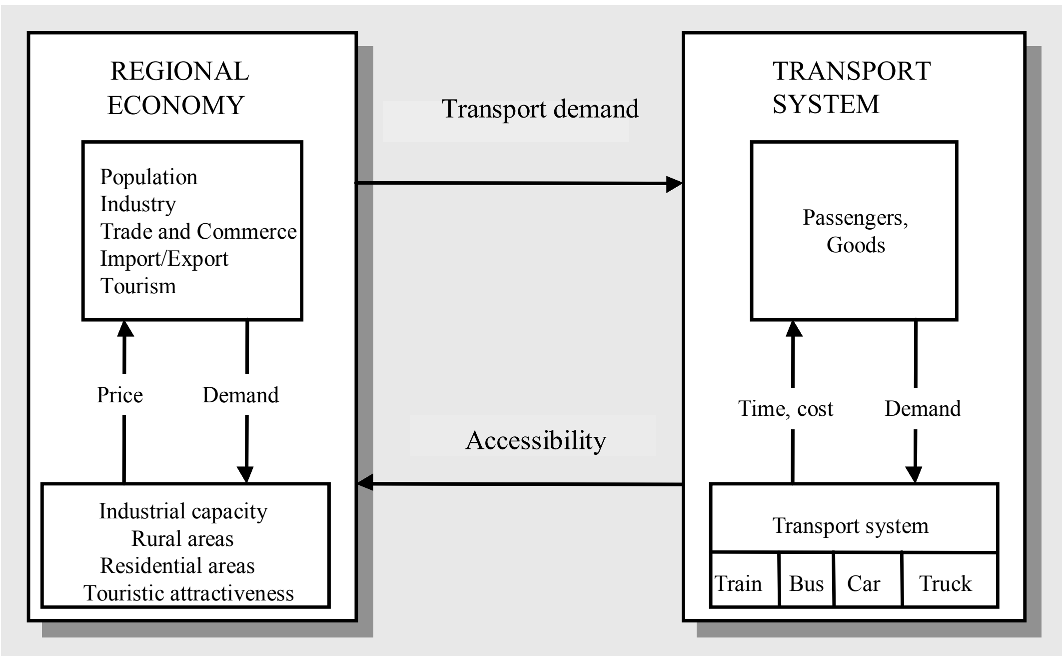


Figure 5.6.2 The South Tyrol model structure

The South Tyrol model also computes impacts on the environment, that is consumption of fuels and emissions (of road modes only). The simulation uses consumption and emission functions linked to speed (on a link by link basis). In turn, functions depend on the average composition of the vehicles fleet.

More details on the South Tyrol models can be found in the deliverable D4.1 of the STEPs project (TRT et. al., 2005).

5.6.2 Implementation of the scenarios in the South Tyrol model

The input data for the South Tyrol model has been drawn from both the D3 definition and the output of the ASTRA and POLES runs.

Data from the European models POLES and ASTRA has been used for defining emission functions for an average vehicle of the car fleet and the fuel price (comprehensive of pure fuel cost and fuel taxes).

Emission functions have been calculated as weighted functions of the ‘base emission functions’ (drawn from the MEET project for each car category and emission standard), where the weight have been defined on the basis of the car fleet structure estimated from POLES for Italy in the base and future years. In this way the development of the car fleet towards the ‘clean vehicles’ is taken into account.
Emission function are estimated for five main pollutants (CO_2, CO, NOx, VOC and PM) so as the model produce total emissions by link with reference to the speed of each transport mode.

Fuel price is not modelled explicitly in the model, but is part of the cost function for car, bus and freight road transport. To estimate the effect of policies affecting pure fuel price and fuel taxes, the total fuel price growth rate (computed as weighted average of gasoline and diesel growth rates) has been applied to the part of the total cost. For example, in the A0 scenario between 2005 and 2020 fuel pump price increases by 11%, for car passenger the total fuel cost is 27% of the total cost per km (as the South Tyrol model simulate also constant costs like insurance and depreciation), so only the 27% of the 11% has been applied: the results is a 3% increase of the total car cost.
The South Tyrol model does not compute fuel consumption of vehicles so efficiency development (i.e. lower unitary consumption) over time that could reduce the share of fuel costs on total car costs could not be considered.

Speed reduction policy has been modelled by introducing a decrease of the free-flow speed for all the main roads (urban or not); the reduction suggested by D3 has been applied for all the road types, without any distinction.

The improvement of public transport service has been input in the model by increasing the frequency of bus and trains, so as to the time spent for a trip with public transport is reduced.

Land-use measures aimed at limiting or avoiding urban sprawl have been included in the model even if its scale is not detailed enough to capture urban development and the relative demand. The four main towns in the region have been selected and it has been assumed that new residential, commercial and industrial settlements could be realised only within the boundaries of the municipality and not in the surroundings. The underlying forecasts concerning the overall changes of employment and population have been kept unchanged and only the distribution among zones has been modified.

Table 5.6.1 summarises how the different scenarios inputs have been implemented in the South Tyrol model.

Table 5.6.1 South Tyrol Model: Scenarios definition

Measure		Indicator	A0/B0	A1/B1	A2/B2
			Annual change (%)		
Socio-economic	Pure Fuel price	Car cost (fuel %: gasoline)	POLES projection	POLES projection	POLES projection
		Car cost (fuel %: diesel)	POLES projection	POLES projection	POLES projection
	Car sharing etc.	Car fleet			
	Fuel tax	Car cost (taxes %: gasoline)	+0.7%	As A0	+4.7%
		Car cost (taxes %: diesel)	+1.5%	as A0	+4.7%
		Kerosene (% of gasoline tax, from 2012)			
	Travel cost due to tax increases	Car/lorry cost per km			
		Air cost per km			
	Telework	Work trips saved	0%	as A0	+0.3%
Spatial	Residential	Central	+	as A0	++
		Inner urban	++	as A0	+++
		Outer urban	+++	as A0	0
	Services	Central	0/+	as A0	+
		Inner urban	+	as A0	++
		Outer urban	++	as A0	0
	Industrial	Central	0	as A0	0
		Inner urban	+	as A0	+++
		Outer urban	+++	as A0	0/+

	Measure	Indicator	A0/B0	A1/B1	A2/B2
			Annual change (%)		
Travel	European rail	European rail time			
	Regional rail	Regional rail time	-0.4%	-1.7%	as A0
	Public transport	Bus time	-0.3%	-1.1%	as A0
	Traffic calming	Road speed limit on main roads	+0.4	as A0	+1.0%
	Road pricing	Charge to enter in the city centre	+2.0%	as A0	+6.0%
	Public transport cost	Bus cost per km	+0.8%	as A0	-1.7%
		Train cost per km	+0.8%	as A0	-1.7%
Freight	Traffic calming	Road time in MPA	+0.4	as A0	+1.0%
	Road pricing	Charge to enter in the city center	+2.0%	as A0	+6.0%
	City logistics	Local average distance	-0.2%	-0.5%	as A0
		Local load factor	+0.8%	+2.4%	as A0
	Rail freight	Rail freight time			
Energy	Energy efficiency for cars and lorries	Gasoline per km			
		Diesel per km			
	Alternative vehicles	Emissions per km	Depending on fleet composition	Depending on fleet composition	Depending on fleet composition
		Car fleet (d)	POLES car fleet	POLES car fleet	POLES car fleet
	Energy use rail	Energy per km			
	Energy use ship	Energy per km			

Calculated by the model

Not used in South Tyrol Model

Input from POLES model

5.6.3 Main results from the South Tyrol model

This paragraph describes the main results concerning the simulation of the STEPs scenarios with the South Tyrol model. Results are presented and commented below for five main areas: transport demand, environment, society, accessibility and land use.

Transport demand

Figure 5.6.3 illustrates the growth of passengers-km in the different scenarios with respect to the year 2005. In the business as usual scenario under the low oil price growth (A0) passenger traffic at 2020 is about 18% higher than in 2005, while the no-policy scenarios A-1 and B-1 are respectively slightly higher and lower (about 20% and 16%). Technology investments scenarios (A1 and B1) are always a little bit higher than the base trend while Demand regulation scenarios (A2 and B2) have a more visible effect. In the scenarios B where fuel price is assumed to grow faster, demand is always reduced with respect to the correspondent scenarios A.

As in the South-Tyrol model the population is fixed and the number of generated trips is not changing, the different amount of passenger-km is due not to suppressed trips, but to lower average distances. So the differences between scenarios at a given year can be interpreted as differences in average distances.

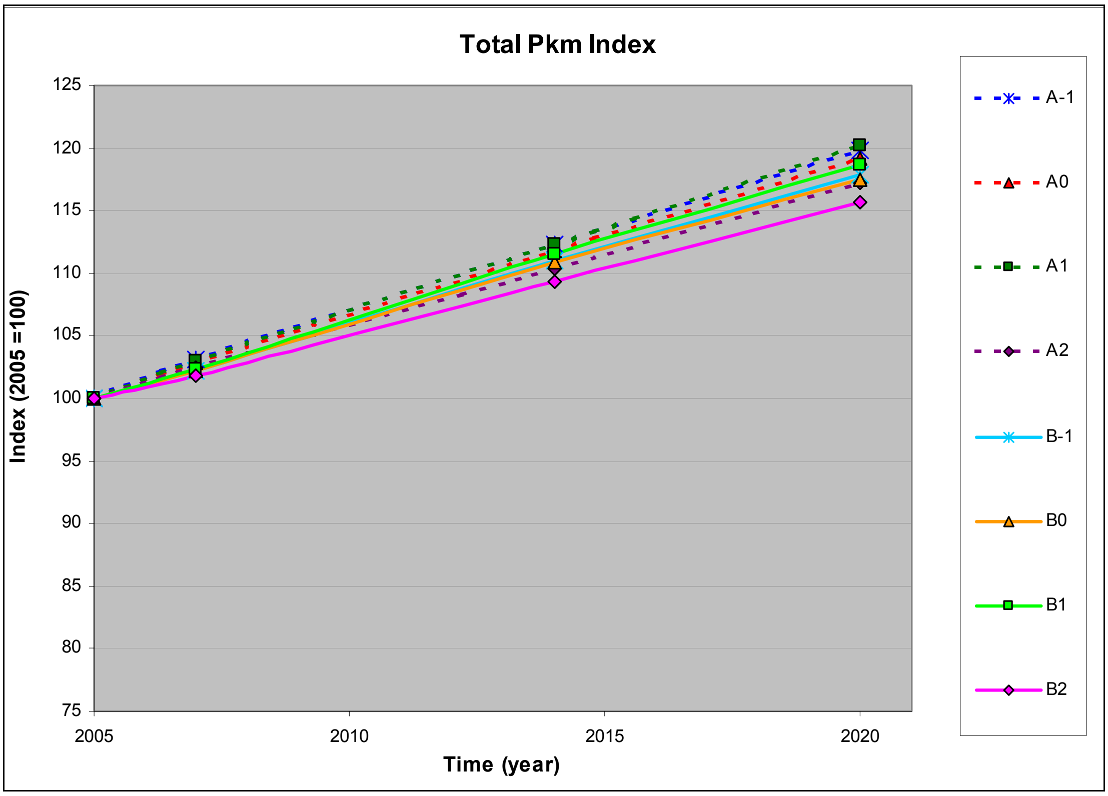


Figure 5.6.3 Total pkm with respect to year 2005 in the eight scenarios

When focusing on the usage of private cars, the differences among the scenarios are larger. In figure 5.6.4 it can be seen that in Demand regulation scenarios the growth of passenger-km by car is significantly lowered. When the high oil price growth assumption is associated to the measures implemented in the demand regulation policy (i.e. in the scenario B2), the total number of vehicles-km by car at 2020 is lower than at 2005 and even if the low oil price growth is assumed, the total growth is not larger than 4%. Instead, technology investments scenarios are less effective in diminishing the use of private cars (although the impact on the environmental side is positive see below).

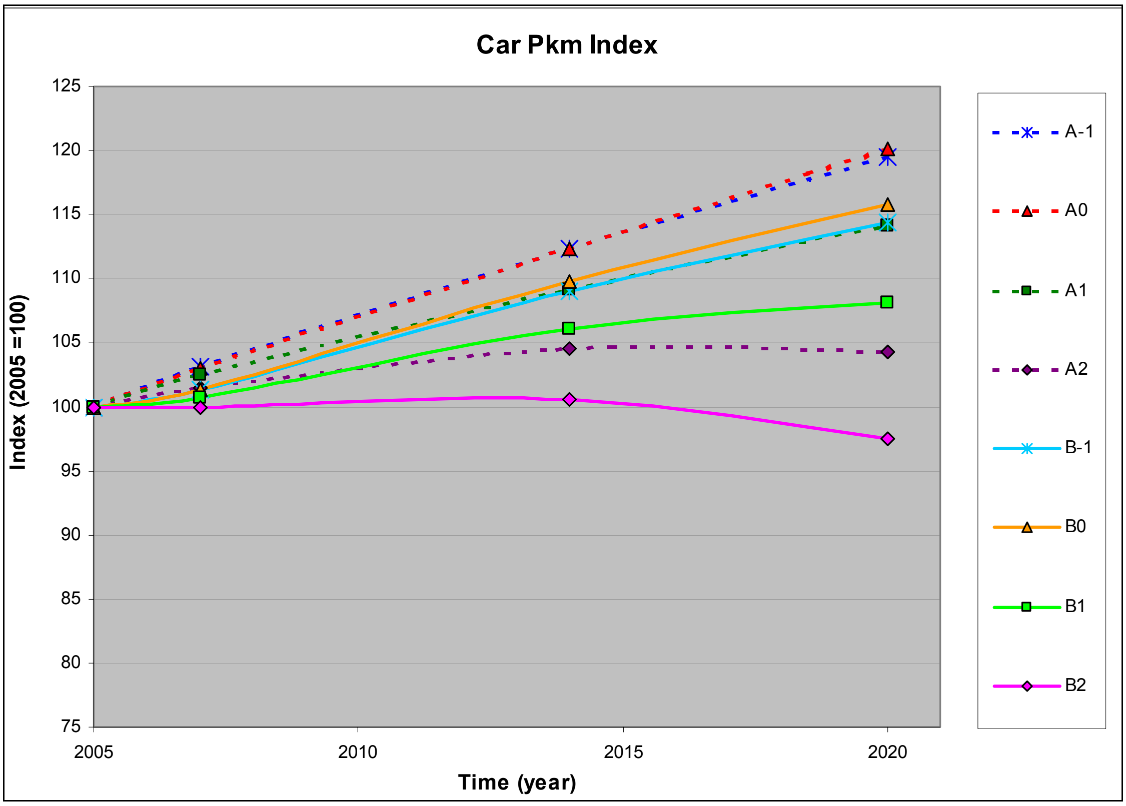


Figure 5.6.4 Car pkm with respect to year 2005 in the eight scenarios

On the freight side the differences between the scenarios are more limited. Demand regulation scenarios are still effective but even in the most extreme case of scenario B2, freight vehicles per km still grow by 23% with respect to 2005 (see figure 5.6.5).

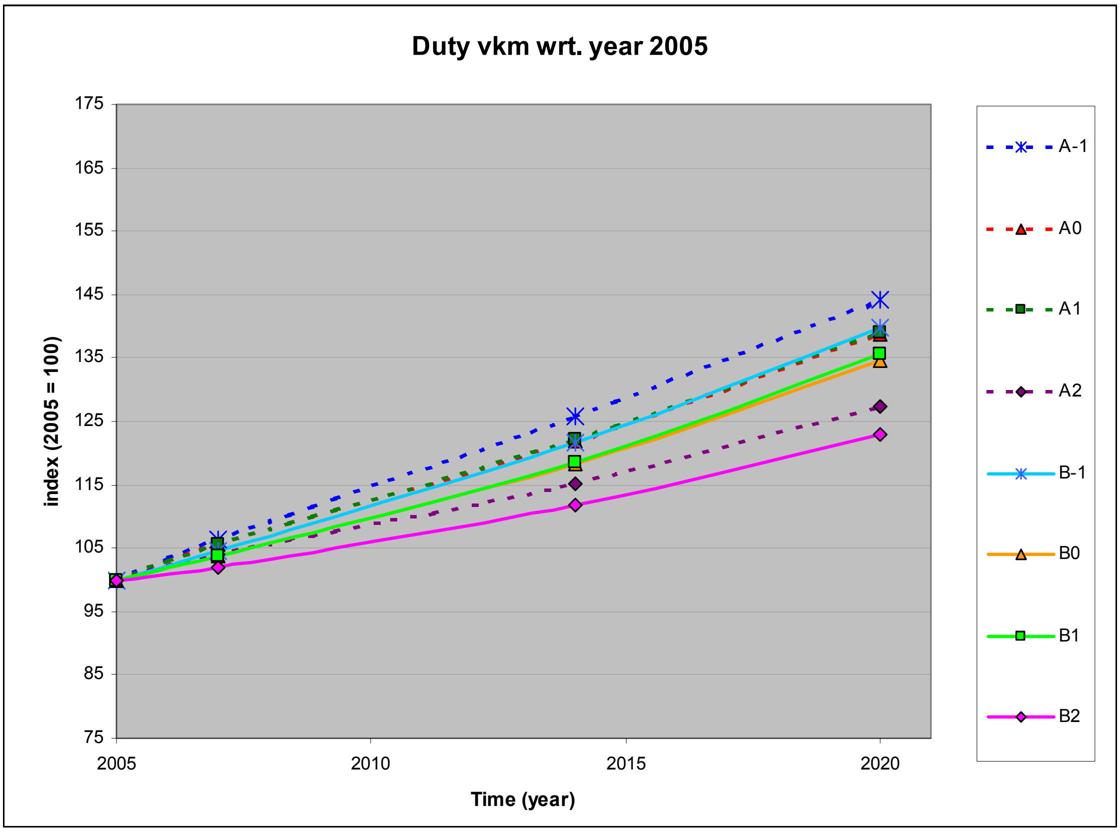


Figure 5.6.5 Duty vkm with respect to year 2005 in the eight scenarios

Mode shares

Mode shares are interesting only for passengers as locally freight is shipped and distributed almost totally by road and, given the relatively low distances and the lack of specific infrastructures, rail could not become competitive even if road costs would increase substantially. From table 5.6.2 one can see that modal shares are affected only marginally. One major reason for this rigidity of demand is the specific context: South Tyrol is a sparsely populated area with a limited level of congestion (with the exception of the main urban agglomerates that are not modelled in detail however) and a high average income. For that reason, private transport has a structural advantage on public transport and even a significant growth of car costs does not impact dramatically on the modal split. However, in A1/B1 and A2/B2 scenarios public modes, especially rail, gain demand and avoid that car shares is even increasing in future years.

Table 5.6.2 Passenger modal shares at 2020 in the eight scenarios

Mode	2005	2020							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Car	86.2%	86.8%	87.0%	85.5%	85.0%	86.1%	86.4%	84.8%	84.3%
Bus	10.1%	9.4%	9.3%	10.3%	10.4%	9.8%	9.7%	10.7%	10.8%
Train	3.7%	3.8%	3.7%	4.3%	4.6%	4.1%	4.0%	4.5%	4.9%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Looking at the index for modal shares we can see small differences between the scenarios: in four scenarios (A0/B0 and A-1/B-1) car share is slightly increasing or stable even if in scenario B0, the impact of higher fuel price leads to a somewhat lower car share in the shorter term, but as the time goes by, car recovers. Bus increases its share in A1/A2 and B1/B2 scenarios while train gains demand also in the B0 and B-1 scenarios. All in all, public transport attracts a higher share of demand in both demand regulation and technology investments scenarios even if in both cases the increment is modest.

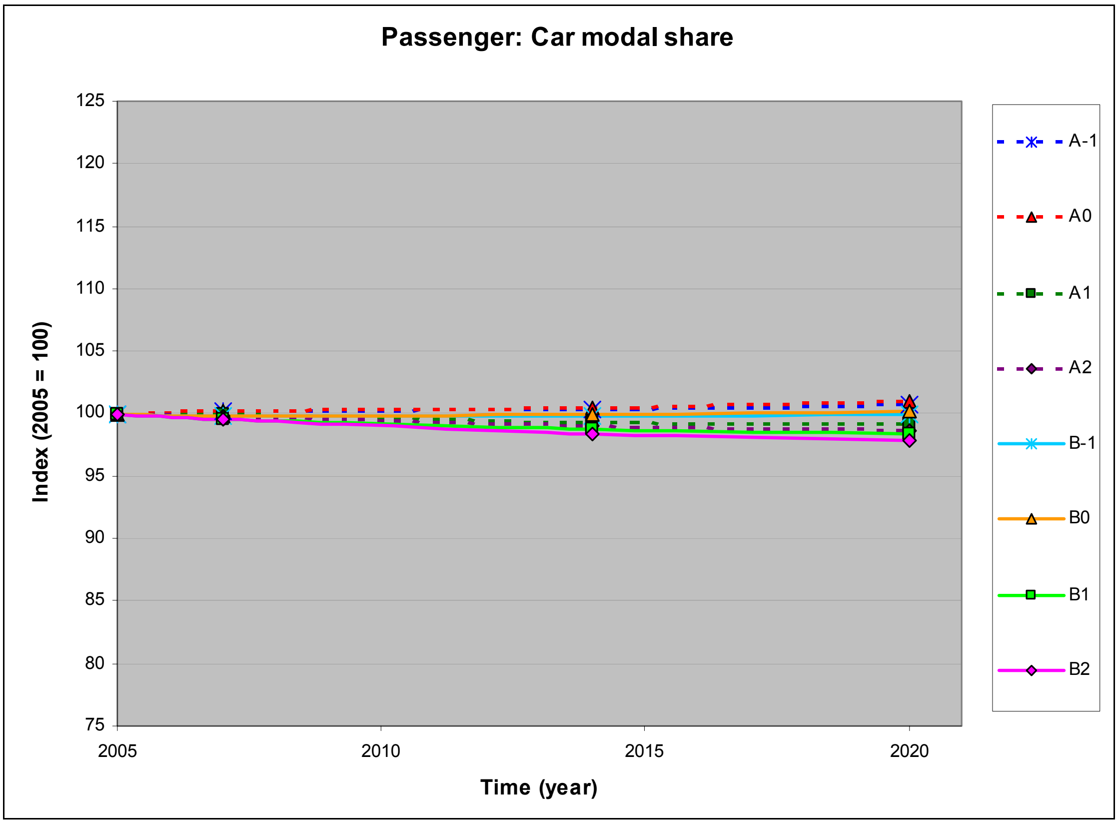


Figure 5.6.6 Passenger car modal share

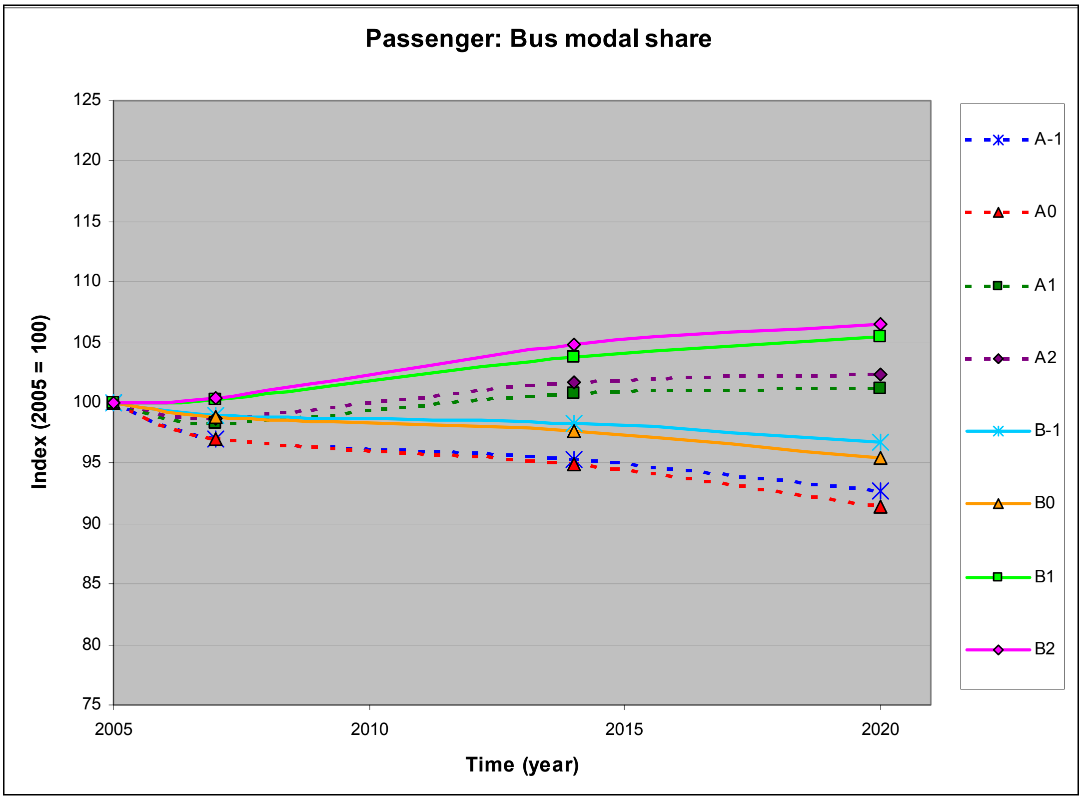


Figure 5.6.7 Passenger bus modal share index

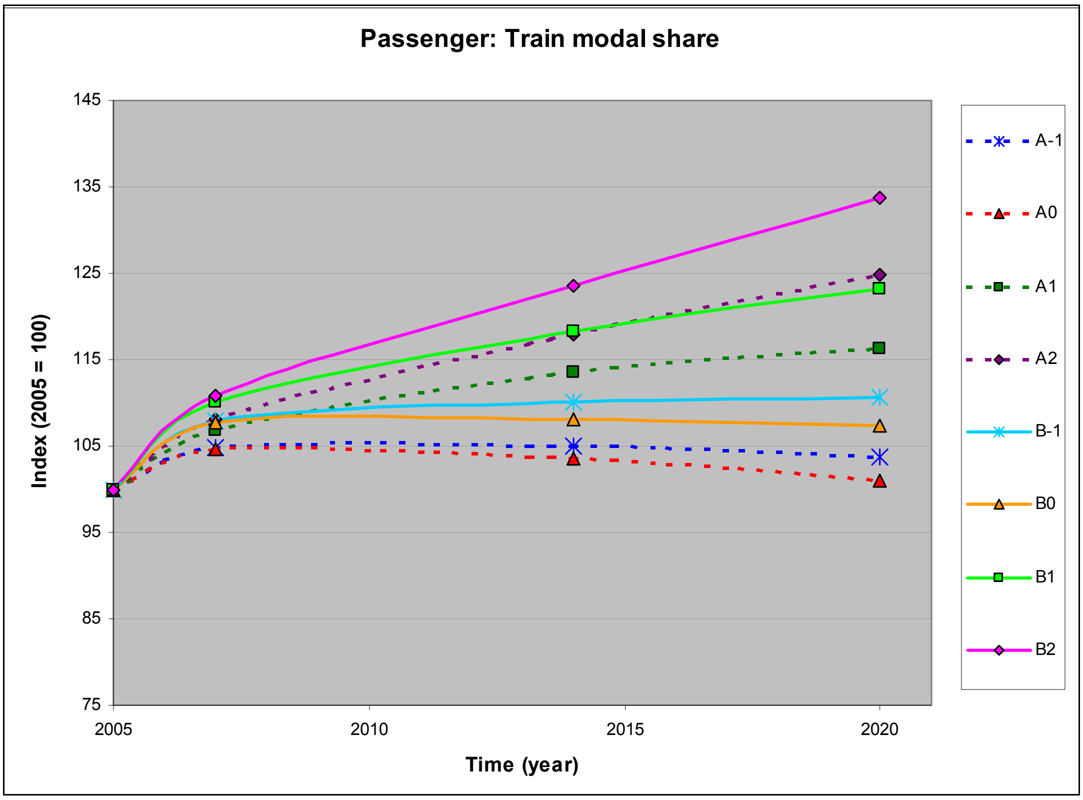


Figure 5.6.8 Passenger train modal share index

Average speeds

Average speeds of passenger modes provided in table 5.6.3 are consistent with the development of modal shares. It should be considered that average speed of rail and bus are computed from door-to-door trip time and so include feeder modes, waiting at stops, etc.

Average speed of roads is quite high at the base year (given the low levels of congestion in the area) and it worsens at 2020 in all scenarios due to the increase of traffic but the reduction is not higher than 7%. The deterioration of speed is the highest in the no-policy scenario under the low oil price growth assumption about fuel prices (A-1), in all other scenarios, as well as in the B-1 scenario, car speed is reduced more slightly as the number of cars-km are reduced.

Average speed of bus is improved in all scenarios also with respect to the base year, with the higher level for the technology investments scenarios where an improvement of the services is planned.

Instead, the average speed of rail is improved with respect to 2005 only in the A1/B1 scenarios as effect of the improvement of the services planned in these cases. In all other scenarios rail speed is reduced. This result could be explained if one considers that average speed of rail include the time spent on feeder modes (including walking). As rail improves its modal share (e.g. because travelling by car becomes more expensive), it attracts also trips starting and/or arriving far away the railway stations. The effect of improved services and of longer distance travelled are conflicting and the net effect is a decrease of the speed in all scenarios, where the assumed improvement of rail service is little (A2/B2) or null.

Table 5.6.3 Average speed of passenger modes at 2020in the eight scenarios [1] (km/h)

Mode	2005	2020							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Car	67.5	62.8	63.0	63.0	64.4	63.7	63.8	63.9	65.2
Bus	25.2	26.0	25.9	32.0	26.4	26.1	26.0	32.1	26.5
Train	58.2	55.7	55.8	67.4	57.2	56.3	56.3	67.9	57.9

1 Average speed of rail and bus are computed on door-to-door trip time and so include feeder modes, waiting, etc.

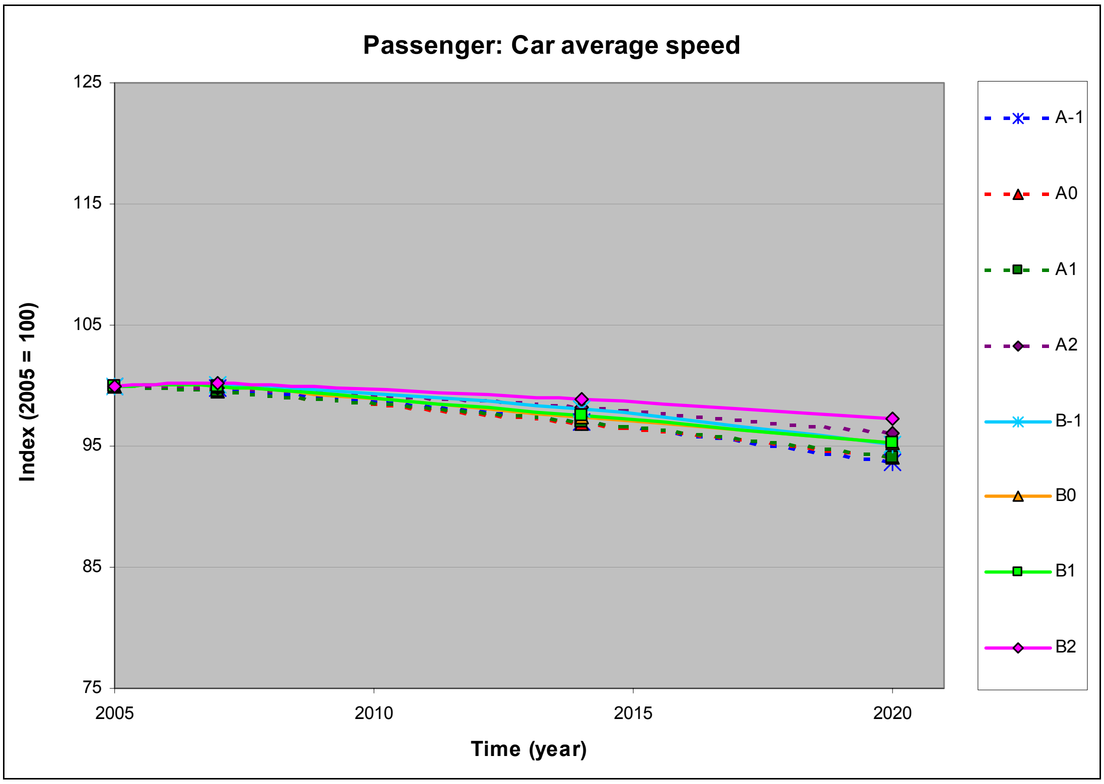


Figure 5.6.9 Passenger car average speed index

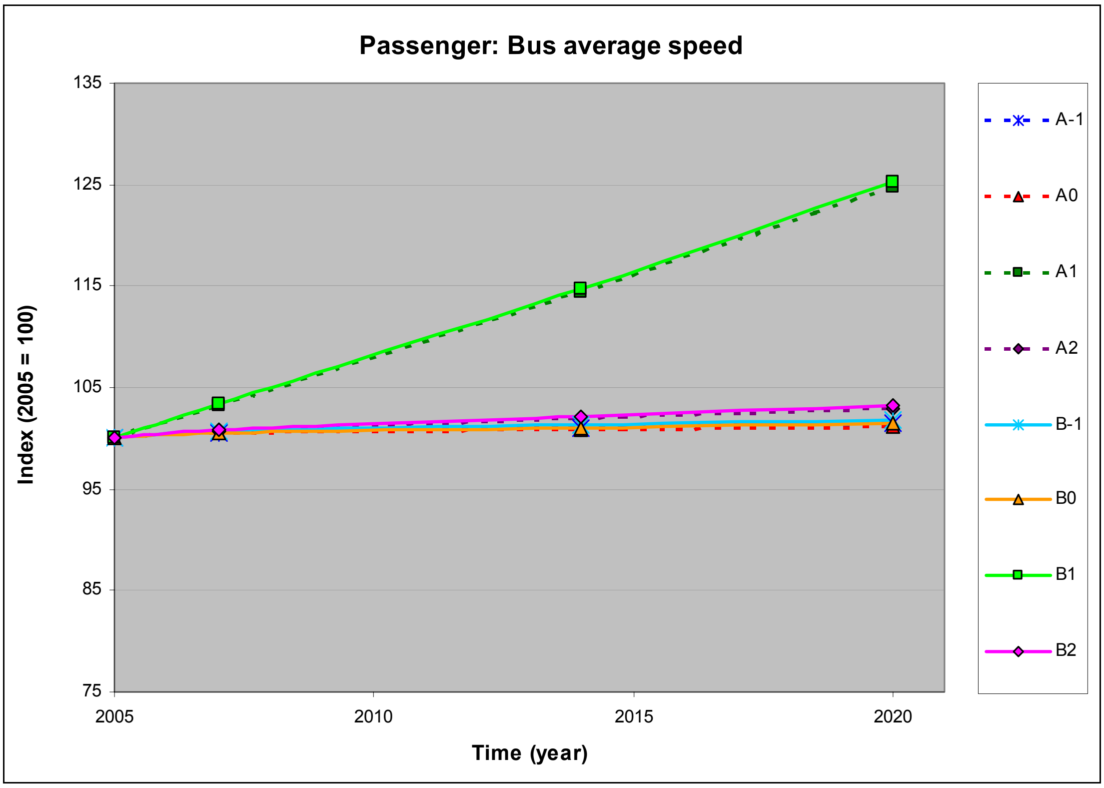


Figure 5.6.10 Passenger bus average speed index

Average trip lengths

As reported above, average trip lengths reflect the effect of the policies on the modal shares, even if in absolute terms the differences are not so significant.

Car distance is always slightly lower at 2020 with respect to the base year. Even in scenarios where specific land-use measures are implemented (scenarios 2), however, the difference with respect to 2005 is very limited. As explained above, the scale of the model does not allow to simulate this type of land use measures in an effective way, so a limited effect was expected.

It can be noticed that in scenarios A2/B2 the average trip length of train is significantly higher as this mode attracts some demand from car, which become more expensive. This explains the lower average speed shown above.

Table 5.6.4 Average trip lengths of passenger modes at 2020in the eight scenarios [1] (km)

Mode	2005	2020							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Car	30.1	29.5	29.6	29.4	29.3	29.6	29.7	29.4	29.2
Bus	17.8	18.2	18.0	19.4	18.9	18.3	18.1	19.5	19.1
Train	60.8	57.5	57.4	59.8	64.6	60.3	60.0	62.4	68.5
Total	36.2	35.0	36.2	37.6	35.1	35.9	37.1	38.9	36.1

1 Average trip lenght of rail and bus are computed on door-to-door trip and so include feeder modes.

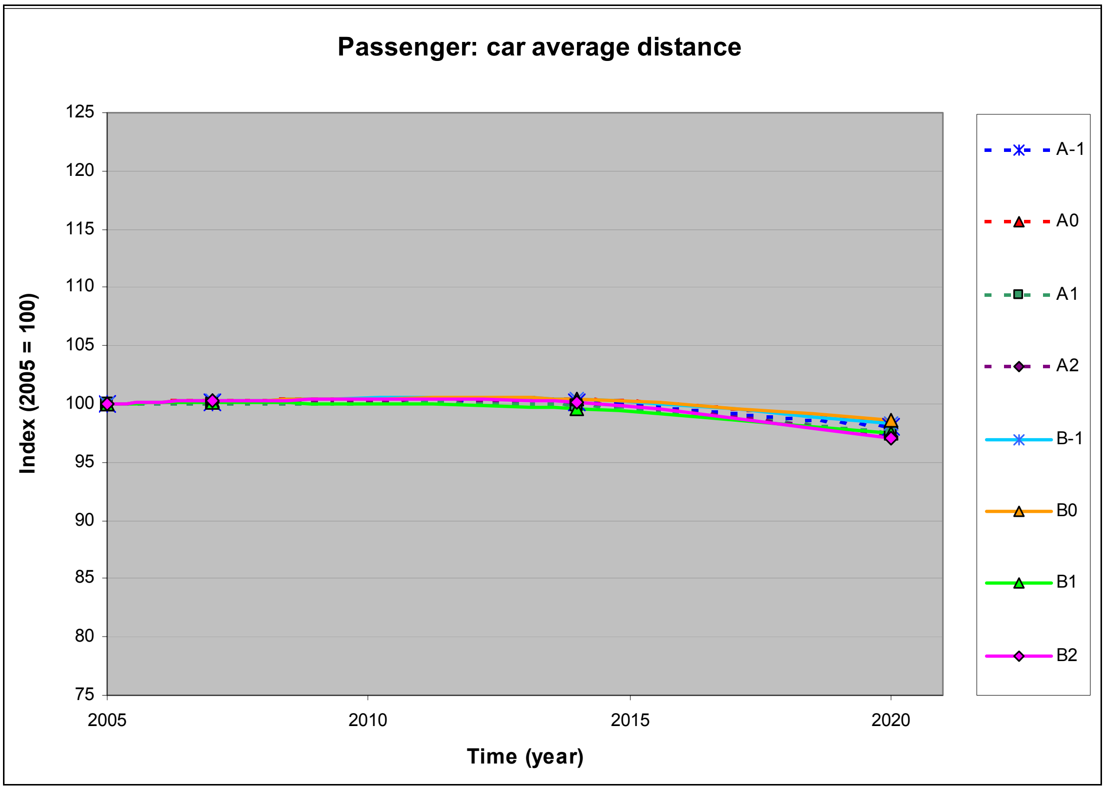


Figure 5.6.11 Passenger car average distance index

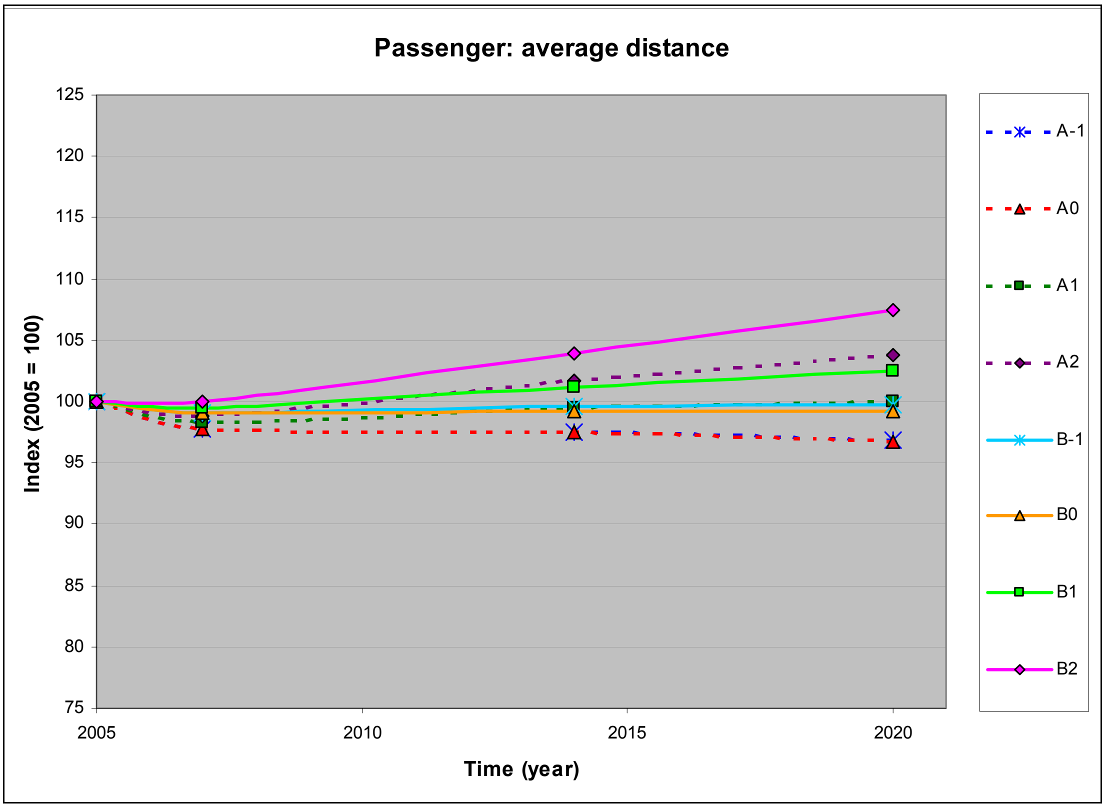


Figure 5.6.12 Passenger average distance index (all modes)

Environment

The South Tyrol model produce forecasts for the emissions of five different pollutants: CO2, CO, VOC, NOx and PM. The emissions are estimated by transport mode for each link; the following graphs show the total results for the model network. Data refers to the emissions produced by road transport modes only. Pollution due to crossing traffic (on the Brenner corridor) is also excluded as such part of demand is exogenous in the South Tyrol model and so it is not affected by the measures in the scenarios.

CO2 emissions are basically growing during the time simulation period in each scenarios, except for the demand regulation scenarios (A2/B2) where the reduced number of trips and the shift towards the public transport bring about a reduction of 2-5% at the year 2020 with respect to 2005 (see Figure 5.6.13). Technology investments scenarios (A1/B1) reduce consistently the CO_2 emissions growth with respect to the no-policy scenarios (A-1/B-1), but even in such scenarios at the year 2020 CO_2 emissions are about 10% higher than in the base year. The increment of emissions is lower than the increment of demand thanks to the technological improvements on the fleet side. As far as the renewal of the conventional vehicles fleet is concerned (e.g. introduction and diffusion of EURO V standard), the potential for reducing CO_2 is low; the bulk of the positive effect is due to the electric and Fuel Cells cars entering in the fleet.

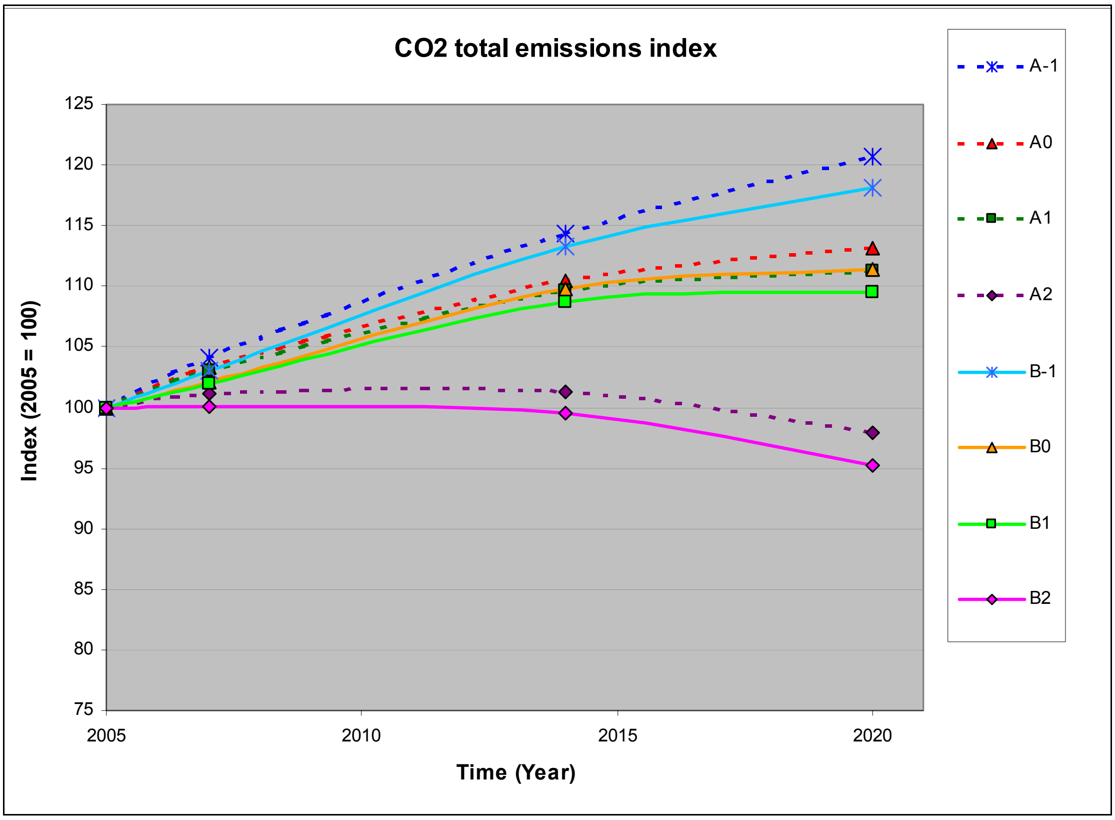


Figure 5.6.13 CO_2 total emissions index (all modes)

Instead, looking at the Figure 5.6.14 the development of the CO emissions index is quite different and shows a consistent reduction in all the scenarios. The minimum reduction amounts to 35% with respect to the year 2005 in the A1 scenario. However, in all scenarios the maximum reduction takes place in 2015 and not in 2020. The cause of the inverted trend in the last period is the slower pace of the fleet renewal associated to the ever increasing demand. In other words, the total vkms growth more quickly than the average emissions are reduced.

The same development can be observed for the VOC (see Figure 5.6.15), while for PM and NOx (Figure 5.6.16 and Figure 5.6.17) the decreasing trend persists beyond 2015. Concerning PM, the graph shows that emissions are slightly increasing until 2007. This is an effect of the increased share of diesel cars in the fleet at the beginning of the forecast period, when the renewal of the fleet is just started.

In any case, as for the CO2 emissions, also for the other pollutants, demand regulation scenarios (A2/B2) are those where the reduction of emissions is more significant.

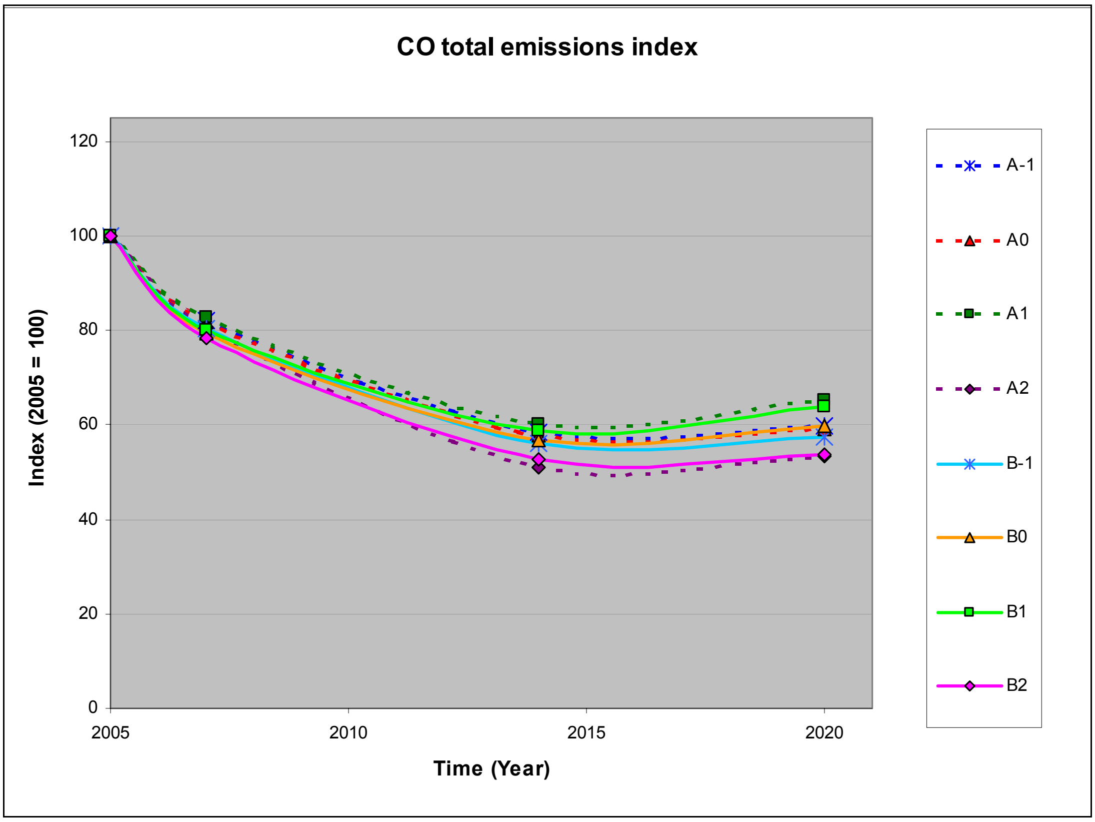


Figure 5.6.14 CO total emissions index (all modes)

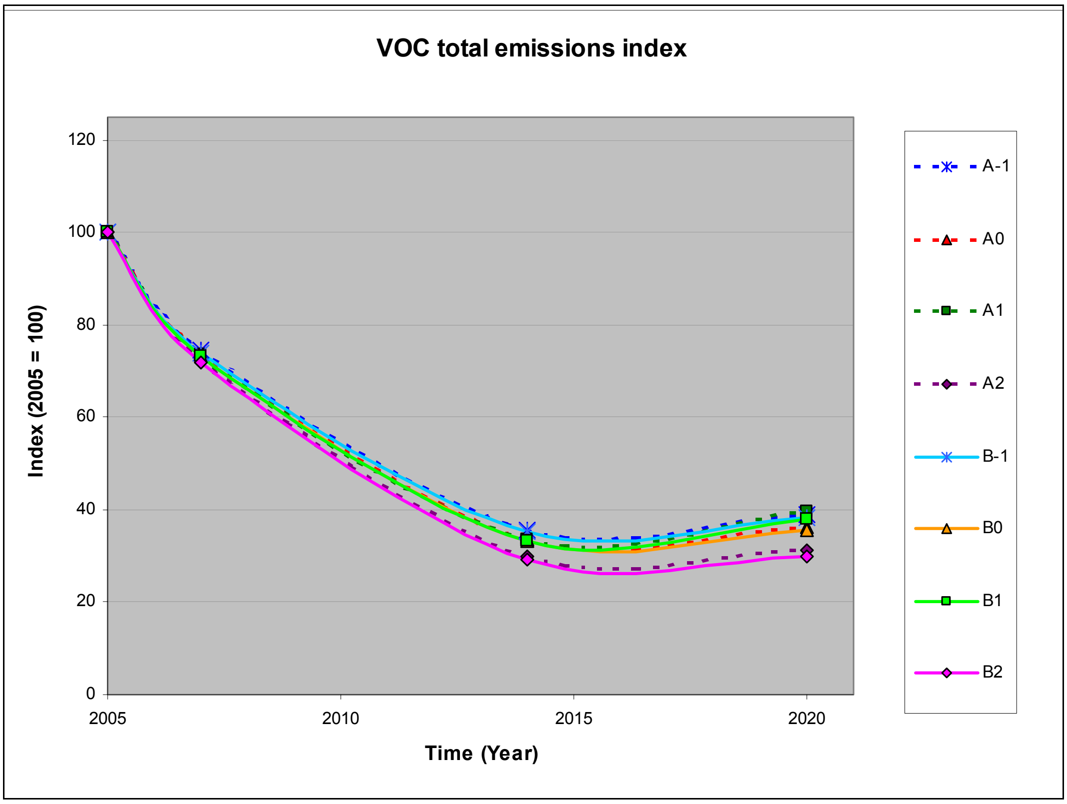


Figure 5.6.15 VOC total emissions index (all modes)

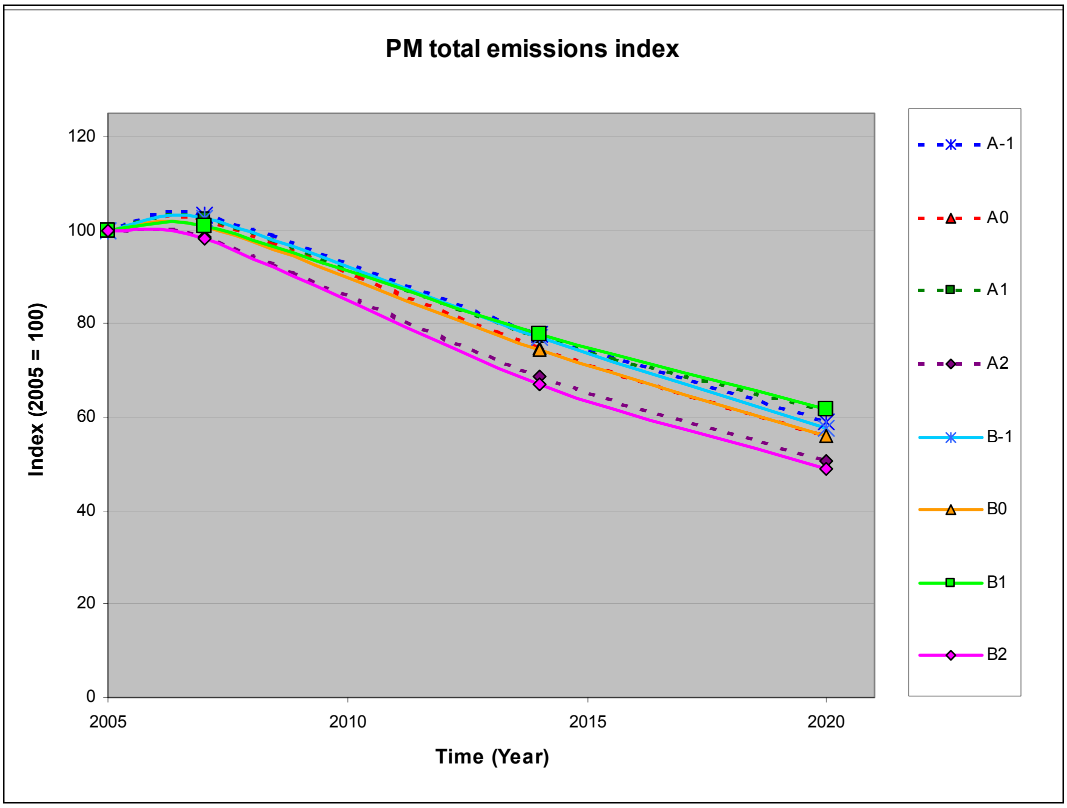


Figure 5.6.16 PM total emissions index (all modes)

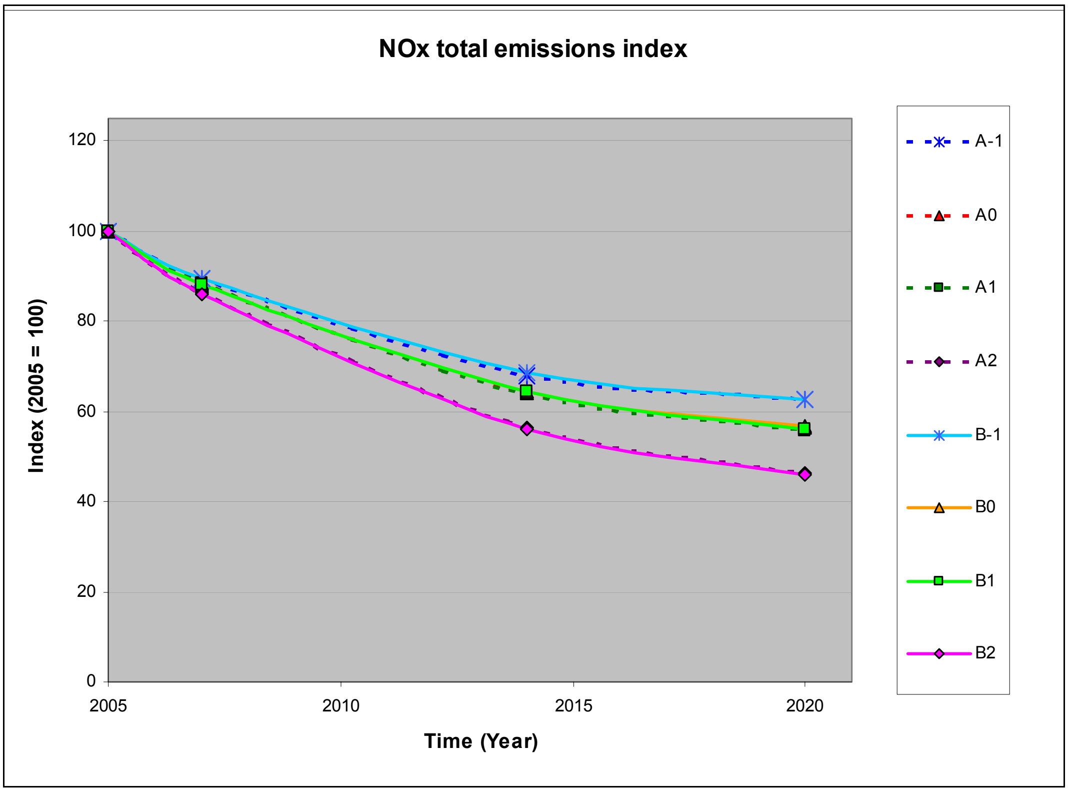


Figure 5.6.17 NOx total emissions index (all modes)

Transport costs

The South Tyrol model does not estimate the car ownership and the number of accidents occurred in the different scenarios, while it permits to calculate the expenditure of the households for the transport service used.

Figure 5.6.18 illustrates the development of the transport expenditure index for the eight scenarios, showing that, not surprisingly, the increase produced by the high oil price growth scenarios is higher than the low ones. Particularly the B2 scenario, where in addition to the high oil price growth assumption higher taxes and charges are applied, shows an increase of 30% with respect to the year 2005. Anyway, even in the scenario A-1 the transport expenditure sustained by the households is increasing by 15%, due to the traffic increase during the time simulation period.

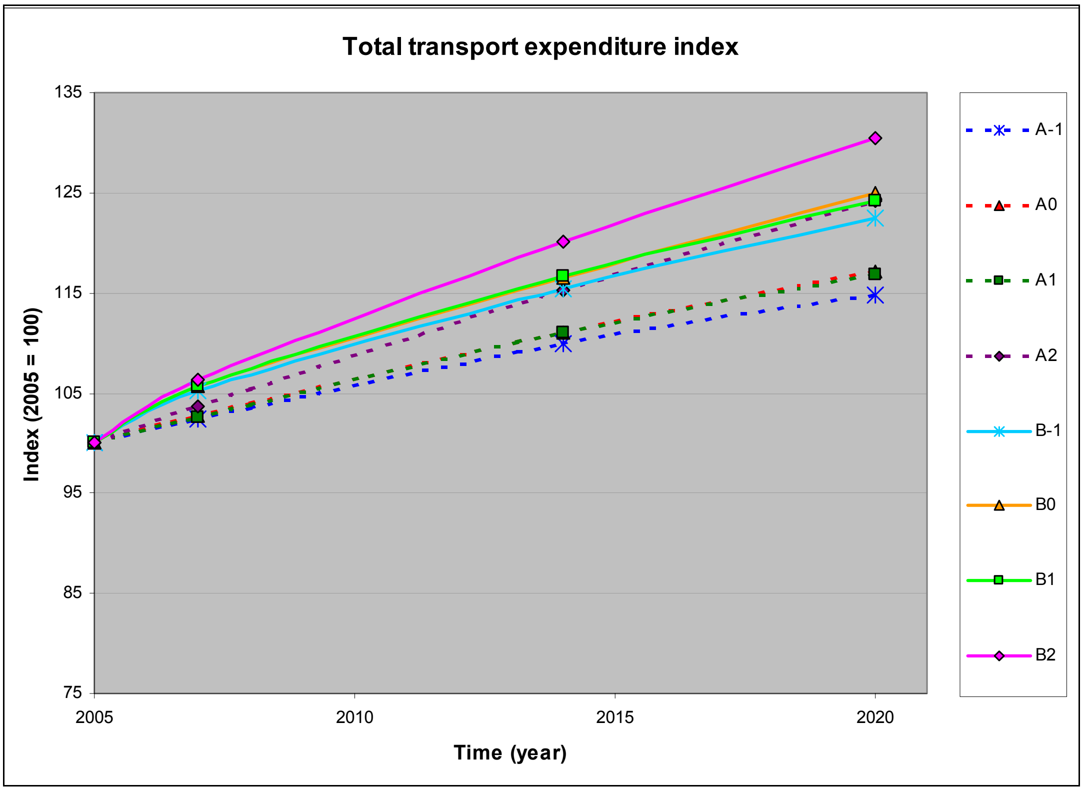


Figure 5.6.18 Total transport expenditure index

The average cost per trip show a similar effect comparing the eight scenarios (see table 5.6.5): in both the high oil price growth and demand regulation scenarios the car cost is higher than in the other ones, due respectively to fuel cost and fuel tax increase. Instead, the bus cost is lower in the demand regulation scenarios, where the PT policies are applied, and is not significantly affected by the high oil price growth. The train cost behaviour is similar to the bus cost development as the same policies have been applied.

Table 5.6.5 Average cost per trip by mode

Cost Per Trip (€)	2005	2020							
		A-1	A0	A1	A2	B-1	B0	B1	B2
Car	2.12	2.09	2.15	2.11	2.40	2.31	2.37	2.32	2.60
Bus	0.59	0.63	0.70	0.73	0.52	0.64	0.70	0.74	0.52
Train	1.54	1.59	1.72	1.88	1.61	1.70	1.83	2.02	1.80
Index car	100	98.7	101.3	99.7	113.3	109.1	111.6	109.3	122.6
Index bus	100	107.1	118.4	123.8	87.5	107.6	119.0	124.5	88.2
Index train	100	102.7	111.7	121.6	104.0	109.8	118.3	130.7	116.6

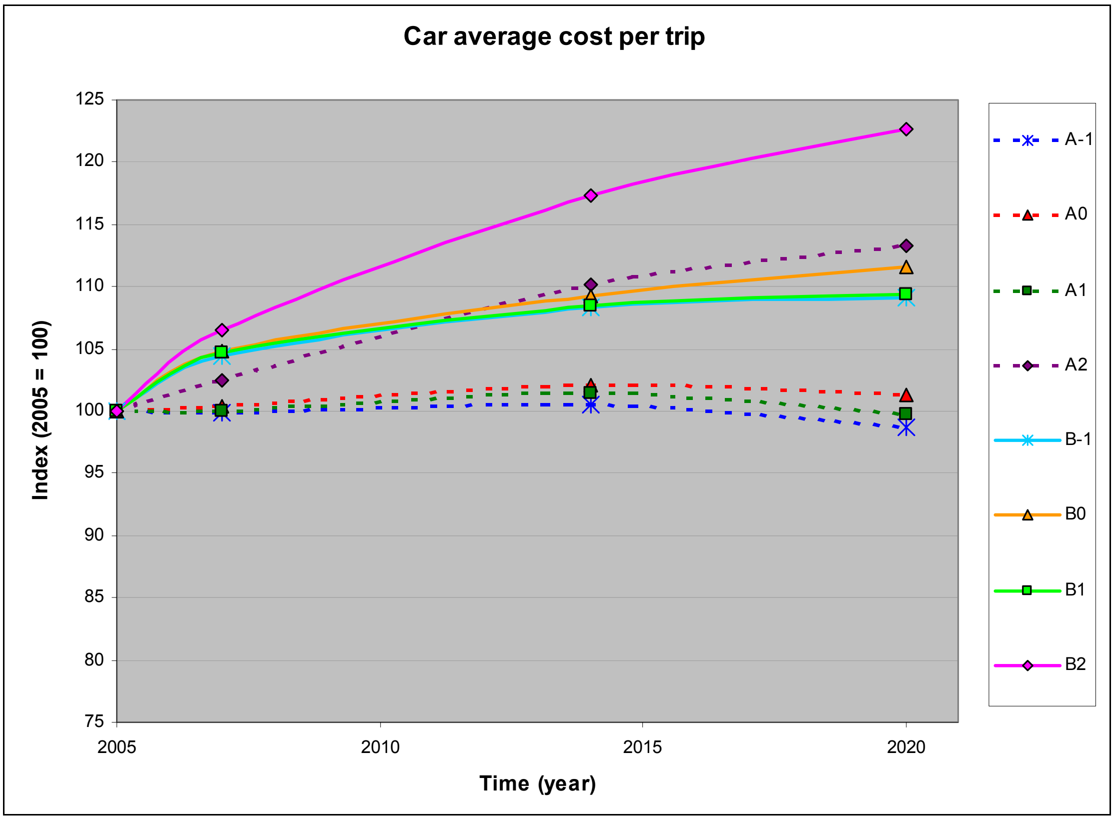


Figure 5.6.19 Car average cost per trip index

The introduction of the policies concerning fuel tax and road charging produces an increase of the revenues for the local administration, which has been quantified in the following table. As expected, the demand regulation scenarios have the more significant values according to the strongest application of the policies. In addition, it is important to note that under the high oil price growth assumption, revenues are reduced because of the reduced demand.

Table 5.6.6 Additional revenues produced by the demand policies

Additional revenues (Mio. Euros/year)	**2020**							
	A-1	**A0**	**A1**	**A2**	**B-1**	**B0**	**B1**	**B2**
Revenue generated by fuel tax increases	-	9.5	7.9	57.5	-	9.1	4.9	51.8
Revenue generated by road charging	-	50.9	50.8	62.9	-	49.0	49.0	60.0

Accessibility

An accessibility index has been calculated for each zone and for each scenario[13]. Below, the most significant results are commented.

If no policies are applied, the accessibility of the zones changes between 2020 and 2005 as shown in figure 5.6.20 (namely, the figure concerns scenario A-1). The figure shows that an increase of the accessibility is expected in the main valleys, especially in the North-West where a new rail network from Merano to Malles is planned (also in the no policy scenarios, the infrastructures planned in the study area are modelled). Instead, more peripheral zones generally face a worsening of the accessibility index.

The STEPs policies were not designed to have effects on the accessibility so only minor differences were expected between scenarios. The largest changes with respect to A-1 scenario can be found in the B2 scenario. Looking at figure 5.6.21 it is apparent that changes are actually little as supposed. Despite its size, all zones benefit of an increment of accessibility in all the zones. The gain is higher where public transport services are improved more significantly.

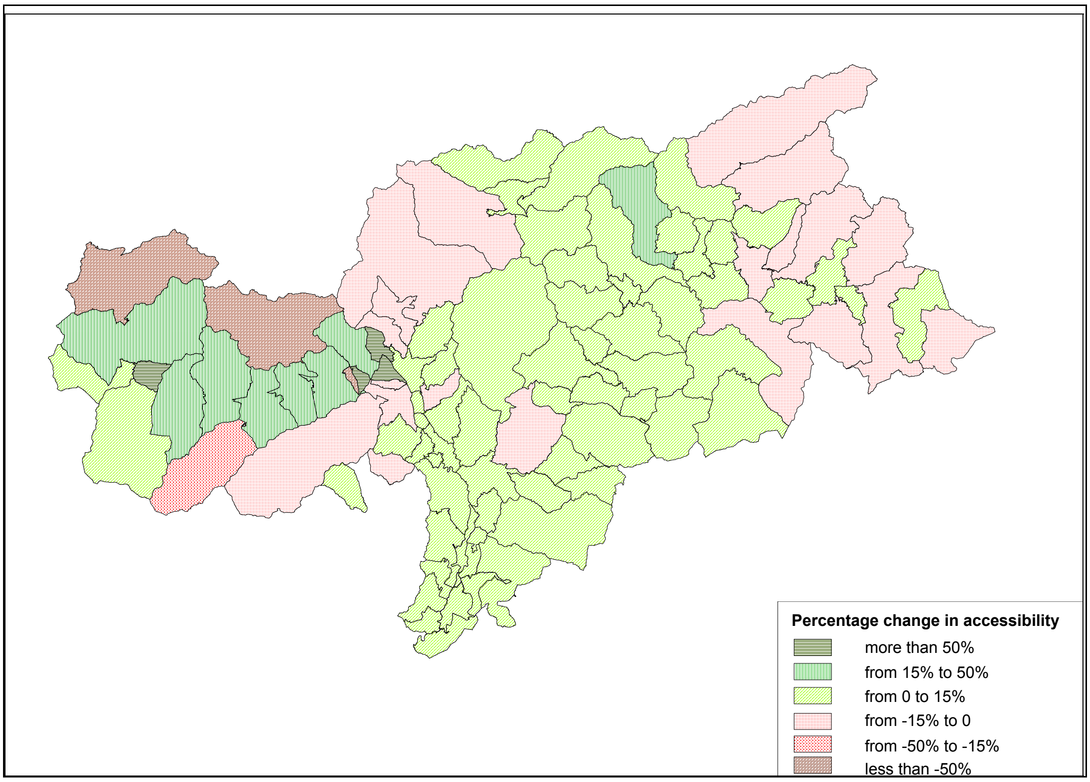


Figure 5.6.20 Difference of accessibility between 2005 and 2020 in the A-1 scenario (in %)

[13] The index has been computed using the formula proposed in WP5 considering the aggregation of the modes available for the passenger

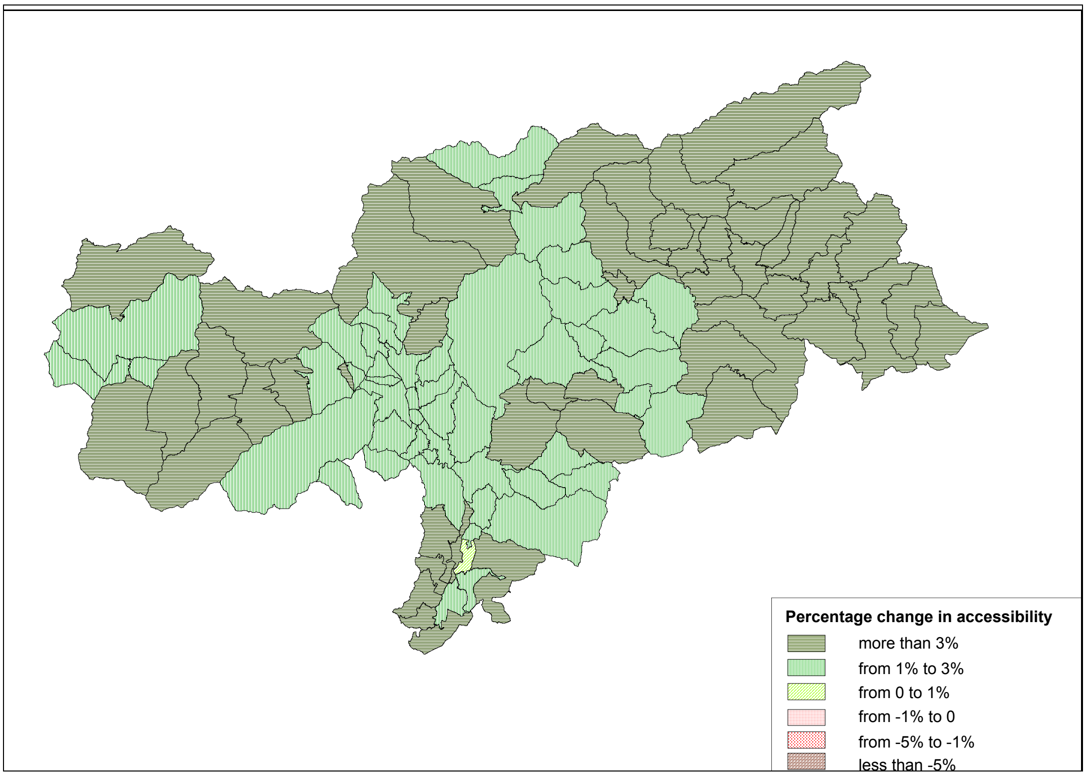


Figure 5.6.21 Difference of accessibility at 2020 between the B2 and the A-1 scenario (in %)

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