Scenarios for the
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STEPs

Transport strategies under the scarcity of energy supply

Edited by:
Andrés Monzón and Adriaan Nuijten

Main authors:
Davide Fiorello, Gé Huismans, Elena López,
Carlos Marques, Thérèse Steenberghen,
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Foreword and Acknowledgments

The fuel price developments during the last years have again showed the relevance and urgency of the subject of the STEPs project. The price of a barrel of oil has risen considerably until the beginning of this century and amounted to about $50 in 2004. The STEPs project started in that year. Currently (July 2006), the project is completed and the price for a barrel amounts to more than $65, which is an increase of 30%.

A clearer illustration cannot be found for the significance of this project, even though it has scenario building as a topic. The complexity of this subject, of which the scenarios cover a time horizon of 25 years, shows an interesting contrast with this astonishing, but simple statistic fact, which covers 2.5 years: exactly one tenth.

But not only energy is threatening the European economy and sustainable development, transport trends are also a real challenge for European Policy. The Common Transport Policy has two basic goals: efficient, accessible and competitive transport systems, and a high level of safety and environmental protection. However, the achievement of these goals requires European Policy to tackle several problems, such as the lack of interoperability of European networks, traffic congestion, a growing imbalance between transport modes, the increasing number of traffic accidents, growing environmental impacts, and problems of cohesion and accessibility in a larger European scene. Besides, the relevance of those problems is different at each policy level; some of them are significant at local or regional level, whereas they do not constitute a relevant issue for the whole of Europe.

How to cope with these problems and threats? There is a wide variety of transport policy options, such as technology improvements, regulation, pricing, or land use and transport integration measures. However, it is difficult to forecast their long-term impacts. It is also difficult to measure their indirect effects on issues such as social equity, accessibility levels, energy consumption, or environmental effects.

This is why there is a need to develop assessment tools that can provide a strategic vision of the expected effects of different combinations of the above policy measures to achieve a more sustainable future for European citizens.

Back in early 2004, the consortium partners for the project STEPs gathered for a kick-off meeting in Brussels to start working on Scenarios for the Transport System and energy Supply and their Potential effects. During the 2.5 years that followed, fourteen consultants and research institutions from nine countries have worked together to achieve a multitude of tasks. Extended research into the State of the Art and relevant trends and analysis formed the beginning of the project and gave the necessary inputs to define a base set of scenarios. These scenarios were simulated using a range of integrated land use – traffic models, on the European as well as on the regional level. The outcomes of the model calculations have been extensively tested, assessed and compared using various tools like meta analysis and multi criteria analysis.

Communication was a second important pillar of the project. All along the process several events were organised in which interim findings were presented and discussed with outside experts. Especially the last meeting in Gothenburg, Sweden, demonstrated that while all model and analysis outcomes represent clear figures, it is the consequences and implications that one can attach to the outcomes that makes one think about the future. Is it possible to decouple economic growth from the growth in transport and energy use? How fast will the oil price growth give rise to the development of other technologies, including renewable resources? What kind of policies will be acceptable to introduce some kind of management of transport demand? It turns out that, at end of the project, the partners have not yet seized the discussions: even at this late stage there are still e-mails coming in on the conclusions and recommendations. This will probably continue for some time.

During this process we realised that the efforts made and the relevance of results would merit a higher quality and more permanent dissemination product. Therefore, we decided to do some extra work, and to dedicate some resources, to publish a final book instead of a simple final report. We received the clear support of all partners to develop this task in parallel to the final part of the project. Thus, we can affirm that the final steps of STEPs have been even more interesting and scientifically challenging, in order to produce a good summary of results and helpful conclusions for all future readers of this book.

It is this active attitude which we have really learnt to appreciate. With the project partners we had a unique co-operation experience which has been a pleasure on the personal side just as well. It is therefore much more than appropriate to thank the partners for the great time together in this project. We cannot name everybody as more than 35 people at the partner organisations and subcontractors have contributed. But we will name some key persons that contributed in a special way.

The STEPs project originates from the LUTR (Land Use and Urban Transport) cluster, which was formed of several earlier projects in the field. Tony May of ITS can in this regard be seen as one as the initiators of the STEPs project. Sander Kooijman, who assumed to take the responsibility of conducting the project should certainly be named. Without the initiative and the additional effort of some colleagues this report would not have reached the quality level that it has. Especially, we would like to thank Elena López of TRANSyT-UPM for this. We would also like to mention Rachel Brooks of TTR, who was in charge of the design of this report.

Furthermore, we really wish to thank the experts that attended the Soundboard Forum meetings and Clustering Meetings. Although the attendance showed some variation, all of you really contributed in a valuable way to the discussions.

Then, there are some people who are not always thanked for their activities in an appropriate way. With all partner organisations, support personnel (secretariat, finance, etc.) played an indispensable role. We especially want to thank Bennie Beernink of BCI for being the STEPs financial manager.

Last but not least, a word of thanks goes out to the colleagues with the European Commission. After all, it is the Directorate-General Research that wrote the task for which the project was designed. It is great that international co-operation in research is supported this way. The first project officer responsible for the STEPs project was Maurizio Maggiore; later Reiner Dunker succeeded him. These are the officials to stay in touch with, when planning projects like this the future.

As a result of the interesting co-operation exercise carried out in STEPs over the last two and a half years, now, in 2006, we have a tangible evidence of our work, and in 2030 we will see if we did the job right.

Thanks to all of you, we certainly hope to see you again.

The Hague, The Netherlands, 22 June 2006
Andrés Monzón and Adriaan Nuijten,
Editors

Executive Summary

Background

The future framework of the transport system is intimately linked with the general energy supply of the future. The relatively cheap availability of petroleum oil has allowed great expansion of the transport system over the past hundred years. This relationship between energy supply and vehicle technology and the characteristics of the transport system is typified by the internal combustion engines that power much of the transport system. The wide availability of fuel, its relative cheapness, and the relative simplicity of the engine itself and the storage requirements has meant that transport system has facilitated an era of increased dispersion of activities with high levels of mobility for those who can afford it. The nature of the fuel technology and economy has been a major influence of the transport system and mobility patterns of today.

However, circumstances are changing. There is an increasing concern about the environmental consequences of the fuel technology used. Just as important are the concerns over the future availability of the fuel required. The recurrent crises and even wars in some areas where oil and gas is produced and the instability of political systems in other fuel producing areas only adds to this. Driven by these issues, a wide range of new or improved fuel technologies are being proposed and developed.

Each alternative fuel technology brings with it issues over the wider consequences of its adoption. These issues include the autonomy and security of the fuel supply, the infrastructure requirements of the fuel technology, the implications for the possible pattern of use of the vehicles, and so possible changes in the patterns of mobility with its impact on land use. There will also be political, social and environmental issues to be considered with the assessment which technologies should be encouraged and invested in. Just as the future is not certain, nor are the eventual 'winners' from amongst the new technologies. There are technological risks with all new technologies, combined with the uncertainties in the energy, social and economic future. The implications of the various futures are best considered by investigation of a series of scenarios reflecting a range of 'best' estimates of future conditions in the energy, transport, economic and social fields.

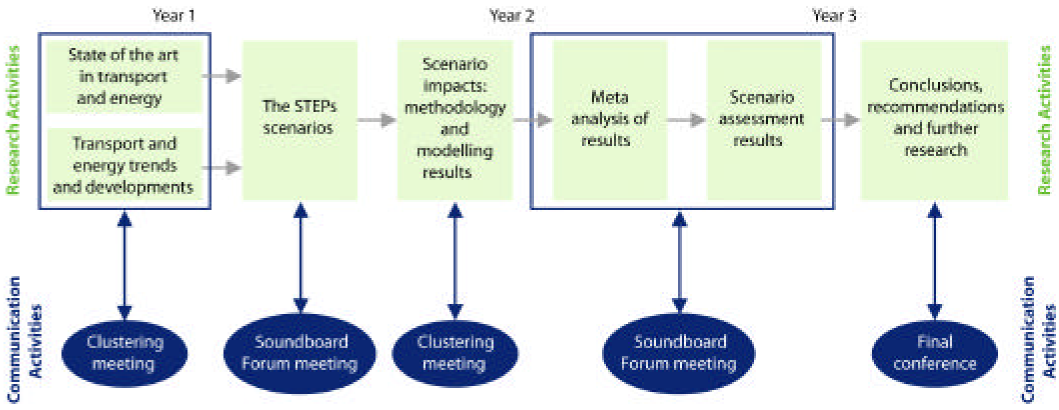
The STEPs approach

STEPs stands for Scenarios for the Transport System and Energy Supply and their Potential Effects. The project ran from January 2004 and finished in July 2006. Its main findings are presented in this report.

The STEPs project was designed and implemented by a group of institutes, companies and universities to achieve the tasks of Research Domain 1.10 within the Sixth Framework Research and Technological Development of the European Commission. The STEPs project had 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 of 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.

To achieve this overall objective, the STEPs project was divided into several tasks with their own specific objectives. In the figure below, the main successive and parallel project tasks are displayed.



The top part of the figure (green blocks) consists of the research tasks of the project. The lower part (blue ovals) represents communication activities, with which the project has tried to involve actors 'from the outside world' within the project in order to discuss results and progress with them and to incorporate their remarks, suggestions additions etc. This has provided added value and helped to enrich the project.

Project results

The project started with mapping the State of the Art, and description of relevant trends in transport and energy supply systems. With these outcomes, a basic set of scenarios was compiled. Two main variables marked the scenario framework. The first was fuel price increase, which is directly related to energy scarcity. In the coming decades the fuel price increase may be as generally accepted in current times, or energy may be subject to more severe scarcity (so pointing to a faster increase in the fuel price). The second variable is represented by the policies that various authorities deploy in response. Will the policy response be like 'business as usual' (not specifically meant to target transport system and its energy supply)? Will there be more targeted policies, for example technology investment to adapt with the use of innovative technologies, or use of more stringent demand management?

The scenarios were simulated with existing integrated land use – transport models, both on the European scale and on the regional scale. The regional models covered five diverse regions in Europe: Edinburgh, Dortmund, Helsinki and Brussels with their respective surrounding regions, and the region of South Tyrol in Northern Italy. Partly, the scenarios worked together to produce the input needed to calculate all parameters needed. In some cases, results from the European models could be used as input in the calculations within the more detailed regional models. The prognosis year was typically 2030 (in some cases 2020). The outcomes were described in an extensive overview of their impacts. The modelling exercise provided indications about the development of several variables (transport demand, economy, energy consumption, emissions, etc.) over the period 2005 – 2020 / 2030 under the different scenarios.

To acquire a good picture of their comparability, the scenario modelling results were subjected to a meta analysis. This gave the possibility to cross-validate the model results, which was needed because of some major differences between the models (their cities, regions) and model techniques. For example the urban regions are of various size, show either growth or decline, are administered in various ways and with various policies.

With the meta analysis showing that the model results were in reasonable agreement about major environmental effects and societal behavioural responses, the assessment and comparison of scenarios was conducted using a multi-criteria analysis. All scenarios were firstly tested as to current policy objectives on the European scale. To establish a valid and credible evaluation framework, a questionnaire was sent to a group of politicians and experts in the transport and energy fields to enquire what aspects they thought were most important: energy (including e.g. reducing consumption and dependence upon import), environmental aspects (emission reduction, global warming), social aspects (e.g. safety) and economic aspects (like competitiveness, employment, GDP and the decoupling of transport growth and economic growth). The resulting weight set was used to calculate value functions to assess the scenarios as to the fuel price effect and the policy effect.

Outcomes and implications

From this last assessment it was concluded that energy and environmental criteria improve in all scenarios and models. Demand management does, in the long term, appear to be more effective than technology investments but this is quite sensitive to the actual policy package which is selected, its efficiency and the way fuel prices will develop. The predicted effect on social criteria is not as straightforward. Both fuel price increases and policy measures tend to result in higher transport costs, mobility constraints and reduced accessibility. Economic development for large parts of Europe could be at stake because of this, and investment in new, sustainable technologies might be a preferable option for a better future for transport systems and their energy supplies.
The results of STEPs constitute a valuable synthesis of the main findings on trends and policy scenarios and their predicted effects. STEPs results serve as a basis for the development of a view on future policy and give insight into research requirements in the area of transport and energy scenarios.
This project has created a valuable contribution in the hugely complicated trade-off between energy and the energy sustainability of our transport networks on the one side, and economic development on the other. To what extent can economic growth be threatened in order to achieve, for example, environmental or social goals? What dilemmas are really crucial for decision makers? Can global megatrends be reversed, and to what extent? Regarding the scenarios' impacts, what aspects can be more important than the air that we breathe, the food that we eat, or the safety of our loved ones? These are profound items to be addressed in the coming decades. We as a project partnership do not think that we can provide actual answers to these issues, but STEPs might well help by taking a small and enlightening peek in the future.

Reader's guide

In this publication, the main activities and results of the STEPs project are described. The report is divided into five main parts which, in turn, each have chapters.

Part I treats the **framework** of the project, including both the trend analysis (Chapter 1) as well as analysis of the relationship between transport and energy use (Chapter 2).

Part II has the **STEPs assessment approach** as a subject. It describes the scenarios that were compiled in detail, as well as the process of compilation (Chapter 3). Also, the modelling system is described (Chapter 4), followed by an account of the multi criteria approach used with the further scenario assessments (Chapter 5).

Part III focuses on the **model outputs.** It features an extensive account of the results of the three European models used in the project (Chapter 6), as well as the regional model results (Chapter 7), followed by a summary of the results (Chapter 8).

Part IV is the account of the **scenario assessment.** The scenarios were investigated and compared in several ways. Firstly, a meta analysis of the model results is included in Chapter 9. Then the assessment results are analysed in Chapter 10. This part ends with a broad cross-model comparative analysis (Chapter 11).

Part V finally draws **conclusions** and presents a synthesis of the main findings, policy recommendations and future research requirements.

At the end of the publication there are references. There is also a full list with the STEPs deliverables: all the reports that were compiled in the course of the project.

Part I: The STEPs framework

PART I: Summary

This first part of this book detailing the results of the STEPs project reflects the first steps made in the project. Before the future scenarios for transport and energy could be developed it was essential to have a thorough insight regarding the trends and developments affecting both sectors. To this end, a trend analysis was carried out as well as a review of previous relevant reports and studies. In addition to this state-of-the-art review, it was considered important to have a detailed overview of current transport and energy policies, not only at national level but also at the EU-level.

This first part consists of two chapters. Chapter 1 includes a review of a large number of relevant trends for a number of topics related to transport and energy supply. In this chapter, trends relating to transport technology, both in road transport and other modes are described. Additionally, trends for fuels and fuel distribution are outlined. The main developments taking place in the automotive and oil industries are also part of this chapter. Finally, an important part of this chapter is dedicated to the description of policies related to transport and energy use, both at the national and international level. An overview of best practice in these fields outside of Europe is also included.

Then in Chapter 2, a more detailed analysis is made of the trends affecting transport, and of the factors and drivers leading to and influencing these trends. Developing scenarios for estimating future energy needs in the transport sector requires an identification of factors affecting energy use by both freight and passenger transport. Therefore, an analysis was made of the political, economic, social and technological (PEST) drivers that are prevalent in spatial development, energy use, freight transport and passenger transport. Then, future trends in freight and passenger transport were identified and described and their relation to the drivers of the PEST environment was analysed. This allowed the identification of the main indicators for quantifying energy use in transport.

The analysis carried out in Chapters 1 and 2 constitutes the basic input for the development of the STEPs scenarios, which is described in Part II, Chapter 3.

CHAPTER 1: Trend analysis

1.1 Introduction

In this first chapter, an overview is presented of the present state of the art in the fields of transport and energy. A number of different topics will be dealt with. Firstly, in the interrelations between both are explained. Why do we need transport and what is its relation with economic growth? Secondly, some insight is provided into modern technologies applied in road transport. Conventional and new technologies are described in this section (1.2). Thereafter, the situation is described for a number of other modes (section 1.3). After that, some attention is paid to the availability, or rather, scarcity of renewable fuels. What forms of transport are possible with what types of fuel? The energy supply (from source to vehicle) is also described in this section (1.4). What are the problems related to that? Following that, an overview is presented of the existing policies on energy supply and transport. Successively, policies at EU level (1.5), national level (1.6) and outside Europe (1.7) are presented briefly. In sections 1.8 and 1.9, the positions of the car industry and oil industry are highlighted. Finally, section 1.10 lists some conclusions of this chapter.

Transport driving forces

Developing long term scenarios on the future of the European Transport System, which was the goal of the STEPs project, requires a thorough understanding of the context to which transportation has been and is currently subject. Therefore, it is necessary to have a clear picture on the key elements driving transportation needs, by understanding the transportation driving forces. In other words, we need to go back to the basics: how does transport originate and what for do we need transport? The fundamental assumption is that economic growth necessarily means increased demand for transport and mobility, which in turn, will inevitably bring demand for more energy, unless fundamental changes in vehicle efficiency and optimised management of the transportation system offsets (at least partially) such effects. Along-side this and often unrealised, a fixed economic growth percentage translates into an exponential rise of transport demand, and is thus accompanied by an exponentially growing demand for resources. This misperception often leads to arguments based on a position of belief rather than a position of knowledge, when it comes to discussions about sustainability issues. It is therefore crucial to understand how much economic growth is feasible (and desirable) in the light of the risk of an energy supply shortage, should energy upstream production throughput not be able to keep up with exponential economic growth patterns.

Looking worldwide at trends in transportation, circumstances differ between the developed world and developing countries, where access to mobility is still a critical issue. Personal travel and goods transport play a role in the pollution and congestion of urban areas. Moreover, they have an impact on global climate change, the CO_2 emissions being directly correlated to the consumption of fossil fuels. The challenge gets particularly worrying as the pace of development in Asian countries does not seem to wait for technological breakthroughs before car ownership figures rise. In this respect, a major concern comes from China that over the past five years accounted for one-quarter of world GDP growth. China became the fastest growing auto market in the world, with 2002 sales of 3.2 million units, nearly 40% growth compared to the year before. Its passenger car segment sales reached 1.21 million vehicles, the first time passenger car sales exceeded the one million mark. China, in a single year, reached the levels of the world's largest automotive markets -- the United Kingdom, France and Italy -- to become the fourth largest automotive market in the world, right behind USA, Japan and Germany. The answer to the question whether this economic growth will slow down over the next few years, or whether it is bound to continue for several years is paramount in all attempts to estimate the future scenarios, not only regarding environmental impacts, but also security of energy supply, with crossed impacts for Europe and USA.

The environmental and energetic footprint of the transport sector

Nearly all methods of transportation use carbon based fuels, either directly (in the case of petrol or diesel fuel) or indirectly (in the case of e.g. electricity or energy carriers like hydrogen, when generated from non renewable energy sources). Either way, carbon dioxide (CO_2) is released into the atmosphere, the most common source of man made greenhouse gases contributing to global warming, as acknowledged by the European Commission in its statement ‘Transportation is clearly a fundamental cause of climate change’ (EC, 2004a).

It is becoming more and more urgent to take proactive measures to reverse this trend. Several carbon free fuels and cleaner technologies have been investigated in order to contribute and therefore help control the pace of global warming and meet Kyoto’s agreed targets for greenhouse gas emissions, while contributing also to decrease the external reliance on oil. This is all the more urgent, since the expansion of renewables in energy supply to the transport system can hardly offset the expected continued rise in mobility; especially considering that over the past decade the worldwide trend for engine sizes has been somewhat at odds with sustainability objectives. This is not only due to unsustainable behaviour patterns such as the market pull for larger vehicles with greater performance and more features, e.g. the so-called *Sport Utility Vehicles* (SUV’s), but also within the general vehicle stock, as a result of increased on board energy consumption in applications not directly related to propulsion, namely safety and comfort (e.g. automatic air conditioning).

To have a better understanding of the changing relationship between transport technology and energy consumption, it is essential to have a better insight in the changes taking place in transport technology. Therefore, in the next section, a closer look will be taken at the developments in road transport industry. The section thereafter (1.4) will consider the other modes of transport in this respect.

1.2 Transport technologies: road transport

Regarding the State of the Art in transportation technologies, there is a clear distinction to make between the commonly-used techniques in road transport and the alternatives which have been or are being developed. In this section, both categories are discussed briefly. First we start with the ‘traditional’ technologies. Then, the more recently developed alternatives are presented.

Conventional technologies

At present, the **Internal Combustion Engine** (ICE), remains largely as the backbone of the road transport technologies, representing the standardized and most well engineered technology worldwide. Key reasons for its wide spread use are the easy handling, the autonomy, the wide spread fuel supply infrastructure and the relatively low costs of the engine itself, in the range of 30-50 € per kW. In general, there are two different types of ICE drives in use: petrol and diesel engines. Modern ICE designs aim at improving fuel charging capacity, mixture processes and combustion, leading to cuts in engine consumption, while maintaining similar levels of performance (EC, 2004b). In particular, diesel technology has shown a spectacular advance in recent years. Hence, both diesel and petrol engines remain as a major option in ICE technology, with developments constantly being brought into the mass market. While most Light Duty Vehicles (LDV) run on petrol, the use of diesel engines has been growing steadily, competing nowadays directly in performance with their petrol counterparts. Lorries and buses run mostly on diesel all over Europe, supported also by a favourable taxation framework. Indeed, in recent years we have witnessed an unprecedented growth in diesel fuel demand in Europe. This trend is likely to continue driven by increased dieselisation of private vehicles. In addition around 15% of the efficiency gains in transportation reported so far in Europe (EEA, 2004) have been a direct result of an increasing share of diesel vehicles, since diesel vehicles are, for thermo-dynamical reasons, more efficient than their petrol counterpart. So, diesel diffusion patterns have been changing fast. But this sudden growth in diesel also leaves Europe with a security of energy supply problem as it calls for more diesel and less petrol than we can produce in our refineries, as these have been historically set up for a production balance focused on petrol. Even from an energetic/emissions perspective, we have that beyond a certain balance, having more diesel cars means a higher cost and CO_2 impact in the refinery, offsetting part or all the gains accrued from diesel usage. So the trend towards a leading position of diesel technology is not flawless. Yet, over the next years, ICE technology and diesel engines is expected to continue to improve.

Although the potential for improvement in the ICE efficiency is still there, it may however be considered as marginal, since performance of ‘heat engines’ is limited by the efficiency of the thermodynamic cycle itself. Therefore their contribution to decreased external dependence on oil is limited to the fuel savings achieved within its technological context. Such marginal, although somewhat important, improvements are achievable by developments in the fields of partial load operation, direct injection diesel, warming-up processes, new materials, electronic management and transmission efficiency. For gasoline technology, downsized spark ignition engines are expected to take a much greater share of the gasoline engine market in the near future, while downsizing with redesigned engines may reduce engine displacement which in turn leads to significant reductions in fuel consumption.

Notwithstanding the dramatic improvements over the last few years and promising advances for the next years, unless there is a chance for a favourable combination between a new alternative fuel and ICEs, bringing radical improvements to emissions and decreased dependence on oil, the long term use of this technology seems questionable and is today seen as an unsustainable long term option while alternative fuels and power technologies are more actively researched and explored. Still, ICEs running either on petrol or diesel represent the most experienced technology so far and are essential in any analysis to 2020.

Alternative technologies

A number of alternative solutions are already on the market, some of them offering significant benefits in terms of carbon emissions, energy consumption, and local air quality. Yet, their advantages are often offset by primary energy feedstock shortage, lack of convenient supply infrastructure, cost, or all these together, plus aspects such as safety and reliability misperceptions. Such options include natural gas, blending of biofuels in modern ICE engines, hybrids, electric and fuel cell vehicles.

Natural gas vehicles, offer a short term direct alternative to its close competitor, the diesel engine. It is particularly attractive as a short to medium term option for heavy duty diesel vehicles, as it burns more cleanly and is quieter, and the heavy and bulky fuel tanks needed are less of a problem with larger vehicles. Fleet applications are particularly attractive, as vehicles can be refuelled overnight through depot-based compressors. These dual-fuel engines can run on up to 90% natural gas with 10% diesel, or can run on 100% diesel. This gives NG vehicles an obvious advantage in terms of flexibility for refuelling, as demonstrations suggest that the emissions benefits can be high – i.e. offering similar CO_2

advantage of diesel combined with the NO_X and noise advantage of natural gas. But while the stationary energy system is increasingly dependent on gas, there are also some doubts about the security of its supply and the extensive pipeline infrastructure needed to bring gas to Europe. A fully gas powered road transport system would therefore bring new energy security risks, as it does not represent a true shift away from fossil fuel and geopolitical dependency. Yet, subject to the right conditions, NGVs can be less expensive to operate than a comparable conventional fuel vehicle, although absolute consumption is generally higher and purchase prices for natural gas vehicles are already only slightly higher than for similar conventional vehicles. The typical price premium for a light-duty CNG vehicle can be 1000 € to 5000 €. Retrofitting may cost $2,000 to $3,000 per vehicle (USA Data).

Hybrids are currently commercially available on the market and may cut consumption and carbon emissions by around 30%, using a combination of two powertrains, a conventional engine and an electric motor. Hybrids feature similar vehicle performance as ICE vehicles in urban contexts while requiring no specific supply infrastructure. With no need for recharging facilities, and running on either petrol or diesel engines, hybrids are essentially conventionally fuelled vehicles, with either a complementary or intermediate electric engine, powered by the electricity generated by the combustion engine. This ICE feeds a battery (commonly inexpensive lead-acid, while new trends point at larger capacity Li-Ion) serving as an energy buffer to cope with peak consumption and the temporary compliance with zero local emission standards. Hence, one of the biggest advantages of ICE-electric hybrids is that they do not require any changes in driver behaviour or the fuel-delivery infrastructure. It can be expected that the current hybrids will evolve as they gain a market share, and it is believed they have the potential to double the fuel economy and halve the carbon emissions of average sized petrol or diesel engine vehicles. The development of the hybrid vehicle can also be seen as a contribution to the progressive 'electrification' of vehicles. Improvements in electronic control systems and electric drive trains, for example, are all vital elements to that end, which are essential to the possible future developments of fuel cell vehicles. Indeed, the first hydrogen fuel cell vehicles being demonstrated are in fact hybrids themselves combining a battery with a fuel cell.

Hybrid cars, may therefore offer many of the benefits of fuel-cell vehicles, with the advantage that they are available now at a relatively low cost. People may actually buy a hybrid at a cost that is not completely out of reach from average consumers, somewhere between 3.000€ and 5.000€ (e.g. Toyota Prius) compared with conventional ICE. So, rather than being a mere pathway towards hydrogen, ICE-electric hybrids are likely to be around for years, with increasing mass production currently underway, upon which Japanese car makers are placing strong emphasis. Still in connection to fuel-cell vehicles, should they become a reality with wide expression in worldwide sales, these will surely require many of the same components adopted in hybrids today, from control systems to electric powertrains. In a way, hybrids have therefore the potential to pioneer the sort of platform from which all future clean vehicles may come to evolve.

Electric vehicles, with virtually no emissions at the point of use, are relatively clean from a fuel cycle perspective provided certain conditions are met. Due to problems with energy storage and the limited range and performance of batteries (unless at a very high cost and at the expense of 'running deadweight' on the vehicle), pure electric vehicles seem unlikely to reach major market share. In addition, although tailpipe emissions are zero, the energy source for the electricity (the majority of which is fossil fuel) has to be taken into account in any assessment on the shift away from fossil fuels and on the environmental impacts of these vehicles. A 'well-to-wheel'[1] assessment is necessary to give a fair comparison with all other available options. Electric vehicles will probably remain confined to niche markets,

[1] 'Well-to-wheel' refers to the complete chain of fuel production and use, including feedstock production, transport to the refinery, conversion to final fuel, transport to re-fuelling stations, and final vehicle tailpipe emissions

and in time may be partly or completely superseded by fuel cell equivalents, unless crucial development in energy storage devices such as super-capacitors or low cost Li-Ion batteries combined with fast charging cycles are used to open new horizons to this technology.

Fuel Cells and hydrogen are often seen as the most promising combination to replace fossil fuels in the long term. In the transport sector, it can be a suitable energy carrier and under certain conditions improve the environmental performance. Hydrogen and fuel cell technologies could therefore contribute to improve Europe's energy security and air quality, whilst promoting a decrease in energy dependence on oil. Indeed, hydrogen fuel-cell vehicles promise to be the cleanest mode of transportation, eliminating harmful tailpipe emissions altogether. But despite much publicity, and the fact that most carmakers are working on the technology, fuel-cell cars will not appear in significant quantities soon. Recent estimates defend that the transition to a ‘hydrogen economy’ will probably take decades, since many challenges remain—in particular, how to produce, store and distribute hydrogen in sufficient quantities, and in a clean manner. On the other hand the applicability of the various hydrogen supply paths to the different types of transport depends to a large extent on the type of hydrogen storage onboard the vehicle. Compressed gaseous hydrogen storage may be suitable for passenger cars, delivery vans, public buses, tramways and certain types of regional trains as well as for boats and small ships. Liquid hydrogen storage is suitable for these applications and additionally for airplanes and possibly large ships. It is unclear at present whether hydrogen storage is feasible for long-haul trucks with present driving distances of over 1,000 km.

Short to medium term development of any hydrogen based transportation will likely depend on natural gas reformation (Natural Gas: CH_4), which is seen as the cheapest and quickest route to hydrogen, although this does not solve the fundamental problem of the heavy reliance on fossil fuels. To make it worse in terms of objective advantage for the near future, the environmental benefits of fuel cell vehicles using hydrogen from gas, does not seem promising. Estimates by the Joint Research Center (2004) state that the ‘well-to-wheel’ carbon emissions of a fuel cell vehicle using locally reformed hydrogen in 2010 might be approximately 80–85 g/km. In contrast, the figure for a diesel hybrid will be approximately 100 g/km, which in turn represents a much more promising technological option, right from today. But the transition to mass market hydrogen vehicles will only be possible with a fully developed hydrogen infrastructure. This is a commonly acknowledged obstacle and therefore Hydrogen taken from natural gas seems likely to provide a step on the route to an acceptable transition to hydrogen vehicles. But the practical feasibility of this option will also depend on factors other than environmental ones. Indeed, since greenhouse gas emissions of fuel cell vehicles using hydrogen from gas are broadly similar to those of diesel hybrids, the “cost” element will play a crucial role against fuel cells and strongly in favour of high-tech hybrids, at a fraction of the cost of fuel cell already today.

1.3 Transport technologies in other transport modes

Besides road transport there are of course a number of other transport modes, where similar or quite different developments are taking place in the application of transport technologies. These of course also have their implications for the consumption of energy. Therefore, technologies in rail, air and maritime transport will be discussed briefly in this section.

Rail transport

In the case of railway transport, this is entirely supplied by either electrically or diesel driven vehicles. Pressure on the environmental performance of diesel traction will probably grow due to tightening European emission standards on diesel engines. But since electrification is economically infeasible in many situations, alternative concepts are currently being discussed in future railways. Different solutions are approached in this context, the most promising being fuel cells and natural gas propulsion, according to a recent UIC study hereby reviewed. From an accomplishment viewpoint, it must be considered that the environmental competition between different transport modes is not a mere question of marketing. It is also a competition for the patronage of public regulation and funding which is expected to gain more importance in the future. This is therefore one major reason to believe that the environmental advantage of railways could be at stake in a long-term perspective, as the environmental performance of private and commercial road transport has improved tremendously over the last decade. Especially as far as emission control is concerned, mainly due to the joint effect of the high innovation dynamics typical of mass markets and the strong pressure from both legislation and public awareness. It is up to the railway sector to react in order to maintain or even improve its competitive positioning in the transport market in this particular respect, something that seems to be already underway, with expected results which should be worth taking into account for the development of scenarios within STEPs.

Air Transport

With regard to energy and emissions' concerns in air transportation, we have seen that it has been growing as much as 4% to 5% per annum and it is expected that despite effects of oil price surges, air transport will continue to grow in its importance within the overall panorama of transportation. However, technology improvements have not been sufficient to balance growth: fuel consumption and hence CO_2 emissions have increased by some 2% per annum, in contradiction to the accepted requirements of limiting GHG emissions. This happens while kerosene remains as the only fuel used in air travel, with some serious environmental impacts caused by combustion; especially the greenhouse gas carbon dioxide (CO_2) that is emitted in large amounts. Further pollution occurs through the emission of nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC), sulphur dioxide (SO_2) and soot. Yet, several technical improvements are planned. There is an emphasis on the development of engines with low nitrogen oxide (NOx) emissions. Engines with combustion technologies called '*Dual annular Combustor*' are already on the market, while the future technologies seem to be the '*Lean Premixing Prevaporising* (LPP)' and the '*Rich Burn Quick Quench* (RBQQ)'. Moreover there are experiments with modifications of the aircraft body such as 'raked wingtips' for reduction of wingtip vortices and laminations derived from fish surfaces for drag reduction. Parts of these technologies proved their functionality in the experimentation phase, so an implementation in the future appears to be realistic (e.g. '*winglets*' are already in use on the recent versions of Boeing 737).

The average kerosene consumption per 100 passenger-km is about 5 litres, taking average fuel consumption value for aircraft fleet derived from various sources flight carriers (e.g. Lufthansa). But the assessment for the direct energy consumption is expected to improve by means of improved technology. To this extent we have seen that the state-of-the-art in energy efficiency is currently at around 3 litres per 100 passenger-km, in the brand new AIRBUS 380, bringing energy efficiency per passenger to the scale of a modern diesel vehicle. Regarding alternatives to kerosene, liquefied Hydrogen (LH_2) has often been mentioned as a promising option. The figure for direct energy consumption and release of CO_2 from LH_2 is very good because the efficiency rate for LH_2 is higher than for kerosene and it doesn't generate any CO_2 at all. As there will be little but not negligible emissions of NO_x the overall view for the other pollutants can still be considered good. Also due to the higher efficiency rate of LH_2 in combination with less weight, the engines could become smaller, lighter and less noise generating. Originally Airbus planned to develop and fabricate a prototype demonstrator of a regional jet aircraft of the type DO 328 which should be operated with liquid hydrogen having a range of 1100 km. This project was stopped in 2003.

Current studies consider only the possibility of replacing the kerosene operated auxiliary power unit with a fuel cell, as several other opportunities improving the aircraft technology are still duly unexplored such as better aerodynamics, innovative light alloys and materials, improved engines and better avionics. According to Lufthansa Airline, these measures hold the potential for a total fuel reduction of some 40% over the next 20 years. And most of these improvements are expected to be achieved regardless the fuel type.

Maritime transport

Maritime transport applications require engines with a high performance and broad application spectrum. Furthermore vessel engines need to have a very high reliability. The engines have a high specific output, a low noise level, a soft and smooth run, reduced fuel consumption and long life in connection with a reduced demand for maintenance. In turn, marine distillates can be broadly divided into two categories: marine gas oil (MGO) and marine diesel oil (MDO). Similar to road transportation, the alternative fuels considered for maritime transport include natural gas, biofuel and hydrogen. However, the most likely technological options according to recent studies show that the evolving pathway in maritime transport will probably relate to bi-fuel capability incorporating biofuels into marine distillates and that although technical, engineering and cost issues need to be addressed, they would not present an insurmountable barrier to dual fuel usage in the short term.

1.4 Transportation Fuels

After having discussed the technologies used in the various transport modes, this section will take a closer look at the implications of the use of these technologies for the use of energy. First, the state of the art on the availability of fuels in general will be presented. The need for alternative fuels is discussed as well. Thereafter, the relations between the various fuels and the technologies mentioned previously will be explained. Finally, the distribution systems of the fuels are briefly looked upon as well as the consequences of a potential use of alternative fuels for these supply systems.

Availability of fuels

A number of international institutions have analysed expectations on fossil fuel supply, mainly oil. According to the IEA (**International Energy Agency**), achieving a truly sustainable energy system will depend on technological breakthroughs that radically alter how we produce and use energy. This calls on governments to take the lead in accelerating the development and deployment of new technologies ‘allowing us to meet our growing energy needs without compromising our energy security and the environment.’

On the other hand, the **World Energy Council** (WEC) published in 2003 its report on the ‘*Drivers of the Energy Scene’*, focusing primarily on past and current trends in oil and natural gas markets, further addressing the functioning of the energy system and how the energy availability and energy acceptability goals could impact on GDP growth and energy accessibility in the future. This report is remarkably original for it’s positioning among International organisations, as it points to developments, both qualitative and quantitative, running counter to most common analysis found. It actually challenges widespread forecasts on GDP growth and oil price, proposing that GDP growth in the coming years is likely to remain below the commonly accepted forecast of 3%. At the same time suggesting that real primary and final energy prices were likely to rise in the following years, a viewpoint that seems to be proving correct.

Finally, according to the **EC Green paper of Security of Energy Supply**, domestic resources are indeed running out and Europe does not enjoy large domestic resources. Hence, expectations are that EU energy resources will steadily fall. The pace at which they will run out depends on world oil prices and technological progress. Enlargement will not improve this situation, except for coal. Still according to the EC Green Paper, in the North Sea, oil extraction costs are much higher than in the Middle East, while reserves are limited. In the best case, these would represent a further 25 years of production or eight years of consumption at current levels.

Regarding natural gas from the North Sea, this is following the same pattern as oil. Still, production from natural gas reserves in Norway, a member of the European Economic Area, may represent 23 years of consumption at current levels. However, we should consider that, on one hand, consumption of natural gas is likely to increase in result of a partial shift from 'dirty' fossil fuel to 'cleaner' natural gas is some applications, including transportation. On the other hand, prices of natural gas may increase making it viable to explore further existing reserves.

The fact that transport is today fuelled to a very large extent by oil has implications for energy policy, but it is also of great relevance from an environmental perspective, notably in view of climate change. The topic of usage of alternative fuels should therefore be on top of the agenda. Recently, action plans have been identified at EU level on the topic of alternative fuels in general and on natural gas and biofuels in particular. It is however important to bear in mind that it is not enough to seek 'alternative' fuels - if we are to move towards a sustainable transport system, these fuels must ultimately come from renewable sources. DG Environment sponsored a study on renewable fuels, looking at the potential of producing alternative fuels in the EU, including the costs and the environmental impacts involved in doing so. It has considered a wide range of options and selects a few for in-depth study and conceivable introduction strategies. The conclusions point at the adoption of new and cleaner fuels in the near future, namely natural gas and biofuels, blended with diesel.

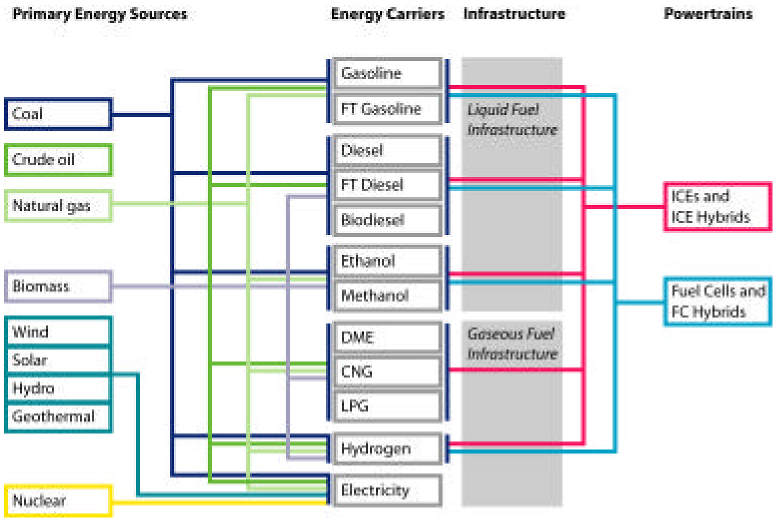
The potential of renewable energy sources, which has hardly been touched so far, remains to be exploited. Should cost and technological related problems be overcome, renewables could become a key energy source for the future in the EU. However, the usage of renewable energy sources calls for a realistic approach. Fossil fuels will probably continue to dominate the market over the next two decades and optimising conventional petrol and (clean) diesel engines will bring the biggest contribution to reducing CO_2 emissions on a European scale within the next years, especially if combined with hybrid electric vehicles.

Natural gas and biodiesel may prove helpful in relieving the stress on demand for fossil fuels arising from transportation. But unless prices of conventional fuels increase steeply (either due to a surge in oil prices or through heavier taxation) and ICE's performance is not improved, the market share of alternatives seems bound to take off slowly. E.g. hydrogen is only expected to start making a sizeable contribution beyond 2020. Likely surprises may come from hybrid power trains.

Relations between fuels and transport technologies

This section provides an overview of the many relations between the fuels discussed above and the transport technologies as presented in the previous sections, according to the figure below:

Figure 1.1: Possible transport fuel pathways



Source: World Business Council for Sustainable Development, 2004 - Sustainable Mobility Project

The previous figure depicts the state-of-the-art in organization of the fuels with propulsion systems. The first column identifies sources of primary energy (or the 'feedstock') at the origin of the energy pathway of propellants in the transport system. These are not always used directly as transport fuels, coal and natural gas being major exceptions.

The transport system actually uses the so called 'energy carriers' produced from the primary energy sources, which are the subject of the second column. Here we may see a myriad of 'energy carriers', either in use at present or proposed for use in the future as transport fuels. For an energy carrier to be used widely as a transport fuel there must be an infrastructure for distribution.

The two major categories of transport energy distribution systems (liquid and gaseous fuels) are presented in the third column, whereas the lines connecting the second and third columns show which energy carriers are capable of being distributed by each category of energy infrastructure. On the right end of the figure are shown the two major categories of propulsion systems either presently being used or likely to be used in transportation.

The next table provides a summary of the most promising combinations between fuels and engine technologies. It underscores that to some extent the future of fuels and engine technology is mutually dependent. Crucial developments in any innovative engine technology including also energy storage capabilities will most probably foster the exploitation of related fuel, while increased availability of a given fuel considered as an alternative to oil will also most probably boost the development of compatible engine technologies.

Figure 1.2: Matrix of possible fuel/propulsion system combinations

	Spark Ignition	Compression Ignition	Fuel Cell	Reformer + Fuel Cel	Electric Motor
Gasoline	●			●	
Diesel		●		●	
CNG	●			●	
LPG	●				
Hydrogen	●		●		
Methanol	●	●	●	●	
Ethanol	●	●		●	
Biodiesel		●			
DME		●		●	
Electricity					●
F - T Diesel		●		●	

Fuel supply infrastructures

Shifting from an oil based transport system will also require adaptation of the infrastructure of supply depending on the choice of technology. The required large-scale expansion of innovative technologies relying on renewable energy sources will be heavily dependent on the attainment of ‘economies of network’.

The problem in attaining ‘economies of network’ for alternative energy sources stems from the fact that none of these alternatives has yet emerged as clearly promising. In a situation like this, it is legitimate to expect that the relevant economic agents will not embark in the necessary investments to provide energy supply to whatever new technology might be proposed, unless costs are either low or strongly subsidised. Hence, currently existing supply networks of alternative fuels tends to concentrate in those cases where the need for a supply network to be built does not imply very high costs, such as biofuels sharing existing supply networks while enjoying similar physical and chemical characteristics and to a different extent, natural gas, already relatively wide spread for industrial and domestic consumption. In the case of public transport operators (UPT), these may enjoy by itself sufficient scale to allow for dedicated supply – for example, a natural gas storage facility in central maintenance and refuelling premises of a bus operator.

In general, a basic natural gas infrastructure for housing and industry is widespread across Europe, making it rather easy to extend the current network to specific spots. However, safety is an important issue and therefore most of the NGV applications remain in the UPT field, where supply infrastructure is built as required at relatively low cost. As happens with ‘less conventional’ technologies, and due to the infrastructure supply issue, UPTs are seen as privileged forerunners in the adoption and testing of fuelling stations in most countries. Natural gas providers are keen on developing this business area and can be often found in join-ventures with transport operators assuming or sharing costs of the refuelling installations. For this reason natural gas is growing its network through pipelines across Europe and represents a rather inexpensive alternative for distribution, compared to other more demanding options such as hydrogen. A remarkable growth in supply infrastructure has been experienced in several countries, Germany and Italy being the best examples.

Natural gas supply infrastructure in Germany is supported by local gas utility companies collaborating to rapidly grow the natural gas vehicles, taking the lead in Europe regarding plans to introduce NGVs. There are about 20.000 vehicles and by 2006 this figure is expected to increase to a total of 70,000, supported by the German federal government which committed a national policy to maintain low tax rates on natural gas through the year 2020, while consistently increasing the taxes on both gasoline and diesel, an example that sends a consistent message about its long term plans to the car companies.

On the other hand, the hydrogen supply network is not at all implemented. All transport related initiatives on hydrogen buses depend on facilities that produce H_2 either locally through hydrolysis (expensive and insufficient) or through compressed H_2 transported from production centres (suppliers such as BP, Air Liquid, Linde Gas, etc.).

Besides the cost of changes in the supply infrastructure, the most important balance will be the well to wheel balancing, ensuring that effective improvements in energy dependence from fossil fuels and their external consequences are taken into account.

1.5 Policies on transport and energy at EU level

The discussion about new fuels cannot be concluded without a clearly defined point of view of the energy policy as a whole. Thus, further integration of transport energy supply into energy policy, should be achieved. In this section, an overview is provided of relevant policies, drafted and implemented at the EU level. In the next sections, policies at national level and outside Europe are described.

Transport and energy policy in general: the White Paper

Regarding Common Transport and Energy Policy, the European Union has clearly adopted Sustainable Development as a key element in its long-term strategic vision of a European society where economic growth, social progress and environmental protection are aligned. Traffic congestion and the consumption of fossil fuels are main threats to sustainable development, closely linked to both energy and environmental concerns, in particular CO_2 emissions that are responsible for climate change. Transport – which represents 32% of energy consumption and 28% of total CO_2 emissions – is clearly a field in which progress is urgently needed.

As acknowledged in the Common Transport Policy reference document, the 'EC White Paper *European Transport Policy for 2010*', transportation is a key factor in modern economies. The transport system needs to be optimised to meet the demands of enlargement and sustainable development. A modern transport system must be sustainable from an economic and social as well as an environmental viewpoint. But there has been little harmonious development of the common transport policy, leading to several suboptimal situations such as unequal growth in the different modes of transport. While this reflects the fact that some modes have adapted better to the needs of a modern economy, it is also a sign that not all external costs have been included in the price of transport and certain social and safety regulations have not been respected, notably in road transport. Consequently, road now makes up 44% of the goods transport market compared with 41% for short sea shipping, 8% for rail and 4% for inland waterways.

The White Paper does acknowledge that the European transport system faces major drawbacks with impact on energy and emissions accrued from the imbalance in the development of the different modes, congestion on the main overland routes, cities, and in airspace. The proposed priorities are to adjust the balance between the different modes of transport, promoting railways, promoting maritime transport and inland navigation, and the development of intermodality, while improving the quality of road transport.

With regard to energy consumption patterns and adoption of alternative fuels, however, the White Paper provides few indications. Nevertheless, the problems with the efficiency of transportation in Europe are mentioned along with the environmental impacts accrued from the sector. Indeed it proposed an Action Plan aimed at bringing about improvements in the quality and efficiency of transport in Europe. It is also proposing a strategy designed to gradually break the link between constant transport growth and economic growth in order to reduce the pressure on the environment and prevent congestion, keeping EU's economic competitiveness. Yet, a set of adjusted strategic propositions seems to be necessary today.

Notwithstanding, it mentions restraining trends in mobility, shifting the balance between the different modes of transport through a proactive policy to encourage the linking-up of the different modes and promote rail, maritime and inland waterway transport. It also acknowledges that a top priority in transportation must be its compatibility with environmental concerns. To this end, the Commission is proposing a number of measures to develop fair infrastructure charging taking into account external costs, encouraging the use of the least polluting modes of transport, while defining sensitive areas which should be eligible for additional funding for alternative transport, and to promote clean fuels. However, the white paper is nowhere clear on what this means in practical terms, setting up merely the long term strategy. Yet, the White Paper advocates a qualitative change of direction in transport policy in order to ensure that measures to promote an environmentally friendly mix of transport services go hand in hand with the measures to open up the markets. To this respect, the White Paper defends that the competitiveness of Europe's economy and the establishment of a high-quality European model for citizens will depend upon the common desire to bring about such changes.

Energy supply security

Concerning the aspects on security of energy supply, as oil prices surged, the EU recalled recently the necessity of having a concerted European approach to the issue of security of energy supplies. The recent increase in oil prices has been underscoring the importance of developing a consistent European policy on the security of energy supply, '*strengthening of the EU's energy partnerships with the main surrounding suppliers and the European system of security stocks are both indispensable parts of such an approach*' (EC, 2004a)).

Accordingly, the stated priorities in the European oil security policy (European Commission, 2000 - Green Paper Energy Supply) are to reinforce the dialogue between producer countries and consumer countries in order to ensure greater oil price stability. This dialogue with the producers must also address the efficiency of the oil markets, besides the issues related to the balance between physical supply and demand. All these elements need to be part of the discussions with producer countries, finding ways of ensuring more stable prices.

The dialogue with the producer countries must also aim at creating 'a more attractive investment framework for the production of hydrocarbons as well as for the infrastructure bringing these hydrocarbons to the EU' (EC, 2004a). Besides attempting to ensure transparency and predictability in the supply of energy to the EU, the EC expects it to enable a better identification and anticipation of dangers threatening the stability of such energy supplies. In fact, the EU does acknowledge that the level of spare oil production capacity is at a minimum, which highlights the vulnerability of the EU's oil supply (Palacio, L, 2004). In this respect, proposals were presented by the Commission in 2002 designed to reinforce the European system of security stocks and crisis measures, in order to endow the EU with means to react in the event of a supply crisis.

Overall, the analysis presented in the Green Paper concluded for the following:

- That the European Union is increasingly dependent on external energy sources,

- That there is limited room to manoeuvre in terms of the conditions of energy supply and is essential to act at the level of energy demand,

- That unless a proactive approach is adopted, it will not be possible to meet the challenge of climate change, and in particular the Kyoto commitments.

This led to the establishment of three major strategic priorities related to energy demand control, managing dependence on supply and ways to ensure a fair and efficient internal energy market. To this end, the Green Paper proposed a strategy focused on two priority sectors: construction and transport. Together, these two sectors account for a considerable proportion of the European energy consumption. Overall, the Green Paper sets out strategies to guarantee Europeans clean energy at a reasonable cost and in sufficient quantity supported by actions regarding both energy supply and demand. It is, however acknowledged that it is much more effective to work on the demand side, by thinking about a more effective use of energy in order to consume less, namely through innovative mobility management thinking. No clear indications are however made regarding betting on alternative fuels and promotion of deep technological changes in the transportation sector.

Finally, the Green Paper expresses the following three major constraints to the security of energy supply:

- **Geopolitical constraints** weigh heavily on the energy sector, hence with a strong impact in transportation. Europe imports 50% of its needs. By 2030 this figure will have risen to 70%., concerning almost exclusively fossil fuels if nothing is done.

- **Environmental constraints** are making themselves felt in daily life. It is necessary to lay the groundwork to produce energy or to travel in a way which is more sustainable. Fossil fuels give rise to many environmental problems connected with their combustion and transport applications.

- **Geological constraints** in 50 years, there will be almost no more oil or gas. Alternatively, it will be very costly to extract these products, in a way which bears no relation to current prices. In other words, these natural resources exist in finite quantities and we are just squandering them.

The situation as of 2000 was already acknowledged to be far from promising. It was clearly stated that '…even if the EU has managed to reduce its energy intensity (the quantity of energy needed to produce a unit of wealth), all the warning lights are flashing. Energy consumption is rising by 1 to 2% a year. Dependence on EU countries is starting to rise above 50% again. Our scarce domestic resources are beginning to run out; in the case of coal, we talk about 'economic depletion', as it is far too expensive to mine…'

Emissions reduction

Regarding EU restrictions on emissions, the European Council and the European Parliament have adopted a target of reducing CO_2 emissions from new passenger cars to 120 grams per kilometre by 2010 at the latest. The car industry committed itself to reduce these emissions to 140 g CO_2/km, but leaving a 'gap' of 20 g CO_2/km which has to be covered in particular by using fiscal incentives.

Meeting the 120 g/km target is of importance for the achievement of the Community's Kyoto Protocol targets. The Community strategy to reduce CO_2 emissions from passenger cars and to improve fuel economy is therefore focused primarily at reducing CO_2 emissions from passenger cars and it is based on three pillars:

- agreements with the auto industry on fuel economy improvements;
- fuel-economy labelling of cars; and
- fiscal measures.

These three instruments will reinforce and add to each other when implementing the strategy. With regard to the first point mentioned, the European, Japanese and Korean Automobile Manufacturers Associations (ACEA, JAMA and KAMA, respectively) entered into commitments to achieve new passenger car fleet average CO_2 emissions of 140 g CO_2/km by 2008/2009 (measured according to Directive 93/110/EC). The European Parliament and Council Decision of 22 June 2000 establishing a scheme to monitor the average specific emissions of CO_2 from new passenger cars (Decision 1753/2000) supplemented this step. The targets of the Commitments must be mainly achieved by technological developments affecting different car characteristics and market changes linked to these developments. But there are no legal requirements in place which oblige industry to reach 120g CO_2/km by 2012 or any other date but, as requested by the Commitments, in 2003, ACEA and JAMA reviewed the potential for additional CO_2 reductions, with a '*…view to moving further towards the Community's objective of 120 g CO_2/km by 2012…*'. However, in their position papers of December 2003, both ACEA and JAMA claim that the technological potential will not be sufficient to achieve the Community target of 120 g/km by 2012. Overall, the aim of the Commission is to achieve the Community goal of 120 g CO_2/km in a 'sustainable way', taking into account the Gothenburg Council principles on environmental, social, economic aspects.

Vehicle taxation

Vehicle taxation in the European context has been an increasingly discussed subject in the last few years. Despite all the convergence treaties that have been driving European policies, this issue remains deserving of an exception regime within Europe, where the existing country borders are still making the difference for those aspiring to own a vehicle. Different vehicle taxation systems in the various countries are commonly seen as hindrances to such convergence. Indeed, there is currently little Community legislation, or harmonisation of national fiscal provisions, applied by the Member States in the area of passenger car taxation.

Therefore, it is for each Member State to lay down national provisions for the taxation of these cars. Hence Member States' taxes on passenger cars are much diversified in terms both of their structure and levels. They include tax payable at the time of acquisition of the car (registration tax), periodic tax payable in connection with the ownership of the passenger car (annual road tax), taxes on fuel, and other taxes such as VAT, insurance taxes, registration fees and road tolls.

Deeper understanding on this specific subject, relating to the purpose of this report, was achieved mainly from two studies recently commissioned by the EC on 'vehicle taxation in the Member States' and the 'Fiscal measures to reduce CO_2 emissions from new cars'[2]. Based on these background studies, the European Commission[3] has recently set up a strategy on the taxation of passenger cars in the European Union[4]. Apart from concerns on removing

[2] COWI, 2002,

[3] http://europa.eu.int/comm/taxation_customs/taxation/vehicles_taxation/index.htm

[4] IP/02/1274 - 9th September 2002 – 'Car taxation: Commission presents new strategy'

tax obstacles and distortions to free movement of passenger cars within the Internal Market, other targets are the relationship between taxation principles and energy/emission related EU policy objectives.

Registration taxes are identified as the biggest problem and therefore the Commission recommends their gradual reduction and even abolition, to be replaced by annual road taxes and fuel taxes (so that the tax burden would remain the same but related to the use of a car rather than its acquisition). Further to recommending a certain degree of approximation of annual road taxes to prevent car market fragmentation, the Commission examined ways of restructuring existing vehicle taxes so as to put more emphasis on environmental objectives in line with Community policy and the Kyoto Protocol. To this respect the former Taxation Commissioner, Mr Frits Bolkestein, has stated that the objective should be to '*…ensure that car taxes are more clearly geared to meeting the Community's environmental objectives.*' In particular, it recommends that the taxation of new passenger cars be more directly related to their CO_2 emissions, urging Member States to take these recommendations into account when evaluating and revising their national vehicle taxation systems.

Given these circumstances, it has been suggested that more significant CO_2 reductions can be achieved if the tax level is more directly related to the CO_2 performance of each new passenger car. The Commission now recommends that both acquisition or registration tax and annual ownership tax should be based primarily on emission factors, recommending the gradual phasing out of registration taxes and the introduction of a new tax structure linked to CO_2 emissions. It also recommends that taxation of the use of company cars should also include a clear and strong incentive to use more CO_2 efficient cars.

From the options proposed for the resolution of the generally identified problems in relation to vehicle taxation, the option that received wider consensus from motor industry and consumer associations, does confirm suggestions to phase out registration tax gradually while introducing a new tax structure linked to CO_2 emissions.

Fuel taxation

Regarding EU fuel taxation, it is seen today as the best available fiscal tool to control the amount of diesel and petrol used, and hence energy consumption and emissions from the transportation sector. The excise duties applicable can e.g. be arranged to be close to the average value of the external costs, increasing the price by the required amount to correct for level of use. Fuel taxes may be differentiated endorsing targets such as promotion of 'cleaner' fuels (unleaded petrol) or low-sulphur diesel, biofuels, natural gas (at present). The aim is to comply with the stringent EU standards, helping to reduce NO_X, PM_{10}, and CO_2, although sometimes at the expense of extra production costs and refinery emissions (for oil based improved / de-sulphurised fuels). Fuel tax is indeed the only pricing instrument *used throughout the EU* that is related to vehicle usage. Road pricing schemes are also related to vehicle usage, but to date their application is limited to motorways in some Member States and to very specific road cordons in some urban areas. Therefore fuel taxes are seen as the most efficient instrument currently available, not only for internalising social costs linked to the use of vehicles, such as infrastructure costs, accident costs and air pollution costs, but also to promote cleaner fuels and alternative energy sources in transportation.

Since the early 1990s the use of taxes to achieve environmental goals by means of 'green taxes', CO_2 tax, vehicle taxes, tax incentives, has been at the centre of discussions. In May, 2001[5], The European Commission has presented a comprehensive strategy for the EU's future taxation policy and a common framework including differentiated rates according to

[5] IP/01/737

environmental objectives was finally set up by the EC in the Energy Products Directive 2003/96/EC that came into force at the beginning of 2004, restructuring the Community framework for the taxation of energy products and electricity.

This EC Directive that came into force on the 1st January 2004, widened the coverage of the Community framework, previously limited to mineral oils, to all energy products including coal, natural gas and electricity and increases the relevant Community minimum rates of taxation. The objective has been to reduce distortions of competition acknowledged between Member States as a result of divergent rates of tax; reduce distortions of competition between mineral oils and the other energy products that have not been subject before to Community tax legislation, to increase the incentive to use energy more efficiently (so as to reduce dependency on imported energy and cut carbon dioxide emissions). Notably the Directive defines exemption regimes, according to a number of principles that include Liquid petroleum gas (LPG), natural gas and methane in specific applications such as public transportation, waste-collection, drain suction and street-cleaning vehicles, reduction in the rate of excise duty on heavy fuel oil to encourage the use of more environmentally friendly fuels.

Policy on biofuels

A very particular case for biofuels in Europe has further determined the adoption of a formal position of EC Policy by means of the Directive 2003/30/EC, envisaging the promotion of the use of biofuels for transport purposes, while meeting goals related to the Common Agricultural Policy, too. But the question of biofuels in transportation tends to divide specialists. Some believe biofuels should be promoted, as the EC did recently. But for other international institutions, like IEA, one should be cautious regarding biofuels, raising questions about what can actually be done and what is the actual potential for a substitution to the extent required in the 2020 targets. Some argue that this will lead to an industrialised, polluting agriculture and insist on the importance of limiting promotion of biofuels to products derived from agricultural practices which are less environmentally harmful and which require less chemical inputs than today's agriculture. Doubts are also expressed about the likely costs of biofuels. Some say that they would be more cost-effectively used for heating than for transport purposes. Others argue that there is a broader range of options available to reduce fuel use in transportation and improve efficiency than those considered in the Green Paper, such as pricing of vehicles and transportation, and tax and technology support to increase energy efficiency. It extols that Member States must ensure that the minimum share of biofuels sold on their markets is 2% by 31 December 2005 at the latest, and 5.75% by December 2010. Any Member State setting lower objectives will have to justify this on the basis of objective criteria. In complement to this specific Directive the previously mentioned Directive 2003/96/EC has incorporated in its Article 16 a provision for Member States to opt for applying a reduced rate of excise duty to pure or blended biofuels, when used either as heating or motor fuel. This directive, unique by its clear support to a specific fuel reflects therefore a strong bet from the EU policy in biofuels to meet decreased energy reliance on external sources and environmental targets. However, it should also be taken into account that current policies related to biofuels in many countries, and particularly in the EU, appear to be driven largely by agricultural concerns, as agricultural policy serves multiple EU objectives. It is therefore questionable whether a strong biofuel policy in Europe will effectively be able to serve fully the EC energy related targets.

Policy on innovative transport

The findings on active EU support to innovative transport, supplementing EC legislative actions, indicated a reinforcement of support for research and technological development, as well as supporting actions carried out to innovate, promote or support renewable energy sources and energy-efficiency in transport. The Community decided to allocate EUR 800 million of the budget for the Sixth Framework Programme of Research and Technological Development, to innovation in the field of renewable energy sources, energy efficiency and clean transport, particularly for public and urban transport (CIVITAS, CONCERTO, CUTE) over the period 2002-2006. These initiatives bring together elements of European transport and energy policy, attracting cities in the EU that have been introducing measures for clean urban transport for many years, assisting cities which are seeking to introduce innovative solutions for developing more balanced and cleaner urban mobility, particularly through the use of substitute fuels, or by greater access to pubic transport. The objectives targeted, are those established by EC policy statements, namely by introducing sustainable urban transport policy strategies, integrating innovative measures, technologies and infrastructures into a single city-wide policy package, developing an attractive alternative to the use of private cars in cities.

The role of EU policy in supporting innovative technologies in urban transport has been discussed along with recent findings of the CIVITAS I and II initiatives regarding procurement of clean vehicles. In this respect, diffusion of technology that might be otherwise closer to the market is hampered by four main obstacles:

1. the lack of appropriate information to buyers,

2. questionable commercial policies (i.e. lack of information to car dealers and poor commercial organisation in certain countries),

3. lack of a single European market,

4. harsh competition between technologies for very small market shares, which renders the conditions for clean vehicles diffusion even more complicated.

A major obstacle preventing diffusion of new technologies remains in the lack of a clear pathway towards its mass production. This same consideration applies to the automobile industry: without e.g. a hydrogen filling system in Europe, manufacturers will not start mass production. And a production of small numbers does not justify the supply network. Recent studies examined the effects of technical change and learning effects on the adoption of renewable energies, emphasizing the importance of institutional commitments to foster learning effects and overcome diseconomies of scale resulting from high fixed costs or market diffusion barriers. In these studies, the role of public support in fostering production threshold at which economies of scale take effect was discussed. In this regard, fossil fuel technologies are generally seen to have smaller potential for learning-by-doing and consequently smaller potential for cost reductions given that these sectors are already mature relative to renewable energies.

Future EU policy

Further EC policy developments are expected regarding the urgent need for short-term action on emissions, in particular in urban areas. Regarding CO_2, this is considered to be the most persistent and most urgent long-term problem for the transport sector, not able to be fully solved by existing policies alone. To this end, improvements of current vehicle technology offer the prospect of the introduction of near-zero emission passenger vehicles in the medium term. To reach such a target it is necessary to mobilise oil energy supply concerns as a supporting driver for CO_2 reduction, since both challenges largely call for measures of a similar type. But there is no single solution to solving the CO_2 problem; all routes under discussion will be needed to achieve the goals.

Hence, fuel taxes will probably need to be further differentiated targeting the promotion of 'cleaner' fuels (like unleaded petrol in the past) or low-sulphur diesel, biofuels, natural gas (at present). The aim is to comply with the stringent EU standards, helping to reduce NOx, PM10, and CO_2, although sometimes at the expense of extra production costs and refinery emissions (for oil based improved / desulphurised fuels).

Fuel tax seems to be the only pricing instrument used throughout the EU that is related to vehicle usage. Road pricing schemes are also related to vehicle usage, but until now their application is limited to motorways in some Member States and to very specific road parts in some urban areas. Therefore fuel taxes are still seen as the most efficient instrument currently available, not only for internalising social costs linked to the use of vehicles, such as infrastructure costs, accident costs and air pollution costs, but also to promote cleaner fuels and alternative energy sources in transportation. Notwithstanding, some studies have shown[6] that despite the fact that fuel demand is quite elastic making fuel taxation the best way to reduce fuel use, it seems almost impossible to do so, particularly in those countries with low prices and high demand. There are indeed great difficulties in raising fuel taxes. One of the reasons for the difficulties is that political pressure influences the decisions regarding taxation of fuel consumption. Not only low taxes and thus low prices encourage high consumption, but high levels of consumption also lead to considerable pressure against raising the taxes.

Faced with these challenges, the EC's post-Kyoto strategy must therefore offer a clear and inspirational long-term perspective to promote innovation by means of an ambitious framework to develop a new breed of cleaner vehicles, including the definition on the role of the transport sector and the most effective steering mechanisms to secure this goal. Governments, industry and consumer organizations should shoulder their responsibilities to support market uptake of clean low carbon fuels and vehicles, and close the loop between product development, policies to encourage take up, and consumer demand. At the same time, industry will need to adopt an offensive strategy, produce clean low carbon vehicles that consumers want to buy under favourable fiscal frameworks, and use their marketing experience to influence consumer choice. There is surely a need to market more energy-efficient power trains, climate neutral (bio-)fuels, further reduce vehicles' air, road and transmission resistance and weight, promote a more energy-efficient driving style (supported by in-car devices), traffic management to improve traffic flow, and innovations in logistics and freight demand management.

So far the EU-instruments to reduce CO_2 emissions from passenger cars have been largely depending on the voluntary agreements with the car industry. This approach will be continued, but it needs to become more ambitious if emissions are to be reduced effectively.

Although market mechanisms should have the lead, EU policy will seemingly play a key role in kick-starting markets by supporting entrepreneurship and taking leadership in shifting cultural and social attitudes, by means of:

- Developing information policies (including CO_2/energy efficiency labelling);

- Developing fiscal incentives and/or subsidies, and working on convergence and harmonization of fiscal incentives and policies, including the full use of the technological

[6] Hammar et al, 2004

capabilities of the GALILEO, associate GPS location features and a standardised generation of on-board units, to an adequate pricing strategy in order to enhance effectiveness of the EU policies on transport, energy and environment;

- Adopting the policy of green purchasing and taking the lead in developing initiatives to create sufficient early market volume by taking part in buyers consortiums, introducing clean low carbon vehicles in urban public fleets and company fleets, and taking an exemplary role by ensuring that government fleets will be leading in this.

Cities seem to be in a privileged places to kick-start markets for clean low carbon vehicles, promoting e.g. joint procurements for clean buses or other fleet vehicles, using the possibilities for controlled competitive tendering of public transport and fleets to incorporate environmental and social requirements. Such measures should also consider privileges for clean low carbon vehicles in cities, such as free access to low-emission zones and exemption from road charging where applicable, that is actually consistent with fiscal incentives and subsidies;

The EC's post-Kyoto policy strategy must therefore offer an inspired long-term perspective to promote innovation by means of an ambitious framework supporting a new breed of cleaner and more efficient vehicles.

1.6 Policies on transport and energy in Member States

Although transport and energy policy among the EU-25, plus EEA countries analysed, do share common concerns, the extent to which related measures are actually implemented is often related to the availability of public funding and can differ substantially. Most countries already comply nearly entirely with the existing EU Directives. However, some of the new member states are still in a process of transposing the Directives into national legislation. The lack of coherence between energy policy statements and the actual promotion of sustainable patterns regarding public transport usage in a number of New Member States show that there is still work to be done in these countries to foster the ‘sustainable rationale’.

Policy on innovative transport

Regarding the adoption of innovative vehicle technologies**,** there are many incentives taking place in the area of sustainable transportation, mostly based on financial incentives such as tax breaks for users of clean technologies and direct support to public transport companies. Additionally, some governments also give subsidies to the industry in order to develop new methods or to support new infrastructure. Yet, some countries, mainly among the New Member States, present still few specific initiatives in this direction and those which exist are mostly concentrated in major cities and capitals. Many initiatives have already been taken in Europe regarding innovative technologies, such as CNG-powered buses, hydrogen-powered buses, electric vehicles and biofuel, among others. The CNG-powered vehicles, mostly in captive fleets but also increasingly in private vehicles in countries like Germany or Italy, are operational in all considered countries, except perhaps in a few countries such as the UK, Hungary, Cyprus, Malta. On the other hand, electric vehicles and hybrids are more and more popular in almost all countries. However, electric still account for most cases, as hybrid are only now becoming more available, in result of recent trends in this technology. Biofuel is being strongly supported by the EC and therefore its adoption blended with diesel, in promptly adjustable conventional diesel vehicles, has been gaining ground, notably in France, Sweden, UK, Germany, Denmark, Norway and Austria.

Vehicle taxation

Vehicle taxation policy tends to be very different, which represents an obstacle for what could become an interesting convergence towards taxation regimes focused on energy and environmental criteria at EU level. In this respect, it becomes clear that in all countries where energy and environmental concerns are at the core of the taxation rationale, both acquisition and ownership taxes tend to be relatively high.

At the other end of the spectrum are countries like e.g. Portugal or Greece, where taxation levels tend to be strongly tied to tax revenue on acquisition. As motorization growth rates in these countries are flattening, the trend will be to transfer vehicle taxation to ownership, bringing greater stability in terms of tax revenue as well as flexibility to incorporate energy related policy criteria, such as energy consumption, type of fuel, age, etc. As a tool to condition and drive technological choices, combinations of acquisition and ownership taxes are likely to have the greatest effect. Denmark is a good example of this policy.

1.7 Worldwide Outlook

In the United States all cars and light trucks there are today at least 96% cleaner compared with vehicles produced in the 1960s. By 2009, expectations are that they will be 80% cleaner than they are today. All new cars sold nationwide in the year 2001– approximately eight million vehicles –met voluntary National Low Emission Vehicle (NLEV) standards. While cars and light trucks currently produce about 25% of smog-related emissions in major United States cities, this proportion should drop to 20% by 2005. The most stringent legislation on motor vehicle emissions can be found in California, where the Zero Emission Vehicle (ZEV) mandate, requiring a certain percentage of vehicles to comply with zero exhausts emissions (ACEA, 2004a).

Regarding hydrogen, industrialised countries with a desire to reduce the dependence on foreign supplies of carbon fuels or those which have the potential to produce cheap renewable electricity have been most prominent in the investment in hydrogen and fuel cell technology, namely USA, Japan and Canada. In most EU countries., with the possible exception of Germany in Europe, the investment in fuel cell technologies and plans for greater hydrogen use is generally not as advanced as in the US and Japan. However, due to the increased reliance on fuel supplies from potentially unstable countries previously mentioned and the commitments to reducing greenhouse gases, the EU is becoming more interested in developing a hydrogen economy from renewable sources as part of their energy strategy, underscored by the EC funded project CUTE.

Also the issue of biofuels is giving rise to increasing interest among the scientific community worldwide, reflected in a series of studies undertaken recently. One of these studies commissioned by IEA (2004a) compared international aspects of biofuels for transports. The most recent biofuels related decisions in some areas of the world are the following:

- US: legislation still pending that could increase ethanol use by 2010 to around 5% of gasoline; strong price incentives already in place;
- India: 5% ethanol blending required in some regions; eventually whole country;
- Latin America: new production initiatives in many countries; export orientation;
- Many other countries have recently announced various incentives and targets.

As a comparison, the EU is targeting at a share of 5.75% of the total motor fuel use by 2010.

In most countries, conventional biofuels (ethanol/grains, biodiesel/FAME) may provide 5% of motor gasoline/diesel fuel without major disruption to other crop production markets. To this extent it should be considered that biodiesel is much more land-intensive than ethanol. It is estimated that above 5%, competition for crop use in many countries may introduce some impacts on crop prices. The expected key factors for any such analysis are future transport fuel demand, ethanol v. biodiesel production, biofuels efficiency impact on vehicles, especially for ethanol, whose average effects are still not documented thoroughly. Yet, the global biofuels production potential appears substantial, as studies suggest that global technical potential for biomass production is perhaps half or more of transport fuels estimated in the 2050 time frame (IEA, 2004b). Just ethanol from sugar cane grown in developing countries might provide 10% globally by 2020, probably at very low cost. Thus, given strong potential for large volume, biofuel production in countries like Brazil and India and global trade in biofuels matching stronger fuel demand in OECD countries and China, could benefit all.

The general conclusions of this report on the worldwide panorama on biodiesel suggest that biofuels use is growing rapidly. Policies aiming at promoting biodiesel are increasingly aiming at favouring production costs, encouraging development and crop's production. While most biofuels will be produced at each country level, resorting to imported biofuels would have global benefits, as the development of trade in biofuels would benefit several countries. Yet, further understanding on biofuels costs and benefits is required along with better knowledge on global production potential and characteristics of biofuels produced, specially in developing countries (IEA, 2004a).

1.8 The car manufacturing industry

Regarding the evolving car manufacturing context, today, car manufacturers face worldwide pressure for greater environmental compliance and part of the challenge lies in anticipating policy trends and market demands, supporting its strategic positioning with respect to technological pathways to follow. The challenge for vehicle manufacturers today is about making winning bets on technology, at high risk. The emerging strategies that each car manufacturer adopts along the way will therefore play a crucial role in this process, enabling its prompt adaptation to market trends, e.g. by keeping technological options open.

But while car makers have indeed increased their technological capacity, productivity and competitiveness, the conditions in which they operate have worsened, and the overall economic context is challenging. Despite its fundamental impact on modern society in both economic and social terms, the car industry is characterised by declining average profit margins, from more than 20% in the 1920s to around 10% in the 1960s and less than 5% today. The ability of the car industry to invest and deliver alternatives into the mass market, is to some extent constrained by the costs it involves. At the same time, there is an ongoing shift of knowledge from the greater manufacturers towards suppliers, who play an important role in the development of new technologies regarding components, yet with no participation in the development of engine design itself. A modern car making plant actually manufactures virtually nothing; it only assembles and puts together parts it receives which have been manufactured elsewhere. The manufacturing process as such is carried out externally by a broad range of different ancillary companies, making parts and components.

Altogether, these are some of the core issues that characterise the current context to which car industry is subject, in view of analysing any sort of fundamental change in the nature of energy supply sources and transport related technologies.

1.9 The Oil industry

A reasonable consensus seems to exist that, unless a new prolific oil ground like the “Middle East” is found soon enough to get its production into the market (usually about 5-10 years), the world production based on actual known reserves will peak within the next decades accompanied by rising costs. In a world relying on oil up to 88 % this means also that the oil industry has an increased interest in developing alternatives to oil, and recent years seems to prove that view, forced by the notion that the dawn of “endless oil” age may take place within the typical timeframes considered in conventional investment analysis.

As a key stakeholder in the current and historical context, the Oil Industry will have necessarily a very peculiar perspective regarding the sort of structural changing suggested by the current prospects on the future of energy supply to the transportation system. There will still be opportunities allowed by their privileged positioning in the energy market and, again, smashing prevalence in the ‘mobility market’, enhancing the ability to adapt successfully to whatever reality might emerge from the current uncertainty about the future. Indeed, several Oil Companies have been going all along to the point of taking active part in pilot tests for new alternative technologies and fuels. Withholding significant financial and human resources, these companies are getting increasingly involved in research and development of new solutions in transportation. This promotes comfortable awareness and involvement levels helping to set up more sound strategic orientations. Along this process, also adjustments are expected to occur within the oil sector itself as, in time, classical cooperation strategies in the oil sector may become subject to stressful individual and less cooperative attitudes. Indeed, a new arena for energy supply to mobility applications may arise where several fuels and primary sources may be considered. Newcomers will eventually be present, possibly reshaping the classical setting of energy supply to transports.

In this new context, individual attitudes of oil companies betting on attaining leading positions might come to influence the adoption of clean technologies in transportation, shifting part of the oil business’ revenues to take stakes in alternatives and triggering a faster pace development in emerging powertrains technologies. This possibility is supported by several studies and oil business consultants such as Woodmackenzie (2003), defending that the oil business upstream business is already becoming a difficult one, despite high oil and gas prices. Strong cash flows have given many companies large cash balances but not all have enough good investment opportunities. Hence, the challenges of the future regarding investment strategies may need to adapt quickly.

Delivering good return on capital is always a challenge for the oil industry stakeholders.
But as most such companies are expected to have significantly more cash than they can promptly reuse in their core business, the diversification of the Investment portfolio management will play a role as companies acquire stakes in emerging energy markets, possibly bringing along the sort of favouring context needed to lay the foundations of a new energy supply systems to transportation.

1.10 Some conclusions

Regarding the state-of-the-art in transport technology, it is the internal combustion engines that represents the most experienced technology so far and are essential in any analysis to 2020. But a number of alternative solutions are already on the market, some of them offering significant benefits in terms of carbon emissions, energy consumption, and local air quality. Yet, their advantages are often offset by primary energy feedstock shortage, lack of convenient supply infrastructure, cost, or all these together, plus aspects such as safety and reliability misperceptions. Such options include natural gas, blending of biofuels in modern ICE engines, hybrids, electric and fuel cell vehicles. Considering the potential offered by new technological developments, the current overwhelming reliance of the car industry on internal combustion engines, seems odd and can be justified by low production costs and circumstantial low cost of fuels rather than to a consensual acknowledgement that ICE based on fossil fuels represent a sustainable option for the future. In the meantime, several factors suggest that even with improving internal combustion engine technology, a transition will occur to electric-drive technology. These include intensifying calls for cleaner, more energy efficient and lower greenhouse gas emitting vehicles, rapid innovation in lightweight materials, energy storage and conversion, power electronics, and computing.

Regarding the state-of-the-art in alternative fuels, while common ICE technologies depend on oil as energy source for fuelling, several reasons contribute to moving on to innovative solutions bringing decreased carbon content, thus less CO_2 emissions, and as much as possible decreased geo-political dependence. This would not only render the transportation sector less oil-dependent contributing to reduce transportation reliance on oil imports, but also promote better environmental compliance, fulfilling the long term trend towards decarbonisation of fuels.

Regarding the development of new policies, we have seen that there is growing lnk between fossil fuel dependence and a general energetic dependence of the developed countries on oil and the political turmoil that currently characterises Middle East, Caucasus and Central Asia. Driven by such concerns, the topic of energy in transports systems have become a major issue on the political agenda, not only in the EU but also in the rest of the world. However, alternatives to address this fundamental problem are still hampered by economic and technical obstacles. This situation is further biased due to the fact that energy prices for conventional fuels do not always reflect its objective full cost, accounting for the externalities and the cost of securing energy supply.

The state of the art in EU policies point therefore at a combined effort on short-term action on regulated emissions, in particular in urban areas. Regarding CO_2, this is considered to be the most persistent and most urgent long-term problem for the transport sector, not to be solved by existing policies. In view of this, the policy trends aim at eliminating transport as a major source of CO_2 emissions., favouring, improvements of vehicle technologies that offer the prospect of the introduction of near-zero emission passenger vehicles by 2015. To this end, there is an urgent need to mobilise also oil energy supply concerns as a supporting driver for CO_2 reduction, since both challenges largely call for political measures of a similar type.

Yet, there are essentially two types of barriers against the adoption such inspiring policy options: economical and political. Economical barriers are nearly always budget restrictions. Political barriers usually imply that politicians are not interested, at least at some point in time, in putting the item on the political agenda. Lack of institutional synchronising of efforts may also hinder the full realisation of transport-energy policy-guidelines.

Since the rationale for government support to deployment programs is that technologies need market experience to reach commercial maturity, pilot initiatives are crucial to foster the development of commercially viable products. To this end, several options are available, from e.g. limiting through heavy taxation of transport usage to subsidising and promoting state-of-art technologies into the market. Governments have therefore a privileged role taking the lead in adopting new, cleaner fuel-efficient technologies, through e.g. public transport operators. Next to measures and incentives to the deployment of cleaner vehicles and technologies, also ‘soft measures’ can bring interesting results providing an insight on current positioning of Member States to that respect. The importance of such initiatives and their potential to have an impact in the ongoing changing process is seen as an important signal that countries are actively engaged in the innovation process, either through technological implementation or by means of energy and mobility demand strategies such as e.g. voluntary Transport Energy Saving Agreements or modal shift from air transport to high speed rail.

The observed trend is that more and more initiatives are being undertaken in Europe to move towards more efficient and sustainable energy use for transportation, but that the implementation paths towards this goal show some variety. Until there is a major breakthrough in energy supply for vehicles that clearly shows the way in which transport will have to develop, this diversity is bound to remain – which is a barrier to implementation on the one hand, but a source of new creative solutions on the other. Most implemented projects are driven by a need to improve air quality in cities. As cities have the highest pollution levels and also the highest number of people exposed to pollution, it is a logical starting point to introduce clean transport means. The trend is for activities undertaken to create new transport energy consumption markets. But in many cases this trend is still in its experimental stage.

Government initiatives and government investments seem therefore necessary to start such projects. The role of public funding is more one of acting as catalyser, rather that in full support of the initiatives. Obviously this is not the case of e.g. fuel cells and therefore pilot initiatives in this respect are worthy mostly for the pioneering interest they reveal and for the public awareness value they contain.

Although long-term goals at EU level seem to be shared in terms of environmental impacts and worrying reliance of oil, several situations underscore that accomplishment levels are different and that several obstacles need to be overcome before massive adoption of one or the other technology or measure takes place, such as developments on the current energy supply infrastructure of alternatives.

Finally, overall conclusions suggest that policy making will face great challenges in the next few years, a crucial period to prepare and shape the next decade in terms of deeper energy-transport structural changes. Indeed, the EC's post-Kyoto policy strategy will need to deliver a clear and inspirational long-term perspective to promote innovation by means of an ambitious framework, covering all transports modes, but specially road transportation. Policies adopted elsewhere, namely USA and Japan will also play an important role, as together with EU policy they have the potential to set the stage for a deeper change in the global transportation technology solutions and active energy supply sources research. In other words, the challenges will be not only to consider what we know already today, but also what might result from influencing key drivers such as growing evidence of climate change consequences, including in the economy itself, or rising oil prices in result of a possible shift from a mild demand driven context to a more severe oil supply driven context.

By acknowledging the existence of worrying signals regarding conventional energy availability and severe environmental consequences, underscored by key international organisations, it seems advisable to assume that all the conventional continuity trends and business as usual perspectives on the topic of energy supply to the transport system and its inherent technology should deserve careful reconsideration, as all evidences point at a significant worsening of both technical and economic energy supply conditions to transportation, with the potential to trigger some important changes in the technological character of transportation, in particular road modes.

CHAPTER 2: Transport trends and their energy implications

2.1 Introduction

The development of scenarios for estimating future energy needs in the transport sector requires the identification of factors affecting energy use by both freight and passenger transport. In doing so, it is necessary to view energy use from a broad perspective encompassing the overall political, socio-economic and technological environment. This chapter examines the relationship between transport and energy use, and the impact of the broader socio-economic, political and technological environment on the evolution of this relationship.

The objective of this chapter is threefold:

- To present a detailed overview of the political, economic, social and technological drivers that are prevalent in spatial development, energy use, freight transport and passenger transport.
- To identify and describe future trends in freight and passenger transport, and to link the trends with the drivers of the political, economic, social and technological (PEST) environment.
- To identify indicators expressing the impacts of the identified trends on the utilization of the freight and passenger transport system, and the associated energy use.

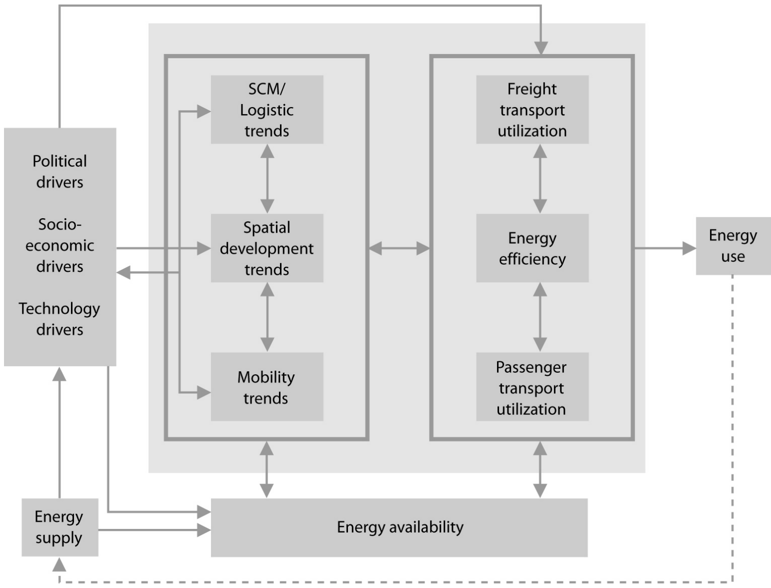
The trends and indicators which are identified in this chapter have been used to compile the scenarios used in the STEPs project for the assessment of the future transport and energy supply system. These scenarios are described in the next chapter of this book.

The rest of this chapter is structured as follows. Section 2.2 presents the methodological framework for identifying the factors drivers affecting energy use in transport. Section 2.3 focuses on the application of the methodological framework on the analysis of energy use in the freight transport sector, while Section 2.4 does the same for the passenger transport sector. Finally, Section 2.5 summarizes the results to assess the impacts of identified trends.

2.2 Methodological framework

The analytical framework illustrated in Figure 2-1 aims at identifying the factors affecting the use of energy in transport. This framework takes into account the influence of energy supply and availability, as well as the influence of the broader socio-economic, political and technological environment. The PEST environment affects energy use in transport: i) *directly*, through its impact on the freight and passenger transport systems and ii) *indirectly*, through its impact on the spatial development, supply chain and mobility systems. The spatial development trends emerging from changes of the broader PEST environment and the availability of energy influence energy utilisation through their impact on the structure of the supply chain and mobility systems.

Figure 2.1: Conceptual framework for identifying factors affecting energy use in transport



The PEST environment is described through the three respective categories of drivers:

- **Political drivers** refer to policy initiatives that are translated into specific measures through the appropriate policy-making process. For instance, political drivers influence the mix of energy resources that will be utilised in order to satisfy energy demand.

- **Socio-economic drivers** describe general economic and population characteristics, such as population demographics, behaviour of basic macroeconomic indicators, and consumers' preferences. For example, an increase in population or in the gross domestic product (GDP) of a country has a direct impact on energy consumption and consequently on the availability of energy.

- Finally, **Technological drivers** refer to the technological achievements that influence the organization of economic activities, and affect the spatial development, supply chain, and mobility systems. For instance, technological advancements may lead to the production of vehicles that are more energy efficient.

The logistics and supply chain management (SCM), land use and spatial development, and mobility trends identified by the PEST analysis affect the planning, organization and implementation of freight and passenger transport activities. Logistics and SCM trends influence the organization and development of the freight transport system (Zografos and Giannouli, 2002), while mobility trends influence the organization and development of the passenger transport system. Emerging spatial development patterns influence both freight and passenger transport. Land use and spatial development patterns affect the organization and development of the freight transport system and determine passenger mobility needs. On the other hand, the organization and structure of the freight and passenger transport system reciprocally affect spatial development and land use patterns. Freight and passenger transport use in relation to the prevailing energy efficiency trends in turn generate new energy use patterns.

2.3 Trends affecting energy use in freight transport

Analysing freight transport energy use: a conceptual framework

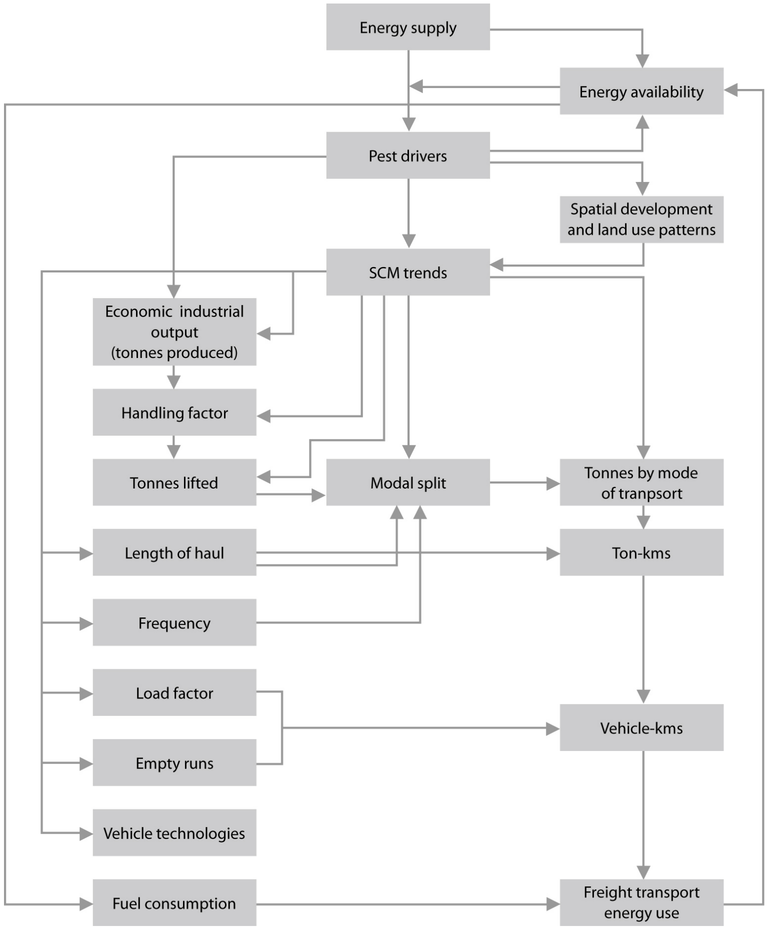
Total freight transport energy use is determined by total freight transport output measured in vehicle-kilometres and fuel consumption per vehicle-kilometre. Fuel consumption per vehicle-kilometre (efficiency) is determined by the vehicle technology used which in turn is influenced by the political, socio-economic, and technological environment. Specifically, the fleet composition (in terms of age and type of vehicles used) is influenced by the availability of alternative vehicle technologies and their cost, the existence of market barriers, the availability of fuel supply infrastructure, and the provision of incentives/disincentives for the adoption of alternative technologies.

On the other hand, total freight transport output is the product of the demand for freight transport services measured in tons transported and the length of haul. The demand for freight transport services is affected by the production output of a supply chain measured in tons and the handling factor. The handling factor expresses the number of times goods are transhipped within a supply chain. The handling factor is influenced by the spatial organization of the supply chain. For instance, vertical disintegration of production and outsourcing contribute to the increase of the handling factor. The length of haul is influenced by the spatial distribution of economic activity, which is affected by the globalization of the economy, regional development policies, and the spatial organization of the supply chains, e.g., spatial concentration of production and warehousing and distribution activities, and geographical distribution of sourcing and distribution.

The total freight transport output can be translated into vehicle-kilometres through the use of the load factor, which is expressed as the ratio of the vehicle's total carrying capacity in tonnes to the actual weight carried. The load factor is affected by transport policies (e.g., deregulation of transport services, which has accelerated the provision of third party logistics), and environmental policies (e.g., recycling, which has contributed to the emergence of reverse logistics).

The conceptual framework for analysing freight transport energy use is illustrated in Figure 2-2.

Figure 2.2: Conceptual framework for analyzing freight transport energy use



The preceding discussion suggests that the development of scenarios for assessing energy use in freight transport should consider the broader PEST environment, freight transport system utilization, fuel consumption and supply chain organizational trends.

Drivers affecting freight transport trends

Several drivers of the political, socio-economic and technological environment affect the development of supply chain organization trends (Zografos and Giannouli, 2001).

With regards to the **political environment**, the following drivers were identified:

- Fiscal policy, related to the provision of financial and tax incentives for the location/relocation of economic activities, and the provision of incentives or disincentives towards the use of certain fuel types (e.g. through the imposition of taxes and excise duties on fuels).

- Transport policy, regarding measures for opening up the transport markets for competition through the gradual abolishment of state intervention, and the removal of regulatory barriers.

- Environmental policy, which concerns the design and implementation of policies for the regulation of the environmental performance of transport activities, as well as issues regarding the recycling and re-use of materials and product components.

- Energy policy, which concerns the regulation of energy use and availability for various economic activities including freight transport.

- Land use policy, which concerns the regulation of the allocation of land to different types of human activities.

- Regional development policy, which concerns the regulation of the development of the spatial distribution of human settlements at regional level, and the transport connections between them.

With regards to the **socio-economic environment**, the following drivers were identified:

- Globalisation of economic activity.

- Level of economic activity, measured through the evolution and actual value of the GDP (WS Atkins, 1999).

- Increase in residential and employment density. Mixed-use, high-density urban districts generate less and shorter delivery trips. Low-density residential areas lead to more and longer delivery trips (Wegener and Fürst, 1999).

- E-commerce, affecting the number of freight transport vehicle trips generated by orders placed through the Internet and by dematerialisation of products which can be received electronically.

- Spatial distribution of economic activity and population, which concerns the distribution of human settlements, and the distance between them and economic activity.

- Prices of fuels, which may send signals to consumers for turning to different fuel types. For instance, targeted incentives might increase the adoption of advanced technologies in freight transport.

- Market potential for fuel types. Market potentials for various fuel types, such as gaseous and alternative fuels, biofuels and LPG seem very promising. Other fuel types are still in preliminary phases of development and need to resolve crucial issues before they can demonstrate a sound market potential (e.g., hydrogen / fuel cells, electric and hybrid vehicles). The most significant barriers that have to be overcome relate to information availability for potential investors, fuel supply infrastructure, and lack of common European standards.

- Market penetration of alternative vehicle technologies and respective market barriers for introducing such technologies.

- Fleet composition, which mainly addresses the utilization of alternative vehicle technologies.

With regards to the **technological environment**, the following drivers were identified:

- Energy efficiency (average vehicle energy consumption): for most European countries there is a relative decrease of the specific consumption, which reflects a slight improvement in the overall energy efficiency of trucks. The average for the European Union has decreased from 33 l/km in 1985 to 31 l/km in 2001, yet ranges across countries vary from 22 to 38 l/km (EC, 2004b70). In OECD countries energy consumption has followed a strong upward trend between 1984 and 1994, increasing by 27%. Specifically, transport has become the dominant oil-consuming sector and its share in oil consumption is expected to increase by approximately 20% between 1996 and 2020 (OECD, 1996).

- Vehicle technologies, with emphasis on technological advancements for vehicles demonstrating lower consumption and emissions.

- Information and communication technologies (ICT): ICT, and especially e-commerce, can cause a net reduction in the freight movement due to the dematerialisation and electronic distribution of certain products. Moreover they can increase the efficiency of freight transportation and distribution through the potential they provide for optimizing freight transportation and distribution operations.

- Development and availability of fuel supply infrastructure.

Influence of PEST drivers on freight transport trends

The influence of PEST drivers on supply chain organization trends and the impact of SCM trends on the utilization of the freight transport system are discussed below (REDEFINE, 1999; SULOGTRA, 2000; Zografos and Giannouli, 2001; 2002).

Spatial concentration of production is affected by fiscal policy, which influences the location/relocation of economic activities, as manufacturers may select to locate production activities in such a way as to better exploit fiscal incentives. This results either in net reduction of the total number of plants or in greater specialization of plants. Spatial concentration of production is also affected by land use policy and regional development policy, as changing land use patterns and regional development incentives may facilitate the relocation and reduction of the number of production activities. Spatial concentration of production primarily affects the length of trips and vehicle utilization.

Spatial concentration of warehousing and distribution activities is also affected by fiscal policy, land use policy and regional development policy, as these drivers influence the decisions regarding the location of stock holding facilities. The resulting product flows among production sites and stock holding facilities should be accommodated by an effective and flexible transport system. Centralization of warehouses occurs at a larger geographical scale, e.g., European Union, as firms take advantage of the development of the common European Market, the removal of frontier controls, and deregulation in the various transport modes. The spatial concentration of inventory affects the length of trips and vehicle utilization.

Wider geographical distribution of goods is influenced by the globalization of economic activity and changes in transport policy, enabling manufacturers to expand the geographical scale of their production and distribution activities from national scale to a continental and global scale. Electronic commerce also enables manufacturers to expand the geographical scope of sourcing and distribution activities. Wider geographical sourcing and distribution primarily affects the length of trips.

Vertical disintegration of production / outsourcing: globalization of markets may create opportunities for manufacturers to exploit local conditions and incentives regarding the cost of new materials and labour. As a consequence we observe a vertical disintegration of production and a trend towards outsourcing of production activities to third parties. This affects the number and length of trips.

Direct deliveries: the increasing need for customized production to cater for the changing and specific needs of customers leads to an increase in the number different products and subsequently the warehousing levels and stockholding requirements. In order to cope with these requirements and maintain a high level of service, manufacturers tend to utilize direct deliveries. This trend has the potential to have dramatic effects on freight movement patterns, as it is significantly affected by mass customisation and the rapid growth of e-commerce. Direct deliveries influence the number, length and frequency of trips, as well as the utilization of freight vehicles.

Nominated day deliveries: manufacturers may “force” customers to adhere to a specific ordering and delivery timetable. Nominated day deliveries are increasing and are expected to continue to increase as suppliers can achieve higher levels of load consolidation, and reduce density and vehicle utilisation. The resulting reductions in traffic levels can be significant. Increase of nominated day deliveries on the freight transport system influences the number, length and frequency of trips as well as the utilization of freight vehicles.

Reverse logistics: increasing environmental concerns and regulation of energy use in economic activities are the main drivers affecting the trend towards reverse logistics activities, as end-of-life products and waste are returned for recycling and re-use, or are re-used as raw material for energy production. In the developed countries, the percentage of waste products sent for disposal at local landfill sites is diminishing, affected by the ever-stricter regulations on environmental protection. Increase of reverse logistics operations affects the number and frequency of trips, as well as the utilization of freight vehicles.

Development of break/bulk transhipment systems: break-bulk transhipment systems are developed in proximity to the end markets which they serve. This structure enables manufacturers in a two fold manner:

- to capitalize on the economies of scale incurred by the mass transportation of products from the production facility to the break-bulk facility, which are usually at large distances.

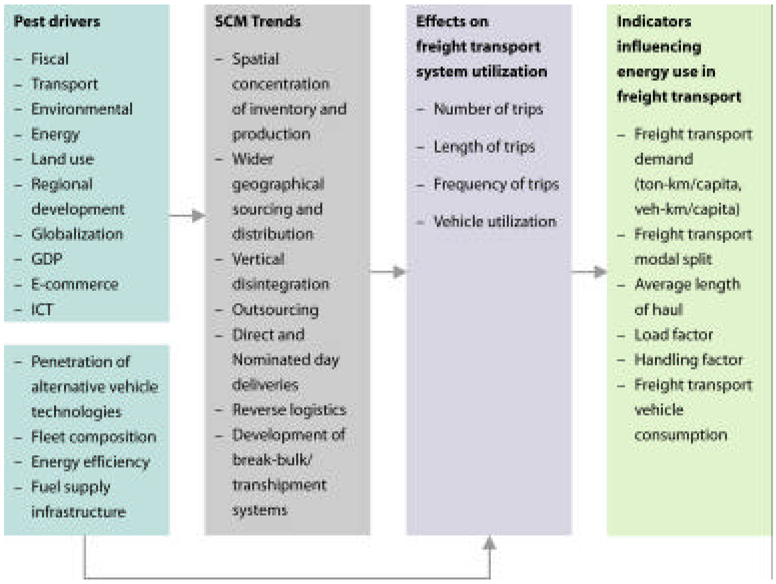
- to capitalize on the savings from the concentration of the warehousing facilities and from the small-sized consignments to end markets that can be effectively served by break-bulk facilities.

The trend in break-bulk freight flows is towards smaller shipments at a national level, and larger shipments at a European and global level. Its impact on the freight transport system characteristics is on the number, length and frequency of trips.

Defining freight transport indicators

Figure 2.3 summarizes the impact of SCM trends on the indicators expressing freight transport system utilization.

Figure 2.3: Relationship between SCM trends and freight transport utilization



The freight transport utilization characteristics analysed above can be quantitatively represented by the following **indicators**:

- Freight transport demand (ton-km/capita, veh-km/capita)
- Freight transport modal split
- Average length of haul (Euro-CASE,2000)
- Load factor (EEA, 2001; McKinnon,2003)
- Handling factor (Cool, 1997)
- Freight transport vehicle fuel consumption

The corresponding analysis of energy use in the passenger transport sector is presented in Section 2.4.

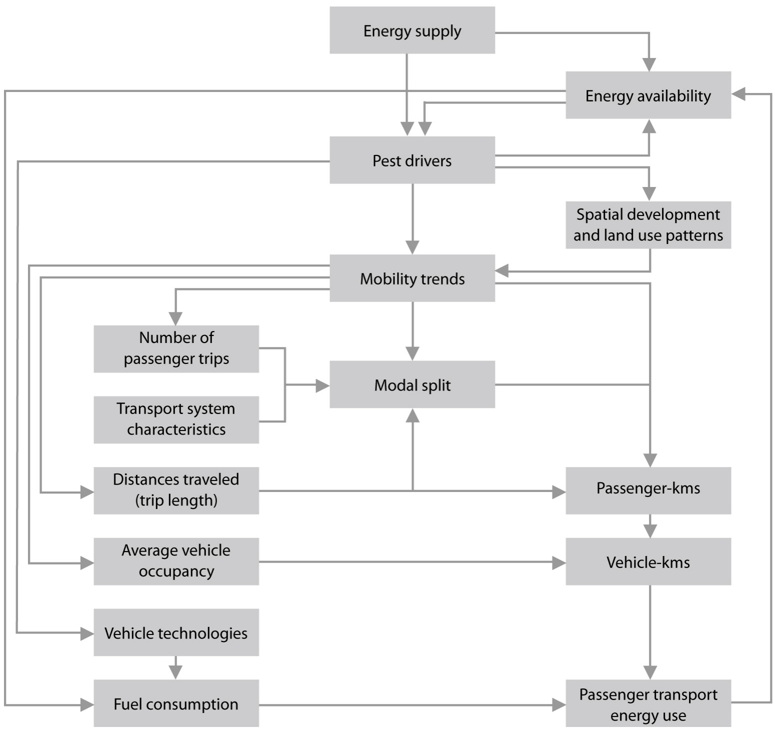
2.4 Trends affecting energy use in passenger transport

Analysing passenger transport energy use: a conceptual framework

Passenger transport energy use is determined by total passenger transport output measured in passenger-kilometres and fuel consumption per vehicle-kilometre. Fuel consumption per vehicle-kilometre (efficiency) is determined by the vehicle technology used, which in turn is influenced by the political, socio-economic, and technological environment. Specifically, fleet composition is influenced by the availability of alternative vehicle technologies and their cost, the existence of market barriers, the availability of fuel supply infrastructure, and the provision of incentives/disincentives for the adoption of alternative technologies.

The total demand for passenger transport (expressed in passenger-kilometres) depends on the income of citizens, on the spatial organization of economic activities, and on land use. The total demand for passenger transport can be translated into vehicle-kilometres by taking into account the modal split and the average vehicle occupancy, which is expressed as the ratio of the vehicle's passenger carrying capacity and the actual passengers carried.
The modal split expresses the percentage of passengers using each transport mode. The modal split is affected by car ownership and use, quality of services offered by the alternative transport modes, and cost of using alternative transport modes. The number of passengers using transport services can be translated into passenger-kilometres through the use of average trip length. The average trip length is determined by the spatial distribution of economic activity, which is determined by land use and spatial development.
The conceptual framework for identifying passenger transport energy use determinants and indicators is illustrated in Figure 2-4. It is apparent that there are strong similarities to the respective framework for freight transport.

Figure 2.4: Conceptual framework for analysing passenger transport energy use



The preceding discussion suggests that the development of scenarios for assessing energy use in passenger transport should consider the broader PEST environment, mobility trends, passenger transport system utilization trends and fuel consumption trends.

Drivers affecting passenger transport trends

Several drivers of the political, socio-economic and technological environment affect the development of mobility trends.

With regards to the **political environment**, the following drivers were identified:

- Transport policy, including measures related to the deregulation of transport markets and the opening up for competition.

- Fiscal policy, which concerns the provision of fiscal incentives for use of particular energy types or sources, or imposition of barriers to useful of more environmentally harmful fuels. Incentives and barriers are usually achieved through taxation and exercise duties in the energy and transport sectors.

- Energy policy, which concerns the regulation of energy use and availability for various economic activities including passenger transport.

- Land use and spatial development policy, which concerns the location of residential developments and economic activities.

- Environmental policy regarding the design and implementation of policies for the regulation of the environmental performance of transport activities.

With regards to the **socio-economic environment**, the following drivers are identified:

- Globalisation of the economy.

- E-commerce.

- Level of economic activity, measured through the evolution and actual value of the GDP.

- Prices of fuels.

- Population demographics and social life-styles: there is an overall strong trend towards de-concentration of the residential function, notably resulting in an increase in urban sprawl. This may induce an increase in the use of the private car as public transport services may be scarce in areas with low residential and activity densities.

- Increase in the number and sizes of houses. With growing affluence, suburban lifestyles became more popular and larger houses became affordable. Together with the trend to smaller households this has led to a continuous growth in residential space consumption per capita. This trend has continued until today in all industrialised countries.

- Increase in residential and employment density. Mixed-use high-density urban districts generate less and shorter delivery trips. Low-density residential areas lead to more and longer delivery trips.

- Spatial distribution of economic activity and population.

- Car ownership: car ownership has increased with GDP, and subsequently car use has increased in line with ownership. In 1970 there were 1,562.3 thousand million passenger kilometres travelled by car in the EU-15.

- Market penetration of alternative vehicle technologies and respective market barriers for introducing such technologies.

With regards to the **technological environment**, the following drivers are identified:

- Traffic management technologies: traffic information services might act as a mobility driver to the extent that they may predict or alleviate situations of traffic congestion.

- Vehicle technologies.

- Communication and information technologies (Internet).

- Energy efficiency: average fuel consumption in the transport sector has increased significantly since 1970 and the technical efficiency of light-duty vehicles has improved steadily over the last 20 years.

- Availability of various fuel types.

- Development of fuel supply infrastructure.

- Fleet composition.

Influence of PEST drivers on passenger transport trends

The influence of the PEST drivers on mobility trends is discussed below. This discussion is not exhaustive but aims to highlight the main drivers that influence the development of mobility trends.

Increase in mobility is a result of the effect of numerous drivers, such as increase of income and economic activity, change in social life styles, land use and regional development patterns, increase in car ownership, globalization of economic activity, changing population demographics.

Virtual mobility (tele-shopping, tele-working) replaces actual or potential journeys. The trend is towards increase of tele-shopping and tele-working, supported by the increasing use of the Internet and e-commerce. Virtual mobility is affected among others by the development of communication and information technologies and the growth of e-commerce, the changing life styles, and transport and environmental policies.

Time-space compression / travelling further faster: the trend towards travelling further faster is affected by the development of traffic management, communication and information technologies, energy policy and efficiency in land use and spatial development, increase of income and globalised economic activity.

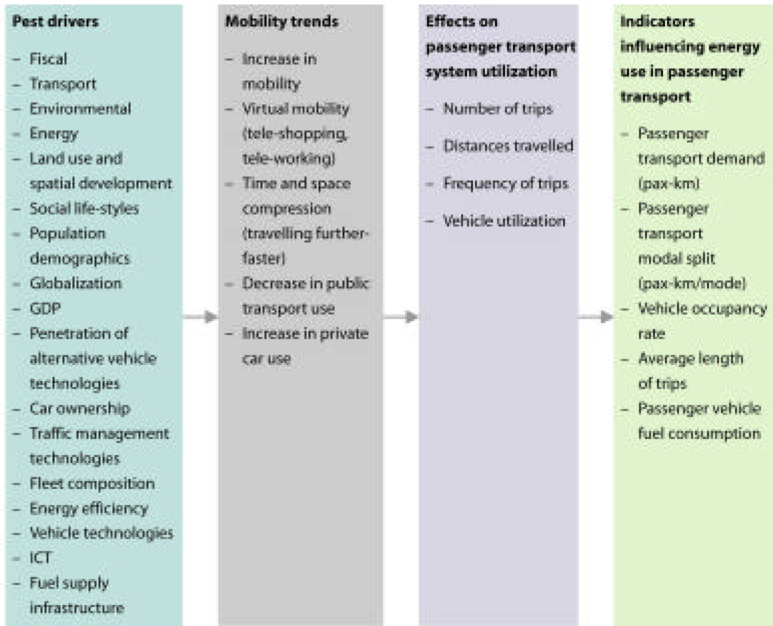
Decrease in public transport use: the ratio of public transport use to car use has decreased substantially over the last 30 years. The decrease in the use of public transport is propelled by drivers such as increasing car ownership, changing demographic patterns, the increase of economic activity and income levels, changing land use and spatial development policies, and expansion of alternative vehicle technologies.

Increase in car use: car ownership has increased with GDP and also car use has increased in line with car ownership. Between 1970 and 2001 private car use (measured in billion passenger kilometres) increased by 142%. Accompanying this increase in car use, there has been a relative stagnation in both walking and cycling and public transport use. The degree to which car use dominates varies between cities, since mode choice is influenced by many issues such as prevailing social norms in terms of attitudes regarding mode choice, weather, topography, availability and affordability of alternatives, and other local factors, e.g., parking provision and pricing. Increase in car use is influenced by land use and spatial development policy, increasing income, population demographics and life-styles, car ownership, alternative vehicle and traffic management technologies, and energy efficiency.

Defining passenger transport indicators

Figure 2.5 illustrates the relationship between the PEST drivers and the mobility trends for passenger transport.

Figure 2.5: Relationship between PEST drivers and mobility trends for passenger transport



The passenger transport utilization characteristics analysed above can be quantitatively represented by the following **indicators**:

- Number of trips produced
- Distances travelled
- Frequency of trips
- Vehicle utilization

The following indicators can be used for modelling the impact of the mobility trends on the passenger transport utilization **indicators**:

- Passenger transport system demand (passenger kilometres)
- Modal split (passenger kilometres/mode)
- Vehicle occupancy rate
- Average length of trips
- Passenger car fuel consumption

Sections 2.3 and 2.4 have presented the results of the analysis of energy use in freight and passenger transport. The final section of this chapter (Section 2.5) summarizes the findings of the analysis and concludes.

2.5 Some conclusions

Trends and their main driving forces

An integrated analytical framework for the identification of factors influencing energy consumption in the transport sector and determining indicators that can quantitatively assess these impacts was developed and implemented. The proposed framework considered political, economic, social and technological drivers that affect the characteristics of the demand for both freight and passenger transportation services, and the energy requirements to service the expressed demand. The results provide an essential input for the development of scenarios for studying the relationship between transport and energy use since they identify the elements of the broader political, economic, social and technological environment that influence the transport-energy relationship along with the indicators expressing the impact of transportation on energy use.

The analysis of the relevant trends that need to be considered in scenarios of future energy supply for transport in Europe has shown that in both freight and passenger transport the most important trends can be related to two major driving forces: technological progress, and growing affluence. Growing affluence can be interpreted as a consequence of the technological progress, which would attribute all development to the “mother of all trends”, technological progress.

Technological progress and growing affluence have afforded people in the most advanced countries of the world a luxurious way of life and high level of mobility never experienced before. However, the analysis has also shown that the wide-ranging implications of these trends are by no means altogether beneficial. The unconstrained continuation of these trends is likely to lead to conflicts in at least three dimensions:

- **Global inequality**: the growth in affluence of the richest countries has not been accompanied by a comparable growth in income in the rest of the world. The income gap between the richest countries and the poorest is not decreasing but becoming larger. Simultaneously, large countries such as Russia, China and India are experiencing rapid economic development and thus impose demand for a growing share of finite world resources, including energy resources.

- **Energy shortage**: it is apparent that the fossil fuel resources of the world – mainly oil and natural gas – will not be available forever. World oil production is expected to peak in the near future and will decline from then on. At the same time the demand for oil will continue to grow in the developed countries and will grow even faster in the developing countries, most rapidly in the largest developing countries, China and India. Alternative fuels, as has been shown in the analysis, will make a growing contribution to satisfying this demand but are not likely to be able to fully substitute for fossil fuels in the foreseeable future. This means that energy for transport will become significantly more expensive, with severe, yet unexplored implications for the economies and ways of life in the most developed countries.

- **Global climate change**: there is growing consensus in climate research that rising global temperatures will result in significant climate change in all regions of the world. Whilst the proportion of global warming caused by greenhouse gas emissions from residential heating, manufacturing and transport is still debated, it is becoming clear that international agreements to curb such emissions, primarily the Kyoto protocol, have failed to meet their targets. Regardless, climate change is a factor accelerating the use of clean energy types.

These real and potential conflicts need to be taken into account when defining energy scenarios for transport in Europe. With this in mind, the most important trends in freight and passenger transport examined in the analysis and the conflicts that are likely to arise if they continue unconstrained are summarised in the next sections.

Trends and drivers in freight transport

In the freight transport sector we observe a trend towards an ever increasing intensity of freight transportation which, based on the prevailing political, social, economic, and technological environment, will continue to exist. This trend is fuelled by seven major drivers:

- Growth in affluence: The countries of the European Union have in the last fifty years experienced a period of immense growth in wealth with the effect that more goods than ever are consumed and hence need to be produced and transported.

- Globalisation. European integration and market deregulation have reduced trade barriers so that importing goods, exporting capital and outsourcing production (and jobs) to other countries (within and without the European Union) has become easier.

- Growing economies of scale in manufacturing, warehousing, retail and services have made large units more economical than small ones with the effect that manufacturing plants, warehousing facilities, offices and retail facilities have become more concentrated, distribution areas have become larger, and average procurement and distribution trips have become longer.

- Mass customization. Customer sophistication demands more tailor-made value-added services and products, greater product variety, shorter lead-times and higher accuracy and support during a product's life span. Mass customization affects the length, speed and frequency of trips, as well as the utilization of freight vehicles.

- Vertical disintegration of production (outsourcing). Manufacturers outsource value-added activities to third companies or downstream distributors. Vertical disintegration of production and outsourcing affects the number, length and speed of trips.

- Declining residential densities, continued urban sprawl, demographic change, smaller households and more diversified life styles, have led to smaller distribution vehicles, more dispersed and on average longer distribution trips on roads.

- Declining transport costs per ton-km because of improved vehicle technology, declining real costs of fuel, faster roads, more efficient logistics management and increasing competition by transport operators from low-wage countries have made purchases of goods from distant suppliers competitive even if they are only marginally better or less expensive than goods ordered from local suppliers.

This increasing freight transport intensity simply means that in order to achieve the same economic output, more tonne-kilometres are required. The greater number of tonne-kilometres is generated due to an increase in the tons transhipped, the length of haul, the decrease in the size of consignments and the subsequent increase in the frequency of deliveries. However, the observed growth trend, if considered alone, may not provide an adequate explanation for assessing future energy needs in the freight transport sector. This is because a number of other trends, related to the provision of freight transport services, may work in the opposite direction to the dominant trend for increased freight transport and energy consumption. However, it is worth mentioning here that currently these trends are not strong enough to reduce, halt or even reverse the increase in freight transport energy consumption.

The following trends associated with the supply of freight transportation services should be considered in assessing freight transport energy needs:

- The use of more energy efficient freight vehicles,

- A change in freight *composition* from heavy bulk goods to high value, high density commodities,

- Improvement in vehicle utilization, higher load factors and reduction of empty runs,

- Increased use of intermodal freight transportation.

Major contributing factors to more efficient supply of freight transportation services, from an energy use point of view, are:

- The emergence of business models and concepts that allow better utilization of freight transport resources, i.e., third and fourth party logistics (3PL and 4PL), city logistics, freight villages and centres,

- The introduction and implementation of transport policies that create a more favorable economic and operational environment for non-truck based transportation, i.e., intermodality,

- The introduction and use of emerging technologies for fleet and traffic management, transshipment and vehicles.

Here it should be stressed that technological progress also has its negative sides. It is becoming apparent that the trend to ever more freight transport and consequent energy consumption is not sustainable. Without a significant reduction of greenhouse gases by road transport, and that includes by road freight , the achievement of the Kyoto targets will not be feasible. Equally important is that the continuation of current trends in freight transport in Europe critically depends on the availability of cheap fuel. If, either by political unrest in one of the major oil producing countries or by a general rise in fuel prices through the increasing mismatch between supply and demand, fuel prices would rise significantly, the whole system of procurement and distribution certain will undergo a fundamental re-organisation. The effect of this will be that nearby suppliers will again be favoured over far-away suppliers, and that in many cases outsourcing production and jobs to low-wage countries will no longer be profitable, with overall positive effects for the environment but negative effects for the economies of the European Union member states.

In conclusion, the development of scenarios regarding the assessment of future energy use in the freight transport sector should consider simultaneously the following trends and their determinants:

- A trend of increasing demand for freight transport services
- A trend for increasing fuel efficiency for freight transport vehicles
- A trend for increasing efficiency in the use of freight transport vehicles
- A trend for increasing intermodality which will lead to a different modal split

Trends and drivers in passenger transport

The analysis of the prevailing trends in the passenger transport sector indicates that we will continue to observe a trend for increased mobility (in terms of the number and length of trips), coupled with a trend for faster and more flexible realisation of mobility needs, and an increase in the use of private automobiles.

These trends are fuelled by the same major drivers that are also responsible for the growth in freight transport:

- Growth in affluence. The growth in income that has fuelled the growth in freight transport has also enabled people to own more cars and travel further faster.

- Globalisation. European integration and market deregulation have reduced barriers to international travel with the effect that more business trips are made to promote international business relations and more tourist trips are made to far-away destinations.

- Growing concentration of manufacturing plants, warehousing and distribution activities, offices and retail facilities have led to on average longer work and shopping trips.

- Declining residential densities, continued urban sprawl, demographic change, smaller households and more diversified life styles have led to more dispersed, and on average longer trips, mostly by car.

- Declining travel costs per person-kilometre due to improved car technology, faster roads, trains and planes, and declining real costs of fuel have made high levels of personal mobility affordable to virtually all groups of society.

The sole consideration of demand side trends may not provide adequate explanation for assessing expected energy needs in the passenger transport sector. A number of factors work in the opposite direction against the dominant trend for more passenger travel and associated energy consumption. However, it is worth noting here that these trends are not likely to become strong enough to reduce, halt or reverse the energy consumption in the future.

The following trends are emerging on the passenger transport supply side which should also be considered in building scenarios for estimating future energy requirements for the passenger transport sector. These trends include:

- Use of more energy efficient private automobiles,

- Increasingly efficient use of private automobiles through more effective traffic management,

- Use of innovative demand management policies and measures,

- Substitution of travel by communication services,

- E-commerce where it remains to be seen if it will be able to contribute to a reduction in shopping trips without a bigger increase in delivery trips,

- Efforts to redirect trips from road and air to more environment-friendly public transport, although they have in the past always attracted less passengers than the concurrent growth in car and air travel.

In conclusion, the development of scenarios for assessing future passenger transport needs should consider simultaneously the following trends along with their determinants:

- A trend for increasing demand for passenger transport services
- A trend for increasing fuel efficiency of private automobiles
- A trend for more efficient use of automobiles

- A trend for introducing policies and concepts for more efficient travel demand management.

However, the previous discussion of technological progress relating to freight transport, applies equally to personal mobility. As with freight, the trend to ever more mobility and energy consumption is not sustainable - without a significant reduction of greenhouse gases by road passenger (car) transport, the Kyoto targets will not be achieved. Also in line with freight trends,, the continuation of current passenger trends in Europe depends on the availability of cheap fuel. If fuel prices rise to a multiple of today's prices, the whole system of daily mobility and long-distance travel will have to be reviewed with the effect that more people will live closer to where they work or work closer to where they live, that many business trips to far-away locations will not be made and many far-away tourist destinations will be abandoned in favour of domestic sites.

Part II: The STEPs assessment approach

PART II: Summary

Part II describes the STEPs assessment approach.

Firstly, Chapter 3 describes the procedure followed to build the STEPs scenarios for the future of the European Transport and Energy system up to 2030. The scenarios have been built combining hypotheses in two dimensions: availability of energy resources and the implementation of policies. On the energy availability side, two possible options were considered: generally accepted energy supply forecast, and worst case energy supply forecast. On the policy side, three different options have been considered: Business As Usual, Technological Investment, and Demand Regulation policies. The resulting six scenarios are described both with qualitative and quantitative variables in Chapter 3.

Chapter 4 describes the modelling tools used in order to simulate the scenarios and to provide quantitative responses on their effects. The models belong to two main categories: models operating at the European level: the ASTRA System Dynamics Model, the SASI socio-economic model and the POLES energy model; and models operating at the urban/regional level: Dortmund, Brussels, Edinburgh, Helsinki and South Tyrol models.

Finally, Chapter 5 describes the assessment procedure followed in STEPs. The assessment was carried out on the basis of a Multicriteria Analysis (MCA) methodology. This Chapter details the process followed for the selection of assessment criteria and the methodological procedure used for the definition of weights and utility functions.

CHAPTER 3: The scenarios

The main objective of this chapter is to describe the scenarios development process undertaken for the STEPs project. Further, the main scenario variables and parameters will be explained.

The scenario development was achieved through the following steps:

- Synthesis of trends into dimensions
- Definition of the scenarios
- Definition of regional contexts
- Building and formulating the scenarios

3.1 The synthesis of trends into dimensions

The trends and developments concerning the transport and energy system explained in the previous chapters were synthesised into two main dimensions: the availability of energy resources and (enabling or regulatory) policies. In a workshop on the scenario descriptions the STEPs-partners agreed to consider the energy resources dimension from two alternative perspectives: the generally accepted energy supply forecast (as described by the International Energy Agency) and a more extreme scenario. The policy dimension would also be considered from two perspectives: regulatory policies (demand regulation) and technology push policies.

Figure 3.1: Framework of the scenario design: two dimensions

Exogenous variables	Policy variables
1 Globalisation	9 'Liberation' of the energy market
2 European integration	10 Environmental policy
3 Economic growth (GDP)	11 Spatial planning
4 Demographics	12 Technological Innovation policy
5. Technological progress	13 Transport policy
6 Availability of Energy Resources	14 Fiscal Policy
7 Spatial development	15 Energy Policy
8 Transport costs	

These two dimensions of the scenario framework were reworked into more specified measures (e.g. transport policy involves mobility management, including car-sharing and traffic calming in urban areas) that can be linked to indicators (e.g. car ownership or average speed reduction), which can be used in the models as an input. See Table 3.3 for an overview of the measures and indicators, which have been grouped into systems as described below.

In order to get a grip on the complexity of trends and developments relating to the dimensions above, and necessary to describe the scenarios in full, all these trends were categorized into a framework system which described the transport and energy supply and demand side. This framework does not necessarily translate directly into the final scenarios derived, but it provided an interim structure for identifying all the relevant variables. Within each system, a number of sub-systems were also identified. The sub-systems were based on the contexts for development and implementation of new vehicle and vehicle powering concepts, energy supply technology, transport system development and spatial developments.

The energy supply sub-systems were:

- Energy production and supply
- Fuel production and distribution
- Car technology

The energy demand sub-systems were:

- Socio-economic and cultural
- • Spatial
- •Passenger transport
- • Freight transport
- • Transport energy by car technology

Input and output variables associated with each sub-system were subsequently translated in quantifiable output indicators for the EU and regional models as set out in Sections 3.2.1 and 3.2.2. The input and output variables that were selected for each sub-system are given in Table 3.1. Two examples of how the variables were quantified to create output indicators are:

- ‘Number of trips’ was quantified in terms of ‘number of trips made per household per day’.

- ‘Knowledge’ was quantified in terms of ‘number of research and development institutions’. This variable was not used further in the project, as it could not be modelled.

Table 3.1: Quantifiable output variables for the systems and sub-systems

Energy Supply System	Outputs for subsystem
Energy Production and Supply	
Knowledge per fuel type (fossil, electric, hydrogen)	Car technology
Fuel production & distribution	
Skills per fuel type	
Production capacity per fuel type	
Fuel Production and Distribution Technology Sub-System	
Knowledge per fuel type	Car technology
Skills per fuel type	
Production capacity per fuel type	
Car Technology Sub-System	
Knowledge automotive industry	Energy supply and production system; Fuel production & distribution
Skills automotive industry	
Production capacity automotive industry	
Knowledge manufacturing industry	
Skills manufacturing industry	
Production capacity manufacturing industry	
Energy Demand System	**Outputs for subsystem**
Social-Economic and Cultural Sub-System	
Number of people absolute and per household	
Number of trips	Transport Freight & Passengers
Number of addresses	Spatial & Freight Transport
Spatial Sub-System	
Density hh/km^2	
Built up area- Surface urban area	
Dispersion	Freight transport
Average distance travelled	Passenger Transport
Passenger Transport Sub-System	
Mode choice	Energy transport system
Infrastructure length & investment per mode	
Total Distance travelled per mode	Energy transport system
Freight Transport Sub-System	
Mode choice	Energy transport system
Infrastructure length & investment per mode	
Logistics	
Total Distance ton/km per mode	Energy transport system
Transport Energy Sub-System	
Propulsion (petrol diesel, hydrogen electric)	
Energy efficiency	Fuel demand
Car Techology Sub-System	
Knowledge	Transport Energy System
Skills	Transport Energy System
Production capacity	Transport Energy System

As the values of the variables are a consequence of the specific circumstances assumed for each scenario, they will differ in each of the scenarios. Consequently, the scenarios can be described using the variables.

3.2 Definition of the scenarios

By combining the policy dimension with the energy-availability dimension, a scenario framework was created which consists of the original six scenarios for the future of the European Transport and Energy system up to 2030, as this is the time horizon of most models used (see Table 3.2). These scenarios are described both with qualitative and quantitative variables.

From the point of view of *energy availability*, two groups of scenarios have been identified:

- Scenarios 'A', based on the generally accepted energy supply forecast. In the following, these scenarios will be named **'low oil price growth scenarios'** or just **'Scenarios A'**;

- Scenarios 'B' are based on the assumption of energy scarcity. In the following, these scenarios will be named **'high oil price growth scenarios'** or just **'Scenarios B'**.

At the same time, from the energy *demand policy* dimension there are also two groups:

Policy strategy '1', concentrating on investments in technologies. In the following, these scenarios will be named **'technology investments scenarios'** or just **'Scenarios 1'**;
Policy strategy '2', focussed on demand regulation. In the following, these scenarios will be named **'demand regulation scenarios'** or just **'Scenarios 2'**.

These two dimensions were compared with **business as usual** alternatives (labelled as **'Scenarios 0'**), where only a limited number of policy measures (comparable with the current transport and energy policy approach) were assumed.

Table 3.2: STEPs scenario framework

		Energy demand		
		Business As Usual	Technological Investment	Demand Regulation
Energy availability	Generally accepted energy supply forecast	A0	A1	A2
	Worst case energy supply forecast	B0	B1	B2

The energy demand policy dimension

The three scenarios of the energy demand policy dimension are defined by three different policy packages. The characteristics of each policy package are:

Group 1: Business As Usual (BAU)
For the policy package BAU, existing policies are used as a starting point. For the outlook on 2030, the likely policy developments, as expected by experts ('expert guesses'), were used to estimate the values of the variables relating to the BAU scenarios.

Group 2: Technological Investment (INVEST)
In the policy package INVEST, direct investments in the infrastructure and technology and innovation systems are assumed. The focus is on the impact of these investments on the transport and energy system in Europe. The basis for this group of scenarios is the BAU policy package. Within this policy package, some explicit technology and capacity related

investment measures are added and described in a qualitative and quantitative way. These concern the following measures:

- investments in infrastructure;
- investments in energy efficiency;
- investments in skills, knowledge, production capacity of alternative fuels and rolling stock.

Group 3: Demand Regulation (DR)
In this policy package, the focus is on the impact of demand regulation measures on the transport and energy system in Europe. Again the basis for this scenario is the BAU scenario. Within this scenario some explicit measures related to demand regulation and taxation are added and described in a quantitative way. These concern the following measures:

- taxation of car use;
- taxation of fuel;
- regulation of urban development with an emphasis on transit use and node development

The next step was to combine the indicators with all the scenarios described. For every variable (see Table 3.1), a set of feasible measures was introduced to make it more tangible. Every measure was connected to an indicator to be able to translate it into a parameter for the models used within the STEPs project (see Table 3.3 for the measures and associated indicators).

Table 3.3: Measures and indicators used within STEPs

Measure	Indicator
Social-Economic and cultural Subsystem	
Mobility management, including car-sharing	Car ownership
Motor Fuel Tax	Gasoline fuel tax/ litre
	Diesel fuel tax/ litre
	Kerosene
Travel cost change due to fuel taxes	Car (General car cost)
	Air (General air cost)
Diffusion of Telework	Commuting trips saved per year
Spatial system	
	floor space index - change to base year
Residential	Central
	Inner urban
	Outer urban
Services+business	Central
	Inner urban
	Outer urban
(light) Industrial	Central
	Inner urban
	Outer urban
Passenger Transport System	
Investment in infrastructure for Trans European Rail Networks	European rail base speed
Investments in regional rail networks	Regional rail base speed
Investment in local public transport infrastructure	Local public transport speed
Traffic calming in urban areas	Average speed reduction for cars
Road pricing in urban areas	Average cost of car km and road ton/km
Lower cost for public transport users	Bus cost
	Train cost
Freight Transport System	
Traffic calming in urban areas	Average speed reduction
Road pricing in urban areas	Average cost of car km and road ton/km
Optimisation of City Logistics	Freight average distance
	Freight Load Factor Short Distances:
Improvement of rail infrastructures and services	Rail base speed
	New freight rail network d or cost
Transport Energy System	
Improving energy efficiency for car	Car fuel efficiency (gasoline fuel consumption/car)
	Car fuel efficiency (Diesel fuel consumption/car)
Investments in alternative vehicle technologies	Emission factors
	car fleet
	Car cost
Improving energy efficiency for train	Train fuel consumption rate [l/(vhc*km)] (diesel trains), Electric Consumption Factors [kWh/km]
Improving energy efficiency for ship	Ship diesel consumption factor [kg/km]

The car technology sub-system was not taken into account any further, as it could not be modelled by the models used within the STEPs project.

In order to be able to calculate figures for the three scenarios described, values for the indicators associated with each of the three energy demand scenarios were estimated in expert sessions, based on the analyses of the state of the art, the trends and the PEST analysis. This led to annual changes (in percentages, with the exception of the spatial system, which was given a qualitative indication of change) in the different scenarios, which could be used as input for the models.

The energy availability dimension

In addition to the energy demand policy dimension, ‘energy availability’ was used as the second dimension to construct the scenarios. Availability supposes that the access to resources is not barred or restricted in any manner. Accessibility will be, under the condition of globalisation and hence open markets, a question of price.

Both dimensions can have any combination of relevant variables, and values for associated indicators, and are more or less continuous. Though for reasons of ‘control’ it was decided to take two perspectives on the dimension ‘availability of energy resources’. These two values were:

- Scenario group A: Generally accepted energy supply forecast
- Scenario group B: Worst case energy supply forecast

Scenario group A: Generally accepted energy supply forecast
Based on expectations as described by the IEA and the World Energy Council (WEC), the STEPs consortium set the oil price within the A group-scenarios on an average of $35 per barrel for the period 2000-2030 and assumes that this price will grow following a linear pattern over time. Based on an oil price of $27 in 2000, this assumption meant an annual growth in the oil price of 2%, resulting in an increased end-user price of 1%. Due to the possibilities for governments to change the various taxes on fuel, the full oil price increase is hardly ever passed on to the end-user at the filling station. The government ‘muffles’ the price increase for the consumer through (slight) tax decreases, to smooth the price increases on the worldmarket.

Scenario group B: Worst case energy supply forecast
For the B group-scenarios an analysis was made of several energy availability scenarios by IEA and Intergovernmental Panel on Climate Change (IPPC). Based on this analysis, it could be concluded that future trends in oil prices are a major source of uncertainty. Supply and demand will in the long run be in equilibrium but in the short run it may be severely disturbed by either unexpected demand pressure or lower resources. Structural shortages will lead to a higher equilibrium-level.

For the purpose of the scenarios, the STEPs consortium has set the oil price within the B group-scenarios on the high price IEA scenario +100%. This means an annual growth of the oil price of 7% for the period 2000-2030, resulting in an increased end-user price of 4%.

Table 3.4 gives the oil prices used in the energy availability dimension.

Table 3.4: Price of crude oil imports

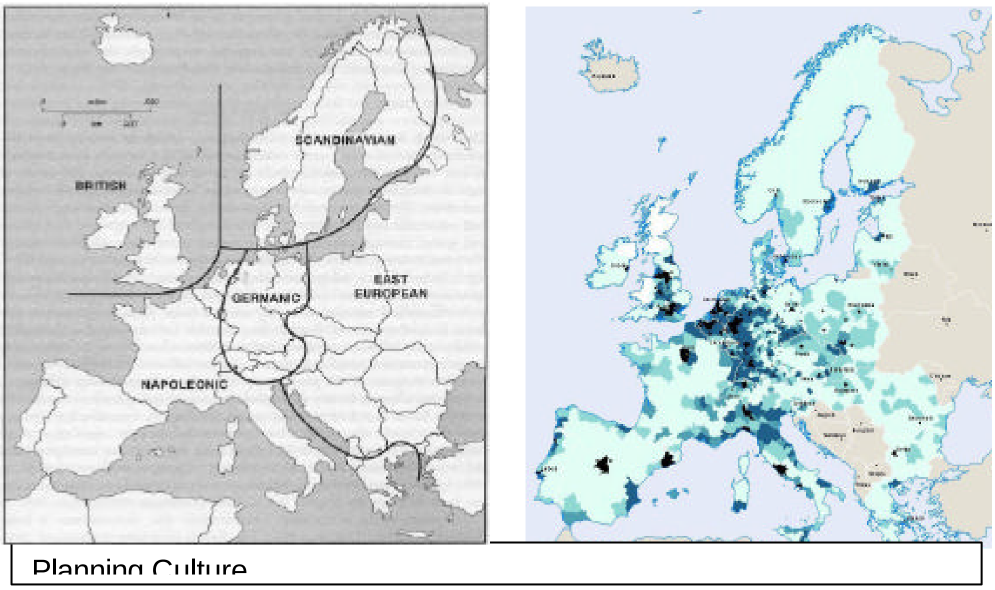
Price crude oil imports ($/barrel) in year 2000 $	increase	average	2000	2010	2020	2030
A: Generally accepted energy supply forecast	2 %/year	35	27	29,8	36,4	44,3
B: Worst case energy supply forecast	7 %/year	71	27	37,9	74,5	146

3.3 Definition of the regional impact

In order to take account of the cultural, political and economic aspects, which vary from region to region, the description of the scenarios also contains a more specific regional description, as well as a more general description at the EU-level as a whole. This regional specification is based on two sets of considerations: the spatial structure of regions, and the planning culture.

The first set takes the planning and policy cultures into account and differentiates between five 'planning families': the 'Napoleonic', the 'British', the 'German', the 'Nordic' and the 'East European' planning families. The second set covers the transport system in relation to land use and differentiates between industrial-metropolitan regions, polycentric regions and rural regions. Figure 3.2 illustrates the planning families, urban density and the overlaps between the two.

Figure 3.2: EU25 by planning culture and urban density



Combining these two, led to a distinction between four European regions:

- Northern Europe: Sweden, Finland, Denmark, (Norway);
- Eastern Europe: Estonia, Lithuania, Latvia, Poland, Slovak Republic, Slovenia, Czech Republic, Hungary;
- Southern Europe: Italy, Greece, Spain, Portugal, Malta, Cyprus;
- Western Europe: Germany, Austria, United Kingdom, Ireland, the Netherlands, Belgium, France, Luxembourg.

3.4 Building and formulating the scenarios

With the result of the main storylines of the scenarios the three energy demand strands for the final scenarios can be broadly explained as below[1].

1. The description of the *Business As Usual* strand is based on current EU-policies that will have their impact on the transport and energy system in the next 25 (and more) years. This means for example, no great efforts in terms of mobility management, an on going urban sprawl, a further diminishing share of public transport due to under-investment, which all results is a greater share of private car use and road freight, and an ever increasing energy consumption by the transport sector, including both passenger and freight transport. It also means that the conventional fuels still hold the largest share of the market, with (very) minor shares for alternative technologies like hybrids vehicles and CNG. Electric and hydrogen cars have only extremely tiny shares of the market.

2. The second strand, *Technology Investment*, includes policy measures that result in direct investments in the infrastructure, technology and innovation systems. It has the BAU scenario as its basis. Within this policy package, some explicit technology and capacity related investment measures are added and described in a qualitative and quantitative way. These concern the following measures:

- investments in infrastructure;
- investments in energy efficiency;
- investments in skills, knowledge, production capacity of alternative fuels and rolling stock.

This means that in this strand of scenarios investments are assumed in rail infrastructure at European, regional and local levels. These investments impact equally on passenger and freight transport by rail. At the same time extra investments are made in energy efficiency measures for cars, trains and ships. The scenarios also promote the development of alternative drive trains and fuels, e.g. hybrids, electric cars, their batteries and hydrogen powered cars.

3. The third strand, entitled *Demand Regulation* focuses on the impact of demand regulation measures on the transport and energy system in Europe. It is also based upon the BAU scenario. Within this strand of scenarios, some explicit measures related to demand regulation and taxation are added and described in a quantitative way.

These concern the following measures:

- taxation of car use;
- taxation of fuel;
- regulation of urban development with an emphasis on transit orientation and node development.

This demand regulation strand relies heavily on legislation to promote alternatives and at the same time adds more taxes to the more energy-consuming modes, such as the private car. The scenarios promote teleworking, but also try to fight the ongoing urban sprawl through legislation and taxes on land development. Some examples of measures taken in these scenarios include investing in mobility management, taxation on fuels (specifically

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1 An explanation in 'essay form', understandable to a wider public of experts, officers, scientists and industrial managers was created as Deliverable 3.2 of the STEPs project (see www.steps-eu.com for available reports)

including kerosene), traffic calming and road pricing in urban areas (both influencing passenger and freight transport) and a lowering of the price of public transport.

Every scenario holds a description in qualified terms of how the variables described will develop in the different regions[2]. One example regarding 'Motor Fuel Taxation (influencing vehicle purchase and transport costs)' can illustrate this for both the BAU and the Demand Regulation scenarios. After a description of how at the EU-level taxation will be handled, and what the annual changes in motor fuel taxation will be, the section Regional Differences describes how the regions are generally likely to react to this topic:

Business as Usual:

> **(…)**
> **All this means that gasoline fuel tax per litre increases annually at 0,7%, while diesel fuel tax per litre increases annually at 1,5%.**
>
> After a general understanding and agreement, **taxing kerosine** has started from 2010 onwards at **50% of fuel tax.**
>
> In general, due to fuel and other taxes, the **cost for cars will show an annual increase of 0,5%. Due to a still growing market share of low-cost carriers, air travel costs will generally decrease by 0,5% annually.**

Regional differences

- **North**: This region includes the highest rates of taxation (mostly the highest VAT: Finland 22%, Sweden and Denmark 25% on energy). Taxation will stay at a relatively high level.

- **East**: Containing most of the countries with the lowest taxation rates, most countries will show a very high increase, even in this Business As Usual scenario.

- **South**: Despite the minimum levels of excise duty specified at the EU level, Southern Europe shows great differences: Spain 16%, Italy 10%, Portugal 5%. This means that the increase in fuel tax will have different consequences for different countries.

- **West:** With the assumed moderate increases in fuel prices in the BAU scenario the level and variation of fuel taxes (varying from 21% in Belgium to 15% in Germany and 19% in the Netherlands) in Western European countries persists at just over the European average.

Demand Regulation:

<u>EU wide perspective</u>
The tax harmonisation by the European Commission has led to a considerable increase in taxes for driving cars. Especially in the Eastern European Member States, where the taxes have risen enormously. The other countries showed a more modest increase. Until 2007, taxation was used to compensate the end user for the rise in fuel price to the end user, but from 2008 onwards, this practice has stopped. From 2008 to meet air qulity standards, to try to stop the increase in car use and to reduce conventional car sales/increase sales of less polluting models (e.g. hybrid and hydrogen powered vehicles) tax on polluting fuels has risen fast:

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2 This description is available in Deleverable 3.1 of the STEPs project (www.steps-eu.com)

(…)
gasoline fuel tax per litre has increased annually at 4,7%. Diesel fuel tax per litre also increased annually at 4,7%.

From 2010 onwards

(…)
kerosine has been taxed at an amount corresponding with 200% of the fuel price.

Taxation on fuel efficiency, noise and other features of the aviation air fleet, will have negative consequences (higher costs) for most low-cost carriers as they generally operate with less advanced technology.

Therefore it is to be expected that due to fuel and other taxes…

…costs for cars have increased annually at 3%. As a result of the slower growth in market share of low-cost carriers, air travel costs have increased anually at 3% as well.

Regional differences

- **North:** The North more or less follows the increased taxation rates in Western Europe, although they remain just above average.

- **East:** Fuel tax has increased enormously; in some countries up to 200% of the former levels due to changes in the minimum EU levels of excise duty in 2010, 2020 and 2030. Car operating costs have increased by the same amounts.

- **South:** Fuel tax has generally increased at a moderate rate, due to existing relatively high excise duties, although some countries have increased excise duties more dramatically.

- **West:** West-European countries have remained the leaders in increasing fuel taxes, although some of them already had high petrol and diesel taxes. Introducing a tax on aircraft fuel (kerosene) was a major blow to discount airlines, most of which were based in Western Europe; some of the smaller airlines went out of business and so brought passengers back to the railways for medium distance trips.

Table 3.5 contains a summary of the main model parameters for the scenarios. These parameters were used in the five regional STEPs models.

Table 3.5: Scenarios: model parameters

Measure	Indicator	Scenario Business as usual	Scenario Technological Investment	Scenario Demand Regulation
Social-Economic and cultural Subsystem		**Annual change in %**		
Mobility management, including car-sharing	Car ownership	+ 1,0%	+ 1,0%	- 0,6%
Motor Fuel Tax	Gasoline fuel tax/ litre	+ 0,7%	+ 0,7%	+ 4,7%
	Diesel fuel tax/ litre	+ 1,5%	+ 1,5%	+ 4,7%
	Kerosene	Kerosene tax 50% of fuel tax	Kerosene tax 50% of fuel tax	Kerosene tax 200% of fuel tax
Travel cost change due to fuel taxes	Car (General car cost)	+ 0,5%	+ 0,5%	+3%
	Air (General air cost)	- 0,5%	- 0,5%	+ 3%
Diffusion of Telework	Commuting trips saved per year	0,0%	0,0%	+0,3% (2030: 7,0%)
Spatial system (floor space index)		**Change to base year**		
Residential	Central	+	+	++
	Inner urban	++	++	+++
	Outer urban	+++	+++	0
Services+business	Central	0/+	0/+	+
	Inner urban	+	+	++
	Outer urban	++	++	0
(light) Industrial	Central	0	0	0
	Inner urban	+	+	+++
	Outer urban	+++	+++	0/+
Passenger Transport System		**Annual change in %**		
Investment in infrastructure for Trans European Rail Networks	European rail base peed	+ 0,8%	+ 2%	+ 0,8%
Investments in regional rail networks	Regional rail base peed	+ 0,4%	+ 1,7%	+ 0,4%
Investment in local public transport infrastructure	Local public transport speed	+ 0,3%	+ 1,1%	+ 0,3%
Traffic calming in urban areas	Average speed reduction for cars	- 1,5% every 5 year (ann. -0,4% = -10% in 25 years)	- 1,5% every 5 year (ann. -0,4% = -10% in 25 years)	- 4% every 5 year (ann. -1% = - 27% in 25 years)
Road pricing in urban areas	Average cost of car km and road ton/km	- 2,0%	- 2,0%	+ 6,0%
Lower cost for public transport users	Bus cost	+ 0,8%	+ 0,8%	- 1,7%
	Train cost	+ 0,8%	+ 0,8%	- 1,7%
Freight Transport System		**Annual change in %**		
Traffic calming in urban areas	Average speed reduction	- 1,5% every 5 year (ann. - 0,4% = - 10% in 25 years	- 1,5% every 5 year (ann. - 0,4% = - 10% in 25 years	- 4% every 5 year (ann. -1% = - 27% in 25 years)
Road pricing in urban areas	Average cost of car km and road tonne/km	+ 2,0%	+ 2,0%	+ 6,0%
Optimisation of City Logistics	Freight average distance	- 0,2%	- 0,5%	- 0,2%
	Freight Load Factor Short Distances	+ 0,8%	+ 2,4%	+ 0,8%
Improvement of rail infrastructures and services	Rail base speed	+ 0,7%	+ 2,0%	+ 0,7%
	New freight rail network d or cost	+ 0,6%	- 1,5%	+ 0,6%
Transport Energy System		**Annual change in %**		
Improving energy efficiency for car	Car fuel efficiency (gasoline fuel consumption/car)	- 0,5%	- 2,0%	- 0,5%
	Car fuel efficiency (Diesel fuel consumption/car)	- 1,0%	- 3,0%	- 1,0%
Investments in alternative vehicle technologies	Emission factors	- 8,1%	- 16,0%	- 8,1%
	Car fleet	Conventional (gas/ dsl): -1% / share: 72% Hybrids: + 12,5% / share: 15% CNG: + 10% / share: 10% Electric + 3% / share: 1% Hydrogen + 3% / share: 2%	Conventional (gas/ dsl): -2,1% / share: 55% Hybrids: + 13,5% / share 20% CNG: +12% / share 15% Electric: +7% / share 5% Hydrogen: +7,8% / share 5%	Conventional (gas/ dsl): -1% / share: 72% Hybrids: + 12,5% / share: 15% CNG: + 10% / share: 10% Electric + 3% / share: 1% Hydrogen + 3% / share: 2%
	Car cost	+ 0,8%	+ 3,0%	+ 0,8%
Improving energy efficiency for train	Train fuel consumption rate [l/(vhc*km)] (diesel trains), Electric Consumption Factors [kWh/km]	- 0,8%	- 5,0%	- 0,8%
Improving energy efficiency for ship	Ship diesel consumption factor [kg/km]	- 0,4%	- 1,6%	- 0,4%

3.5 Additional scenarios

In a later stage of the project some additions were made to the original matrix of six main scenarios, as depicted in Table 3.5 below.

For modelling purposes, it is important that the effect of the development of energy price can be isolated. The set of six scenarios was therefore enlarged. A set of scenarios where only the assumption concerning the oil price growth is considered was defined. These scenarios were labelled **'Scenarios –1'** and are further referred to as **'no-policy scenarios'**.

With the objective of testing an 'extreme' case of fuel price development, a new group of scenarios was defined in a later stage. In this group of scenarios, the end-user fuel price grows at 7% per year. These scenarios were labelled as **Scenarios 'C'** and are further referred to as **'extreme fuel price growth scenarios'**.

Finally, a further set of scenarios was 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 3.6: STEPs full scenarios framework

	No policies	Business as usual	Technology investments	Demand Regulation	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 to the project, implementing, testing and reporting fifteen different scenarios was a challenging task, especially for some models. For that reason, a sub-set of **main scenarios** to be simulated by each modelling tool were identified. 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 in Table 3.5) being considered additional scenarios. The main scenarios (coloured blue) were simulated in all models. The model simulations and their outcomes are the topic of the following chapters.

CHAPTER 4: The Modelling system

4.1 Models and simulation strategy

Several modelling tools have been 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:

- 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 4.1: 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

All models were already established and applied at their scale. They have worked as independent models and loosely linked in terms of input and output exchange and comparisons (see Section 4.3).

4.2 Description of models' main features

The Astra model

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 4.2: 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

The SASI model

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 4.3: Overview of the SASI model

SASI Model

TRANSPORT SYSTEM ⟷ **SOCIO-ECONOMIC SYSTEM**

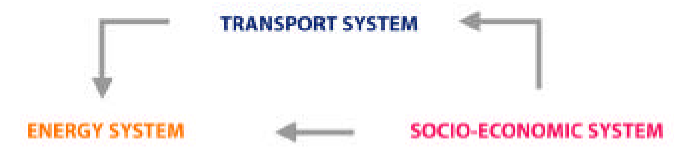
	KEY INPUTS	MAIN OUTPUTS
TRANSPORT SYSTEM	transport project, transport policies	regional accessibility
SOCIO-ECONOMIC SYSTEM	labour productivity, endowment, fertility, mortality, migration policies, transfer payments	accessibility, GDP, employment, population, labour force

The POLES model

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 4.4: Overview of the POLES model

POLES Model



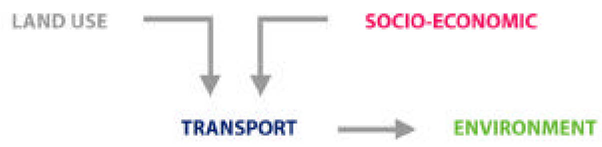
	KEY INPUTS	MAIN OUTPUTS
TRANSPORT SYSTEM	techno-economic characterisation, fuel efficiency, emission factors, car costs	car fleet size and composition, fuel consumption, emission levels
ENERGY SYSTEM	techno-economic characterisation	energy prices
SOCIO-ECONOMIC SYSTEM	GDP, population, fuel taxes, carbon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

The Brussels IRIS model

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 4.5: Overview of the Brussels model

Brussels Model



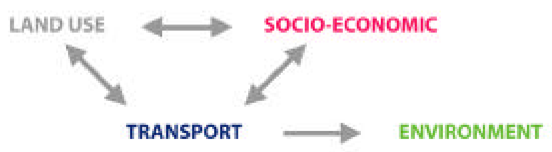
	KEY INPUTS	MAIN OUTPUTS
TRANSPORT	public transport services, road network, transport costs, tariffs, car ownership	passenger-km for the public transport, vehicle-km for the private vehicles
SOCIO-ECONOMIC	employment, population	
LAND USE	location of households, jobs and commercial activities	
ENVIRONMENT	emission functions, fuel consumption factors	Fuel consumption, CO_2 emissions

The Dortmund model

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 4.6: Overview of the Dortmund model

Dortmund Model



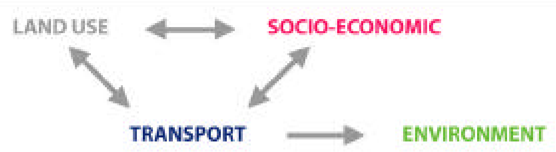
	KEY INPUTS	MAIN OUTPUTS
TRANSPORT	public transport lines and services, road network projects, fuel costs and consumption, public transport fares	accessibility, trip by purpose and mode trip length, travel time car ownership
SOCIO-ECONOMIC	total regional employment by sector, total regional immigration 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 MARS model

The MARS (Metropolitan Activity Relocation Simulator) Edinburgh model is 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 4.7: 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

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 4.8: 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,

The South Tyrol model

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 4.9: 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

The following tables resume and compare the main features (time thresholds, geographic coverage, zoning system level of detail, transport modes, etc.) of the models described in this section.

Table 4.10: European models features

Features		ASTRA	SASI	POLES
Base year		1990	1981	2000
Time threshold		2020	2021	2020
Time interval		1 year	1 year	1 year
Geographic coverage		EU 25 + Bulgaria, Norway, Romania and Switzerland	EU 25 + Norway, Switzerland, Bulgaria, Romania, Albania, Bosnia-Herzegovina, Croatia, Macedonia and Yugoslavia	World regions
Zoning system		Nuts 2	Nuts 3	Country (EU25) or aggregation of countries
Passenger mode	Car	yes	yes	yes
	Train	yes	yes	yes
	Bus	yes	yes	yes
	Ship	no	no	no
	Plane	yes	yes	yes
	Slow modes	yes	no	no
Freight mode	Truck	yes	yes	yes
	Train	yes	yes	yes
	Ship	yes	yes	no
	Plane	no	yes	no

Table 4.11: Local models features

Features		Brussels	Dortmund	Edinburgh	Helsinki	South Tyrol
Base year		2001	1970	2001	2001	1999
Time threshold		2015	2030	2030	2021	2020
Geographic coverage		Metropolitan area	Metropolitan area	Metropolitan area	Metropolitan and rural area	Rural and urban area
Area extension (km^2)		4 332	2 014	2305	13 827	7 400
Population base year		2 900 000	2 600 000	1 070 000	1 657 000	457 000
Passenger mode	Car	Yes	Yes	Yes	Yes	Yes
	Train	Yes	Yes	No	Yes	Yes
	Bus	Yes	Yes	Yes	Yes	Yes
	Walking / cycling	Yes	Yes	Yes	Yes	No
Freight	Freight	Yes	No	No	Yes	Yes

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. The proper features of the tools should be taken into account when comparing the outcomes of the simulation runs.

4.3 Models simulation strategy

The STEPs scenarios have been implemented in the modelling tools according to their specific features and capabilities. 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 4.12 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 4.12: 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
	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 Chapters 6 and 7 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:

4. 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.

5. 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.

6. 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 Section 4.3.1.

7. 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 (see again Section 4.3.1).

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[3].

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 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 4.1) 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 4.2 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 transferred 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 the definition of scenarios.

3 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.

Figure 4.1: The POLES – ASTRA iteration

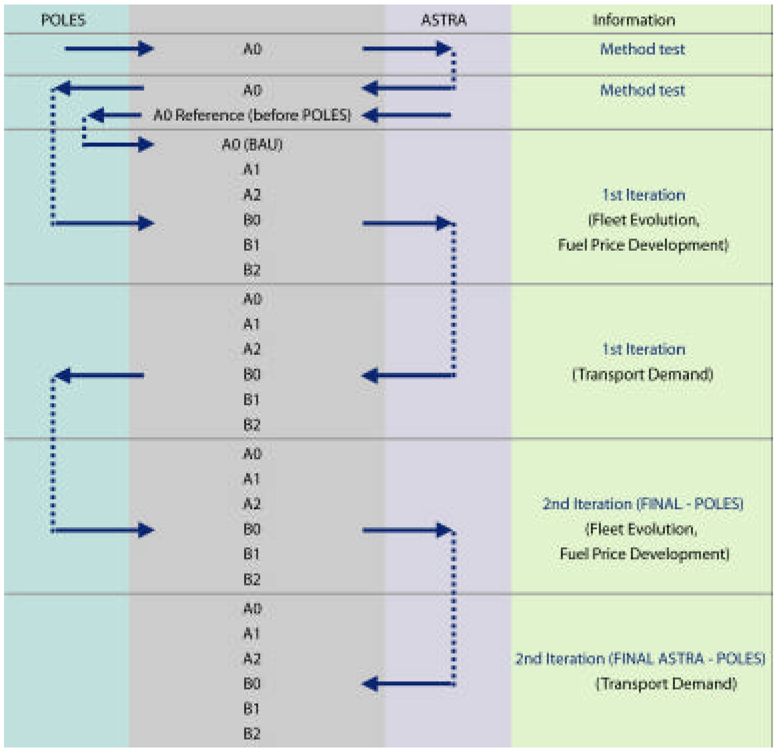
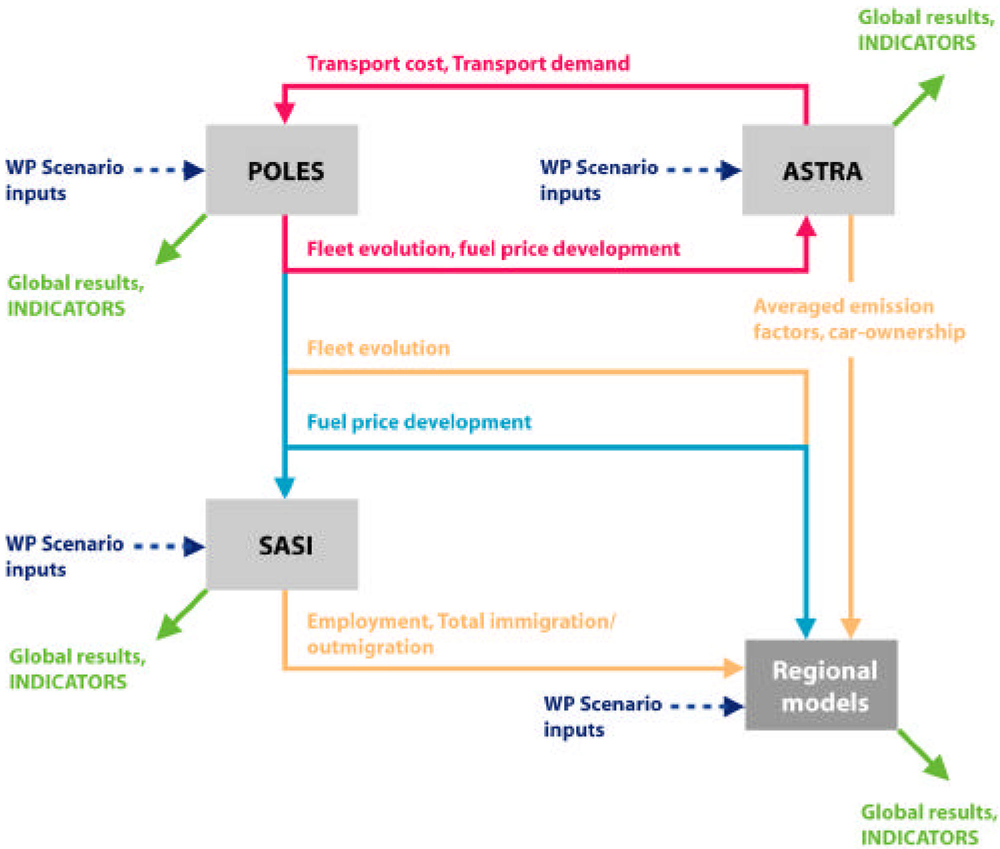


Figure 4.2: Data exchange between models in scenarios simulation

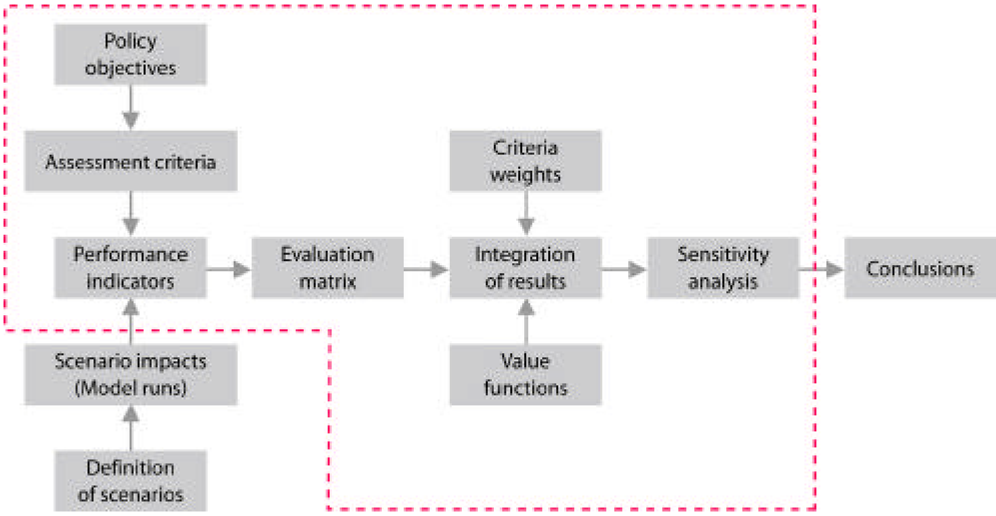


CHAPTER 5: The assessment methodology

5.1 Outline of the MCA procedure

This Chapter describes the MCA methodology which has been used in STEPs: An outline of this methodology is included in Figure 5.1.

Figure 5.1: Outline of the MCA methodology



The starting point for this methodology is a review of the main EU transport and energy policy documents, in order to derive the set of assessment criteria to be used in STEPs. The corresponding set of “performance indicators” links model outputs with assessment criteria. They are included in Table 5.1.

The relative importance of each criterion has been defined according to the responses to a targeted questionnaire distributed by STEPs partners among key researchers and other relevant stakeholders. Subsequently, for each criterion, model-specific linear value functions have been built based on the extreme values of the corresponding performance indicators.

For the four STEPs criteria categories: energy, environment, social and competitiveness, the MCA allows computing a score representing the performance of each scenario in each of these four categories, namely “energy”, “environment”, “social” and “competitiveness”. No aggregation of the corresponding four scores has been made in STEPs, mainly for two reasons. The first is that none of the models provides performance indicators for all the indicators, and therefore it is not possible to compute a “strict” global social utility value for each scenario. The second is to intentionally leave the decision maker with the final decision on the best scenario, depending on his/her trade-offs between the often conflicting scores obtained in each of the aforementioned four criteria groups.

The objective of the research carried out in STEPs is to provide the decision maker with comprehensive information on the predicted effects of a set of, in a sense, plausible/ possible changes in fuel availability and related policy responses. Political, social and many other factors beyond the scope of the STEPs project will presumably drive the decision makers selection of the package of policy measures to be implemented.

The assessment is carried out on the basis of the results of different models, with different geographical scales, initial assumptions and output indicators. Although a considerable effort has been made to homogenize the models output indicators, their results are not fully comparable. Hence, only broad comparisons across models, in terms of the observed direction of the effects, are carried out in STEPs.

5.2 Selection of assessment criteria

In order to select the list of assessment criteria to be used in STEPs, a review of the major energy and transport related policy documents at a EU scale was conducted, as described below.

The starting point for the selection of the criteria to assess STEPs **transport** and **energy** scenarios was the identification of the main concerns and policy targets of the European Union related to the aforementioned sectors.

The growing importance of Energy and Transport sectors in the EU became clear in 1999, when the Commission created a specific Directorate-General for the management of Energy and Transport Policy. These two sectors share a number of fundamental characteristics(EC,2004a):

- they are essential to economic competitiveness;
- they contribute to social and territorial cohesion;
- each is the subject of important public service missions guaranteeing all users and consumers, wherever they may be on the territory of the Union, equal access, on equitable conditions, to quality services at affordable prices;
- they require substantial infrastructure with quality, inter-connected networks and the question of investments is vital to each;
- often organized in a monopolistic basis, they face similar problems when confronted with the integration of national markets and regulatory changes;
- both have a major influence in the quality of our **environment** and are subject to the same requirements in terms of **safety** and **security**;
- they each have a major international dimension.

In summary, the main objective is that energy and transport contribute to **sustainable development:** making Europe both a homogenous area of economic development and an area where the environment in the broadest sense of the term is conserved.

The following sections review the main concerns and policy targets of the European Union in terms of transport and energy related to the objectives of STEPs, which will constitute the main input for the selection of the assessment criteria. A complete list on EU's legislative Acts on transport and energy sectors can be found in (EC, 2004a). It is beyond of the scope of this task to include them in this Deliverable.

Common Energy and Transport Policy

The Common **Transport Policy** (CTP) has two basic goals: **efficient**, **accessible** and **competitive** transport systems - essential to growth and employment and to keep EU businesses competitive - and a high level of **safety** and **environmental protection**. Therefore the CTP Action Programme seeks:

- better integration of transport modes and greater use of environmentally friendly and energy-saving modes;

- stimulation of new technologies;

- promotion of a "Citizens' Network" to provide high-quality collective transport of all kinds;

- fair competition between the different modes;

- improvement of road safety.

EU's main **Energy Policy** targets have been recently summarized in the Treaty establishing a Constitution for Europe Official Journal of the European Union, 310/01 of 16 December 2004 (EU, 2004).

"In the context of the establishment and functioning of the internal market and with regard to the need to preserve and improve the environment, Union policy on energy shall:

- ensure the functioning of the energy market,

- ensure security of energy supply in the Union,

- promote energy efficiency and energy saving and the promotion of new and renewable forms of energy".

(Article III-256, Section 10: Energy, Title III, Part III)

Current activity in the fields of transport and energy is based on two major Policy documents: the White and the Green Papers:

White Paper: *European Transport Policy for 2010: time to decide* (EC, 2001). It proposed four main priorities:

- adjusting the **balance** between the different modes of transport;
- implementing the trans-European transport network;
- placing the **user** at the heart of transport policy;
- managing the effects of **transport globalisation**.

Green Paper: *Towards a European strategy for the security of energy supply* (EC, 2000). It established three major strategic priorities:

- controlling the **increase in demand**, identifying two priority sectors : transport and construction;

- managing **dependence on supply**, no to maximise the Union's autonomy on energy, but to reduce the risks involved in dependence;

- ensuring that **the internal energy market** works well.

Finally, the recently adapted *Community Guidelines for the development of the **trans-european transport networks*** (EC, 2004c) include essential EU transport policy objectives. The following list constitutes a selection of the relevant objectives in the context of the STEPs project:

- ensure the **sustainable mobility** of persons and goods (…) under the best possible social and safety conditions, while helping to achieve the Community's objectives, particularly in regard to the **environment** and **competition**, and contribute to strengthening **economic and social cohesion**;

- be, in so far as possible, **interoperable** within modes of transport and encourage **intermodality** between the different modes of transport;

- cover the whole territory of the Member States of the Community so as to facilitate **access in general**, link island, landlocked and peripheral regions to the central regions and interlink without bottlenecks the major conurbations and regions of the Community.

Current European Commission Concerns

The main concerns from the EC on energy and transport issues have recently been stated in a Report from the Directorate of Energy and Transport (EC, 2004a). This document constitutes a starting point to structure the set of criteria to be included in the STEPs methodology.

Europe's transport system is dealing with important issues, such as:

- **Traffic congestion** reaching disturbing levels, with the existence of certain bottlenecks on the major intra-Community routes and its negative economic impacts;

- **Lack of interoperability** between modes and systems;

- **Growing imbalance** between different modes: growing air and road market shares and decreasing rail and sea modes;

- **Traffic safety**: although the situation in the EU15 has improved in recent years, the new Member States show alarming results.

However, as the development of passenger and goods transportation is directly linked to **economic growth**, **decoupling** transport and GDP growth, while dealing with increasing mobility needs, is essential. In addition, enlargement and more intensive trade relations with neighbouring countries will both contribute to an intensification of trade flows.

The rights of users and passengers are also of vital importance: European citizens should benefit from equal access to transport services under acceptable conditions. In this sense, the influence of the transport system on socio-economic disparities among regions is not clear and it can either reduce differences or introduce further spatial polarisation, i.e. increase or reduce **cohesion**.

Regarding the energy sector many warnings have been issued, not only concerning the **long-term** decline in world hydrocarbon reserves, but also the more **intermediate threat** of a reduction in the availability of crude oil on the markets - with the resulting pressure on prices- resulting in particular from the emergence of very substantial new consumers, such as China. Extensive oil consumption, combined with the expected growth in demand for natural gas, will increase the Union's **dependence on imports** from non-member countries.

Apart from the question of **physical supply**, the **price of energy**, and more particularly of oil, will be another serious cause of concern for the EU, for its implications in terms of GDP growth reduction.

It is also important to mention the international dimension of the transport and energy sectors in a growing **globalisation** and unstable geopolitical context. Given the current dependence on imports, the EU needs to strengthen its relations with the producing countries – in which the key element in energy cooperation is Russia-, and to play a more active role in certain international organizations.

Finally, there is the fact that transport is a fundamental element of the problem of **climate change** and its consequences on the deterioration of the environment. In this sense, it is urgent to take proactive measures to reverse the growing trend in Greenhouse Gas (GHG) emissions to comply with the Kyoto Protocol agreed in 1997.

All the above mentioned concerns have been translated into three essential dimensions: safety, security and protection of the environment (EC, 2004a):

- **Safety and security of transport and energy supply systems:** reducing the risks inherent in systems of mobility or supply, which have been increased by the globalisation of trade. These include:

- **Safety in the mobility of goods and persons**: in the last four years there have been important developments in transport policy standards, as well as the establishment of three European Agencies set up for the maritime, aviation and railway fields, and the set up of a group of experts to advise the Commission on the development of a European policy for the prevention of accidents in all modes of transport, including the transport of energy (oil and gas pipelines).

- **Ensuring transport security**: in response to the terrorist attacks of 11 September, a policy on security in the aviation and maritime fields has also been initiated, as they have been selected as potential targets of malicious action.

- **Ensuring the reliability of the nuclear sector**: dealing with all the risks, whether damages to human health (radiation protection), misappropriation and misuse of nuclear materials (security), or malfunctioning of installations (safety), as well as the environmental risks stemming from the disposal of radioactive waste.

- **Making energy and transport a part of sustainable development:** making Europe both a homogenous area of economic development and an area where the environment in the broadest sense of the term is conserved. The achievement of this overall objective entails:

- **Preventing breaks in the energy system**: this include the regulations needed for the completion of the internal market, the development of trans-European networks (mainly in terms of improving cross-border gas and electricity connections as well as transport), but also the reduction of the heavy structural dependence of EU on energy imports, by means of diversification of energy sources, promotion of energy efficiency and re-balancing between modes of transport to promote the least energy-consuming and emission-contributing.

- **Controlling demand for energy**: including measures such as energy labelling, rationalising the cycle of production, distribution and use of energy, increasing energy efficiency at the stage of the final use of energy.

- **Diversifying supply of energy:** raising the share of new and renewable energy sources, promoting the use of substitute fuels (mainly biofuels), and financing the research and promotion of “more intelligent” energy, with policy packages intended to encourage greater demand management.

- **Combating imbalances in the transport system:** revitalizing rail transport, short sea shipping and inland navigation, supporting the progress of intermodality (e.g. MARCO POLO programme), creating essential infrastructures and technologies to make transport more efficient and fluid (e.g. GALILEO and ERTMS systems), or introducing pricing measures and infrastructure charging for a fair competition between modes.

- **The rights of users and passengers:** European citizens should benefit from equal access to energy products and transport services under acceptable conditions.

STEPs Assessment Criteria

The assessment criteria and corresponding performance indicators, -as defined in D5.1.-are included in Table 5.1. Four main criteria categories have been defined, namely energy (abreviated name for efficiency and security of energy supply), environmental, social and competitiveness.

Table 5.1: STEPs criteria and performance indicators

Criteria categories	Sub-Criteria	Base indicator
Efficiency and security of energy supply	Reducing total energy consumption	Total energy consumption (toE)
	Reducing import dependence	% of energy from imports
	Increasing % of renewables	% of energy from renewable sources
	Reducing energy consumption per unit of transport/economic activity	toE/trip toE/GDP
Environmental	Global warming	CO_2/pers-km, t-km total CO_2
	Emissions of PM/NO_x	PM/NO_x emissions (urban/rural area)
	Emissions of traffic noise	Noise emitted (urban/rural area)
Social	Increasing transport safety	Total Deaths/Injuries
	Improving equity	Territorial cohesion indicators of accessibility, GDP & employment
Competitiveness	Changes in accessibility	% change (each mode)
	Increasing regional GDP	% change GDP
	Increasing employment rates	% change unemployment rates
	Decoupling transport and GDP growth	(%GDP growth-%transport growth)

5.3 Criteria weights

Criteria weights have been defined through a targeted survey performed among experts, academics and stakeholders in the field of transport and energy. Criteria weights have been defined following a direct method, as it is explained in Deliverable 5.1 (see Nijkamp et al., 1990) for a review on existing weight estimation metholodogies), in which each respondent of the survey is asked to distribute a constant number of points (in our case 100) among the objectives distinguished in such a way that the number of points allocated to a criterion reflects its relative importance. The survey obtained a total of 89 responses.

The respondents were also asked to define their role in the decision-making process, among the following categories: scientist, planner, administration, politician, citizen and other.

In order to obtain a base weight profile the average of the responses from each country has been computed[4] and their mean across roles has been computed in order to derive the final values. The resulting base set of weights is included in Table 5.2.

Table 5.2: Base weight profile

Criteria	Sub-criteria	Base Indicator	Weights		
Efficiency and security of energy supply	Reducing total energy consumption	Total energy consumption (toE)	8	28	100
	Reducing import dependence	% of energy from imports	5		
	Increasing % of renewables	% of energy from renewable sources	7		
	Reducing energy consumption per unit of transport/economic activity	Energy/trip (toE/mio. trips)	8		
		Energy/GDP (toE/Euro)			
Environmental	Global warming	CO2/pers-km, t-km (g/km)	10	26	
		Total CO_2 (t)			
	Emissions of PM/NO_x	PM/NO_x emissions (t)	9		
	Emissions of traffic noise	Noise emitted	7		
Social	Increasing transport safety	Total Deaths/Injuries	10	19	
	Improving equity	Territorial cohesion indicators of accessibility, GDP & employment	9		
Competitiveness	Changes in accessibility	% change (each mode)	10	27	
	Increasing regional GDP	% change GDP	5		
	Increasing employment rates	% change unemployment rates	6		
	Decoupling transport and GDP growth	(%GDP growth-%transport growth)	6		

As none of the models provides results covering all the indicators, each model's weighting system is unavoidable different. For that reason, in each model, a 0 weight is assigned when the model does not provide values for the corresponding indicator/criterion, and then the weights are redistributed among the indicators actually produced, keeping the proportions of the four main criteria (energy, environment, social and competitiveness). The resulting particular set of weights of each model can be found in Annex 3.II of Deliverable 5.2.

[4] Annex 3.I in Deliverable 5.2 includes the results of the country-specific weight profiles.

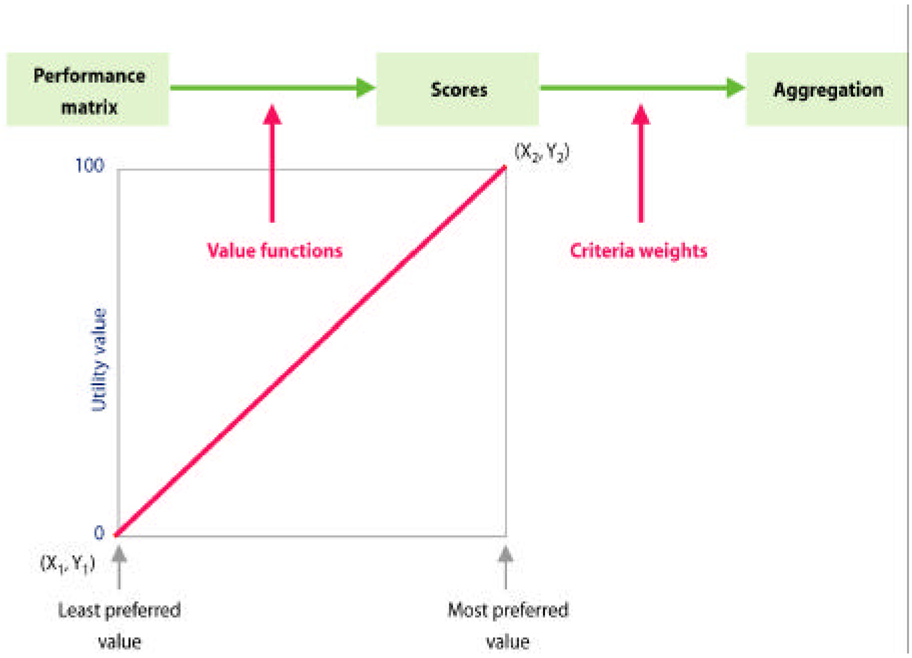
5.4 Value functions

In order to transform the values obtained in each indicator into an utility value, linear value functions have been defined. Figure 5.2 represents the role of the value function in the MCA procedure. The values of the performance indicators predicted by each model in each scenario have been included in Annex 4.I of Deliverable 5.2.

The heterogeneity among models made difficult the definition of common value functions for all the indicators used in STEPs. Therefore, each indicator in each model has a different value function, which has been defined by each of the modellers.

The value function assigns utility values varying from 0 (to the least preferred value) to 100 (to the most preferred value) as Figure 5.2 shows. Least (X_1) and most (X_2) preferred values have been defined to represent points 10% beyond the extreme values of the performance indicators obtained by each model[5]. The definition of the two extremes points (X_1, Y_1) and (X_2, Y_2) of each value functions can be found in Annex 3.III of Deliverable 5.2.

Figure 5.2: Value functions in the MCA procedure



The last step in the MCA process is to apply the linear additive model, which multiplies the score of each indicator by its weight and aggregates them to obtain the utility value[6] of the scenario considered. Figure 5.2 illustrates this explanation.

[5] The specific characteristics of each model allows for some variations in this general rule. Hence, a certain degree of freedom has been left for modellers in the definition of the units in which indicators have been measured and the selection of the least and most preferred options. This holds, e.g., for some Dortmund indicators, which have been standardized in terms of per capita/day.

[6] As justified in Section 5.1., no "global" utility value has been computed in STEPs. Instead, a score representing the performance of each scenario in each of the four categories: energy, environment, social and competitiveness, has been calculated.

Part III: Model Outputs

Part III Summary

Part III includes the STEPs model results, both at the European level (Chapter 6) and the regional/local levels (Chapter 7), while the summary of model results is included in Chapter 8. Starting with the reference scenario, where only the lower growth rate of oil price is modelled, the results show that transport demand is clearly growing both for passengers and for freight, while private car and road freight clearly continue to be the main transport modes. However, total fuel consumption remains largely unchanged over the simulation period due to the evolution of the vehicle fleet. Technical improvements in road vehicles are also clearly evident when considering environmental effects: emissions of local pollutants are decreasing significantly. The exception to this is the rate of emission of greenhouse gases (primarily CO_2): in the Business As Usual scenario the trend is not significantly different to the reference scenario.

In the scenario where a faster growth of oil price is assumed, demand is only slightly reduced (freight demand is more rigid than passenger traffic levels), effects on the economy are negative but of limited size, pollution diminishes further as does energy consumption. In this situation negative effects can result in relation to accessibility. In brief, according to the modelling simulations, the EU transport and economic system could cope with a faster growth of fuel price, assuming that the modelled reactions in terms of improved efficiency are actually put into practice.

The technology investment measures are able to bring about improvements for almost all the variables considered with some local exceptions. Progress is generally made with respect to year 2005 for all indicators, although CO_2 emissions are generally increasing and accessibility levels are diminishing. The demand regulation measures improve most of the variables as well. Improvements concern mainly the same variables that are positively affected by the technology investment 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. Both policy measures are effective at reducing energy consumption as well as greenhouse and local pollutant emissions without a very negative impact on the economic growth. However, demand regulation policies in particular significantly reduce accessibility, i.e. impose constraints on mobility, especially to passengers' private mobility.

CHAPTER 6: Results of the European models

In this chapter the results of the three European models used for the simulation of the STEPs scenarios – POLES, ASTRA and SASI – are presented in detail. Each model has specific capabilities and therefore the presented results differ, at least partially. Notwithstanding this, forecasts concerning the same variables from different models are reported together. 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 could 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 also 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.

6.1 The ASTRA model results

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 values in order to fit them 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. 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.

TEN infrastructures have been introduced into the model indirectly, as ASTRA does not have an explicit network: 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).

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

Main results from the ASTRA model

Economy

Figure 6.1 and Figure 6.2 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 rates. In the technology investments scenarios the growth rate is 2.8.% p.a., which is higher than in the no-policy scenario. 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. In modelling terms, this can be explained in terms of improved efficiency stimulated by the higher price of energy. Instead, 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 GDP 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.

Figure 6.1: ASTRA model results: GDP index development for EU25 (2005 = 100)

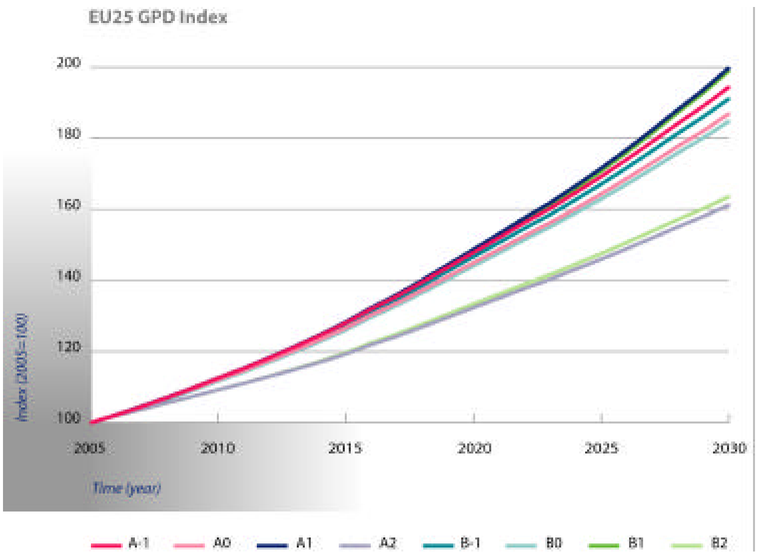
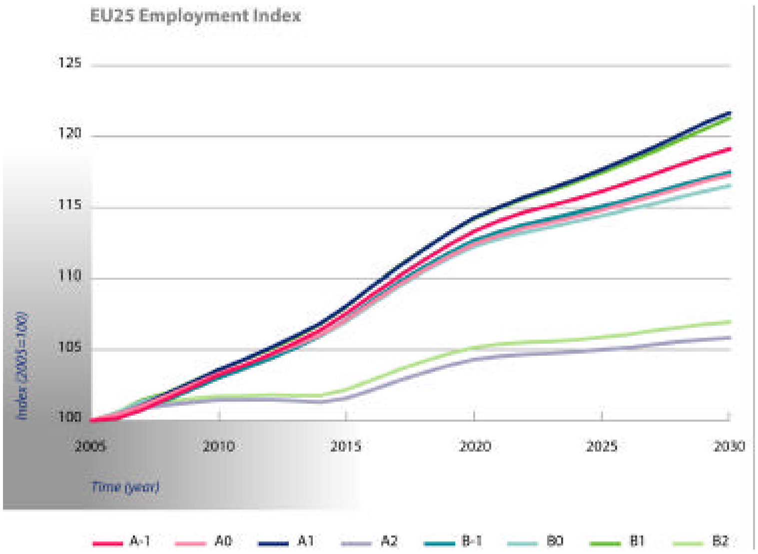


Figure 6.2: ASTRA model results: Employment index development for EU25 (2005 = 100)



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.

Transport demand

Figure 6.3 and Figure 6.4 show how passenger and transport demand are forecasted to develop in EU25 until the year 2030 in the STEPs scenarios. Total passenger demand is increasing in all scenarios. The implementation of the business-as-usual policies brings about a slight growth in passenger traffic. 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 because of a higher car ownership and of some demand shift to rail, whose average distance is longer.

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 6.4) it can be noticed that in all scenarios transport demand at 2030 has not increased above that in 2005 and is 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.

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 future. In the policy scenarios, total tonnes-km are even more than in the A0 scenario (Figure 6.5), 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[1]. 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 6.3: ASTRA model results: Pass-km index development for EU25 (2005 = 100)

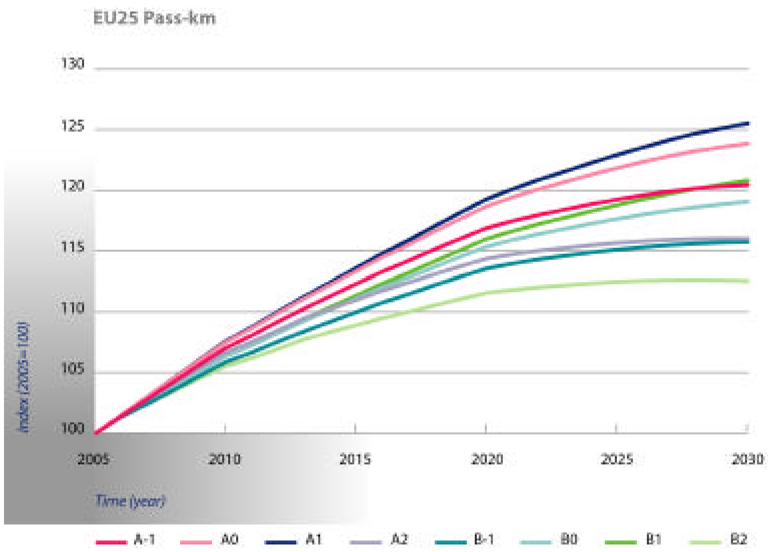
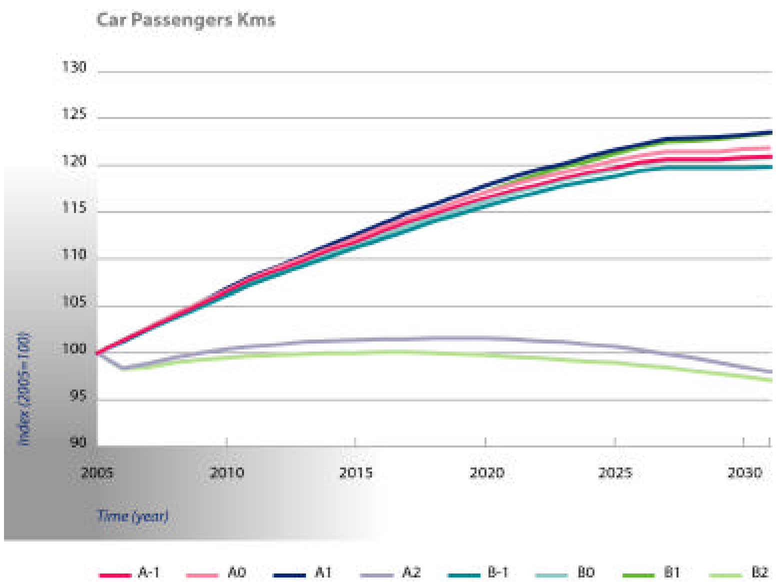
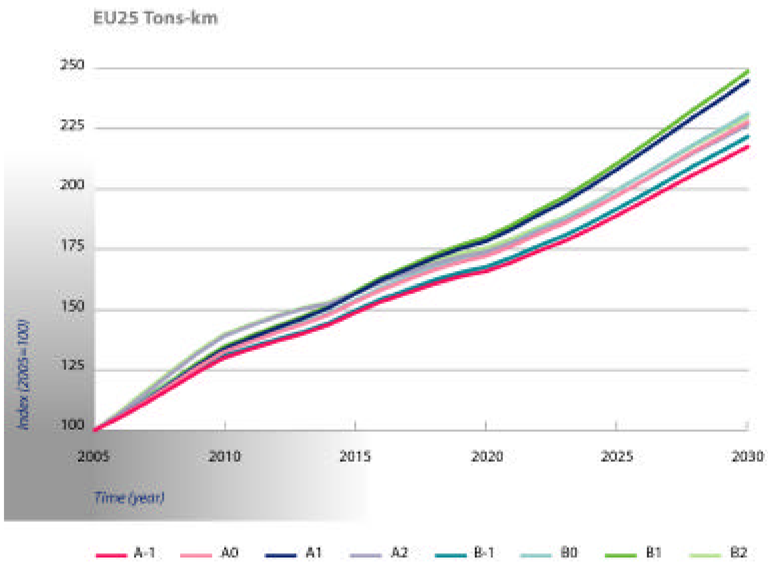


Figure 6.4: ASTRA model results: Car pass-km index development for EU25 (2005 = 100)



[1] 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

Figure 6.5: ASTRA model results: Tons-km index development for EU25 (2005 = 100)



Freight mode shares

Table 6.1 shows 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 is an improvement 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.

Table 6.1: ASTRA model results: 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%**

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, including the A0 scenario, 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 the 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 particularly through the renewal of car fleet. If fuel price increases faster, as 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. In this respect, demand regulation scenarios (A2 and B2) are more effective than technology investments scenarios (A1 and B1).

Figure 6.6: ASTRA model results: Emissions of CO_2 for EU25 in the STEPs scenarios

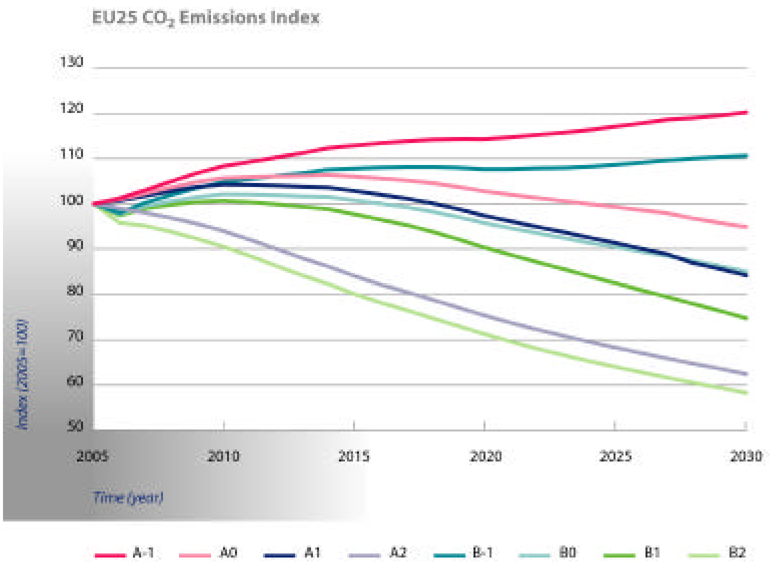
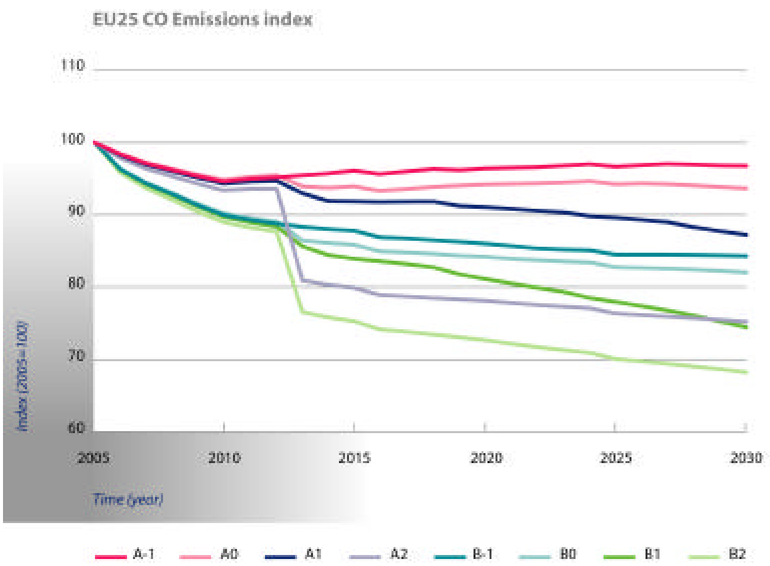


Figure 6.7: ASTRA model results: Emissions of CO for EU25 in the STEPs scenarios



6.2 The POLES model results

Implementation of the scenarios in the POLES model

POLES is an energy model which deals with energy supply and demand market and it is 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.

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.

Main results from the POLES model

Economy: fuels consumption and fuels prices

Fuel consumption (Figure 6.8) decreases in all the scenarios as the difference in the oil price increases faster with respect to the A0 scenario. Energy shortages represented by the high oil price growth scenarios (B scenarios) lowers 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.

The resource cost of fuel in the business-as-usual alternatives and the demand regulation scenarios are very similar, However, the difference in the fuels prices between the high and the low oil price growth scenarios is very marked. Within each set 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.

Figure 6.8: POLES model results: Average fuel consumption change for EU 25 (2005=100)

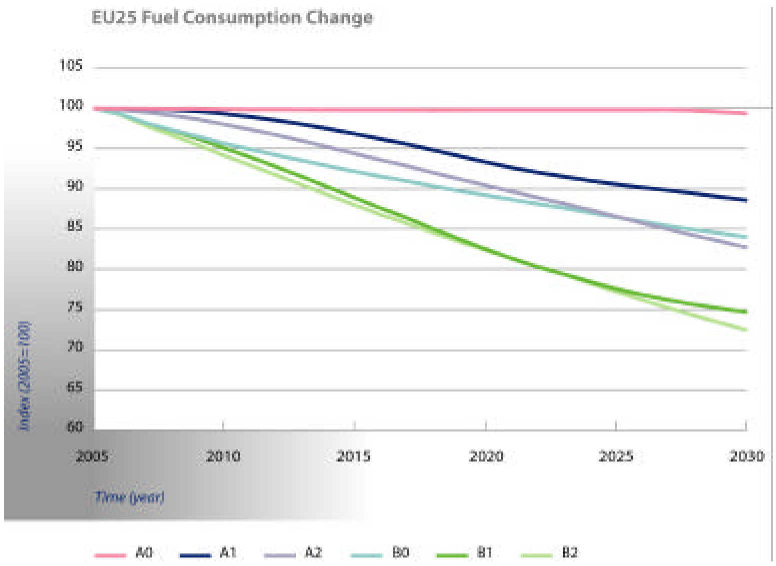
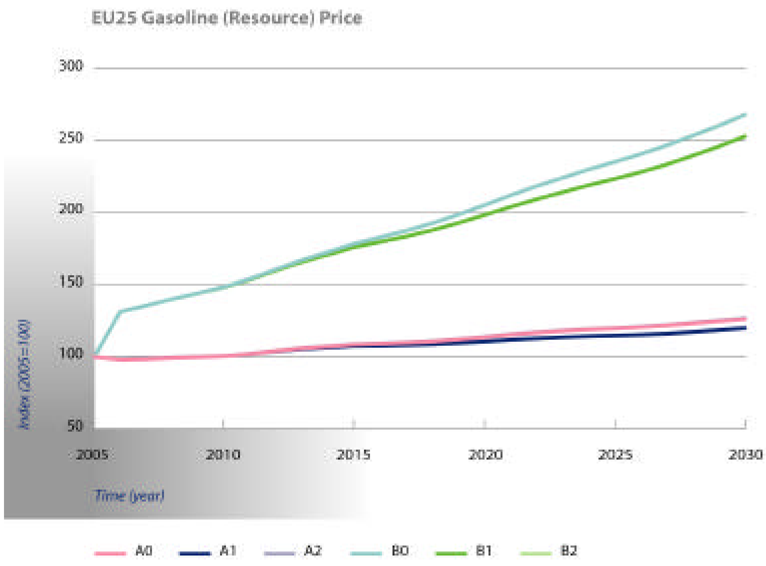


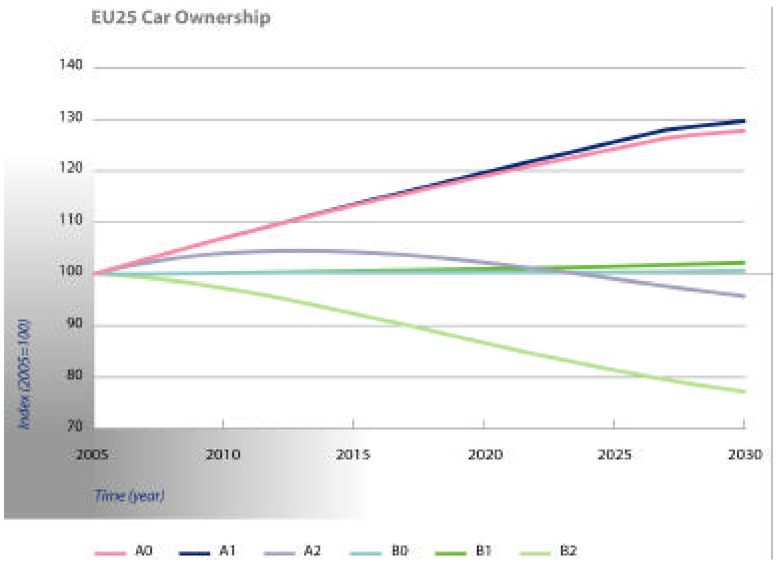
Figure 6.9: POLES model results: Average gasoline (resource) price for EU 25 (2005=100)



Society

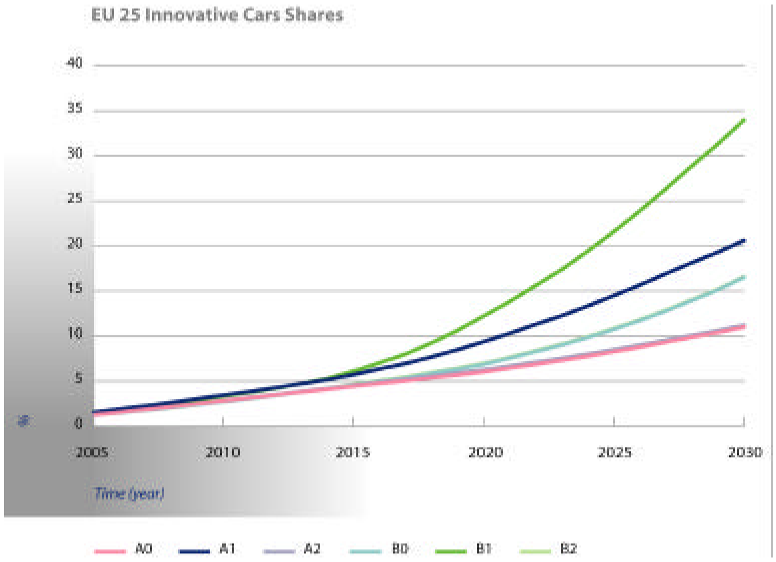
Car ownership increases significantly and consistently in A0 and A1 scenarios, while it decreases strongly in the B2 scenario. The application of demand regulation measures in the A2 scenario decreases the car ownership level from around the year 2025. Scenarios B0 and B1 show relatively very little 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.

Figure 6.10: POLES model results: Car ownership level for EU 25 (2005=100)



Innovative (electric, hybrid, natural gas, and fuel cell) cars shares increase continuously in all scenarios (Figure 6.11). 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 6.11: POLES model results: Innovative cars shares (%) for EU 25



Energy

The following tables report the impact of the scenarios on two indicators concerning the use of energy. Table 6.2 shows the development of the dependency of the EU on external 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.

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 6.2: POLES model results: % 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%

Table 6.3: POLES model results: % 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%

6.3 The SASI model results

Implementation of the scenarios in the SASI model

The SASI model was used to simulate all the fifteen modelling scenarios defined, i.e. including the scenarios defined to examine the effects of more comprehensive policy combinations (A3, B3 and C3) and those including even stronger fuel price increases (C scenarios). It is worth to mention that in the SASI model, the assumptions concerning the fuel price increment have been applied to the fuel pump price and not on fuel resource price (i.e. net of taxes). In this way, the impact of the increment is larger as, implicitly, also a proportional increment of fuel taxes is considered.

The only regional model to use the forecasts of regional economic development from the SASI model was the Dortmund model (see Section 7.2). 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.

Main results from the SASI model

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 6.12; the corresponding diagram for freight based on road and rail is displayed in Figure 6.13.

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 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 or through a reduction of rail fares per km. For passenger travel, the magnitude of the negative impact depends primarily on the assumption about fuel cost.

The different policy scenarios result in different spatial patterns of accessibility change. Figure 6.14 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 leads to gains in accessibility in several regions, especially of the new member states. 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.

Figure 6.12: SASI model results: accessibility road/rail/air travel 1981-2031 (million)

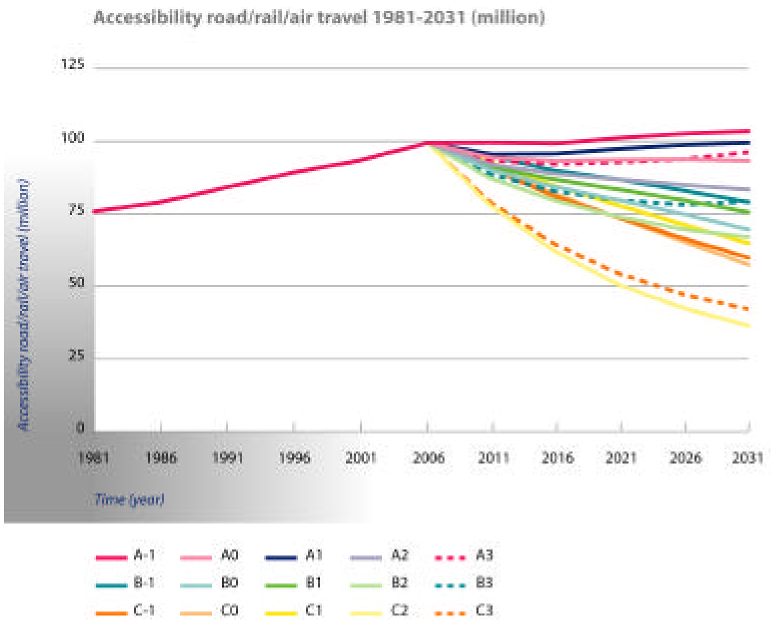


Figure 6.13: SASI model results: accessibility road/rail freight 1981-2031 (million)

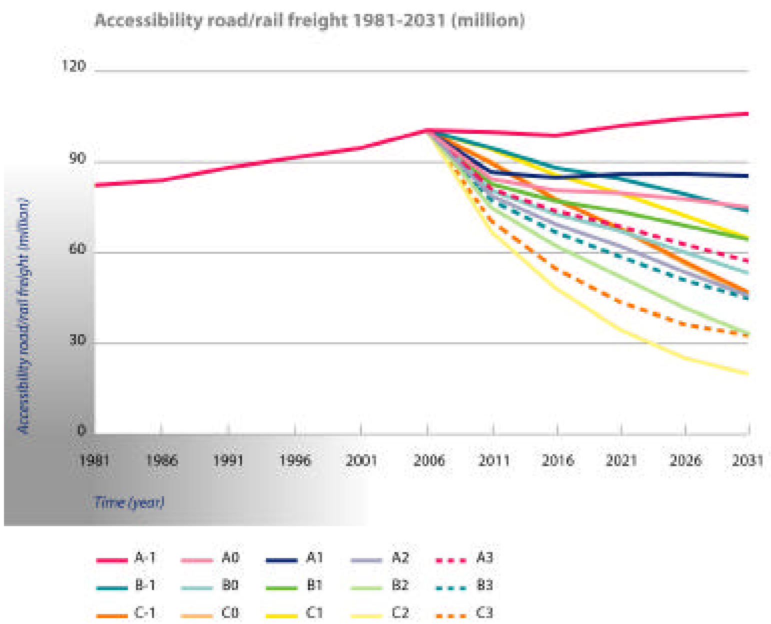
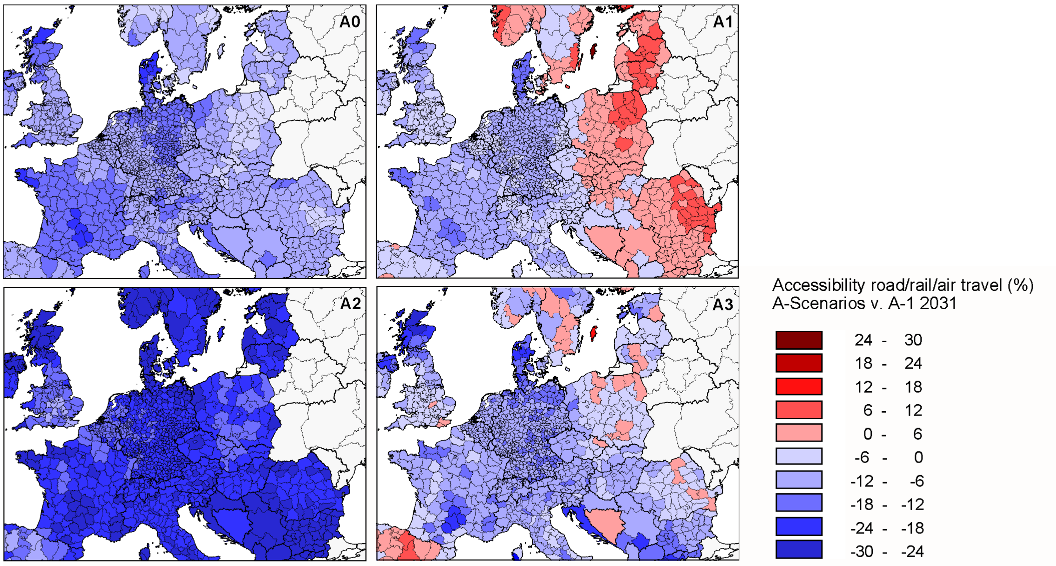


Figure 6.14: SASI model results: accessibility road/rail/air travel, Scenarios A0 to A3, difference to Scenario A-1 2031 (%)



Economy

The development of GDP is shown in Figure 6.15 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. The reduced economic growth results in less employment in all scenarios than in the A1 Scenario (Figure 6.16). The employment curve follows also the population decline. Not a single policy scenario brings a net addition to jobs. More 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 the transport policies.

Figure 6.15: SASI model results: GDP per capita 1981-2031 (1,000 Euro of 2005)

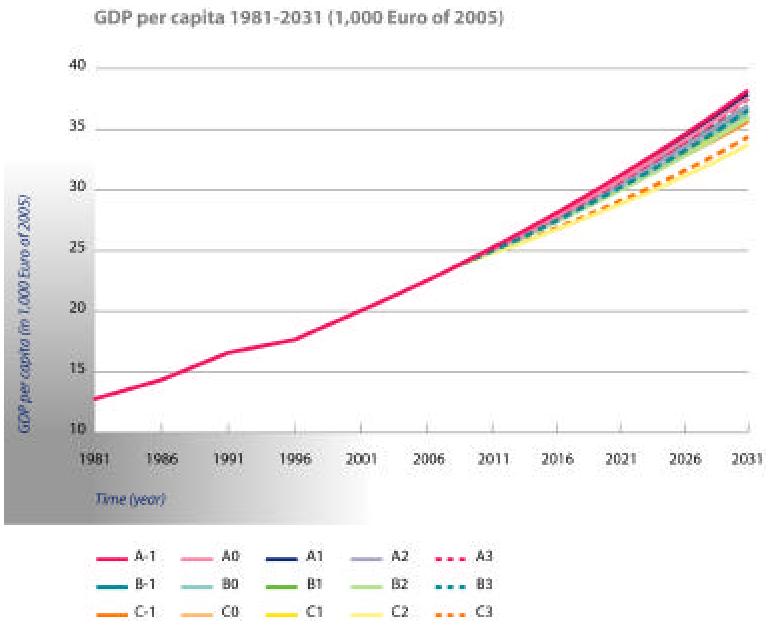
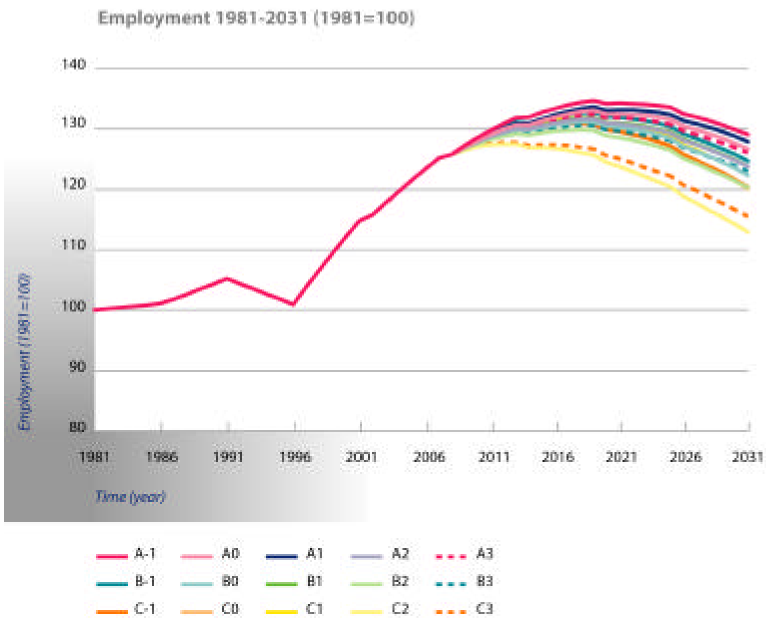
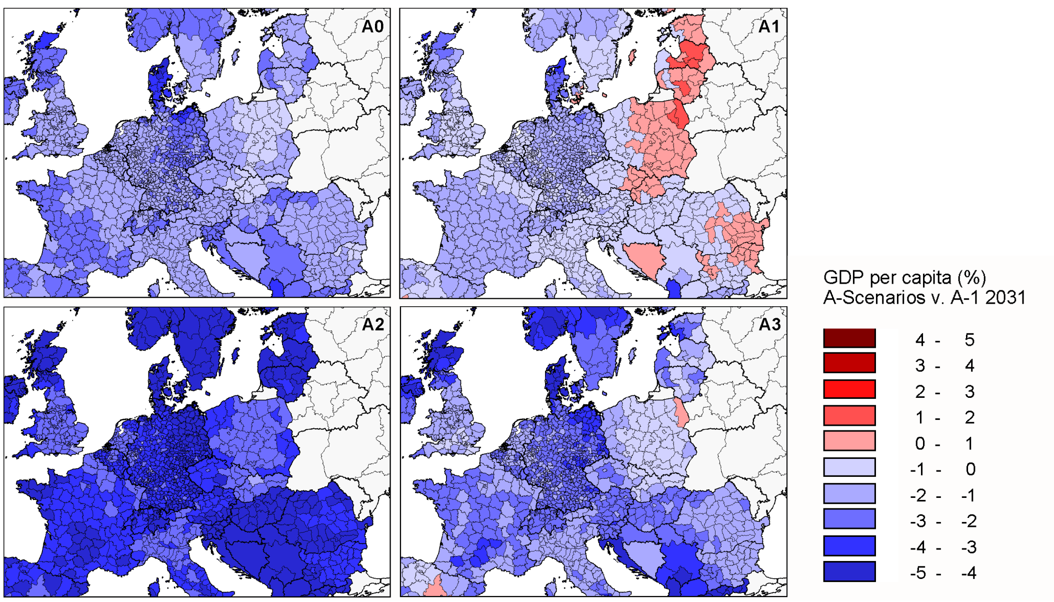


Figure 6.16: SASI model results: employment 1981-2031 (1981=100)



The spatial distribution of scenario effects is presented in Figure 6.17 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, do some regions have a better economic performance than in the A1 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 6.17: 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.

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. 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.

CHAPTER 7:Results of the regional models

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 as in discussing the European-wide models in Chapter 6, addressing separately the impacts on different systems: transport demand, economy, environment, energy, etc.

7.1 The Brussels model results

Implementation of the scenarios in the Brussels model

Most of values implemented as scenarios inputs have been taken from the POLES/ASTRA models:

- *car ownership* (the absolute value computed endogenously have been used for the base year, the POLES/ASTRA differences for each scenarios have been integrated in relative terms);
- fuel consumption percentage change;
- fuel resource cost;
- fuel taxes;
- emissions factors CO, CO_2, NO_x and VOC;
- cold emissions factors.

Main results from the Brussels model

Demand and Mode shares

Changes of PCU*km and car trips (see figures below) are forecasted to develop in a similar way, however the number of trips seems to be more sensitive to the variation of costs while the amount of vehicle*km seems to be more sensitive to the variation in car ownership.

Figure 7.1: Brussels model results: Representation of trips for the period 6PM-10PM for the years 2005, 2015 and 2020.

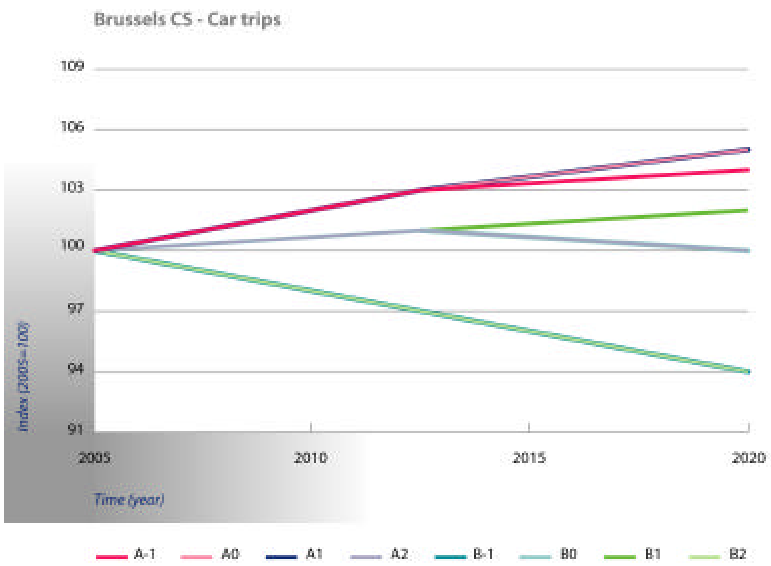
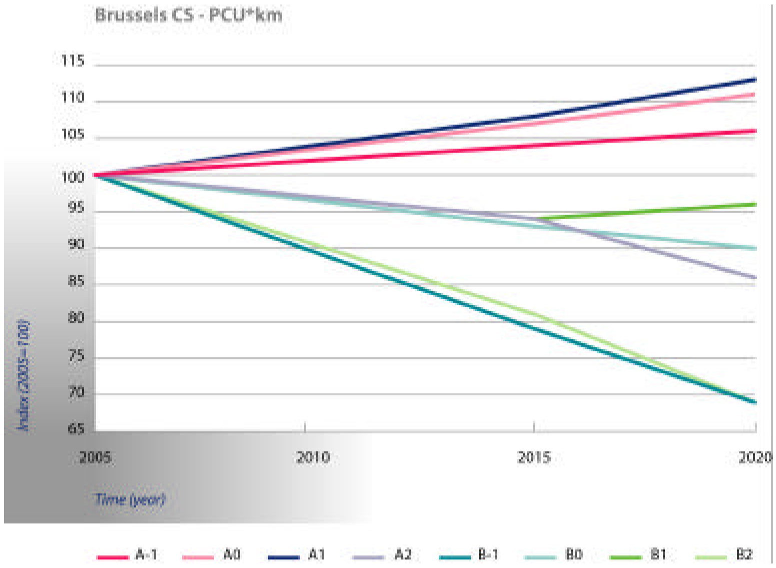


Figure 7.2: Brussels model results: PCU*km for the period 6PM-10PM for the years 2005, 2015 and 2020



The following figures presents for the different scenarios the modal shares forecasted by the Brussels model.

Figure 7.3: Brussels model results: Private car share index for the 8 scenarios for the years 2001, 2015 and 2020

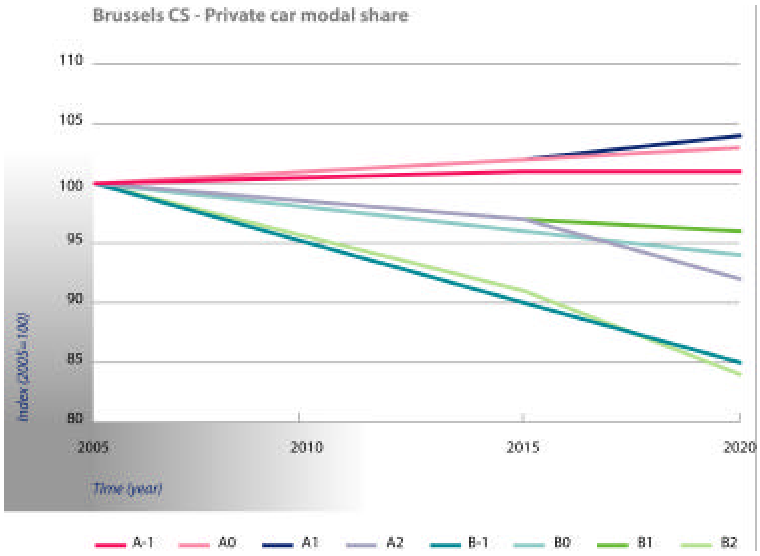
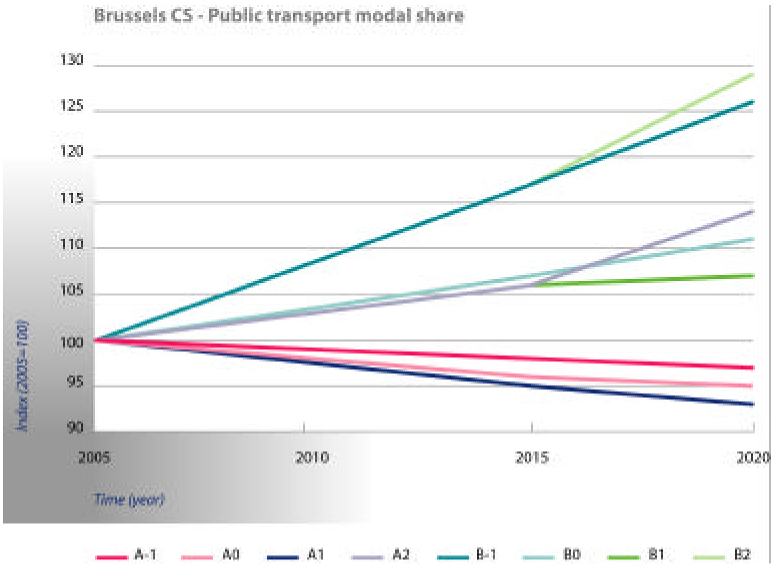


Figure 7.4: Brussels model results: Public transport share index for the 8 scenarios for the years 2001, 2015 and 2020



Average trip lengths

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

Table 7.1: Brussels model results: Evolution of average distance per car trips for the 8 scenarios for the years 2015 and 2020

	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

Energy

The main changes on the energy consumption side 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.

Table 7.2: Brussels model results: Consumptions for the for the 8 scenarios for the year 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
Hydrogen [kg]	273	7.818	9.529	6.230	146	6.160	11.653	4.173

Environment

The following figures show the pollutant emissions. The scenarios with the highest positive impact on environment are the Demand scenarios.

Figure 7.5: Brussels model results: CO emissions (period 6PM-10PM) index for the 8 scenarios and the time horizon 2005, 2015 and 2020

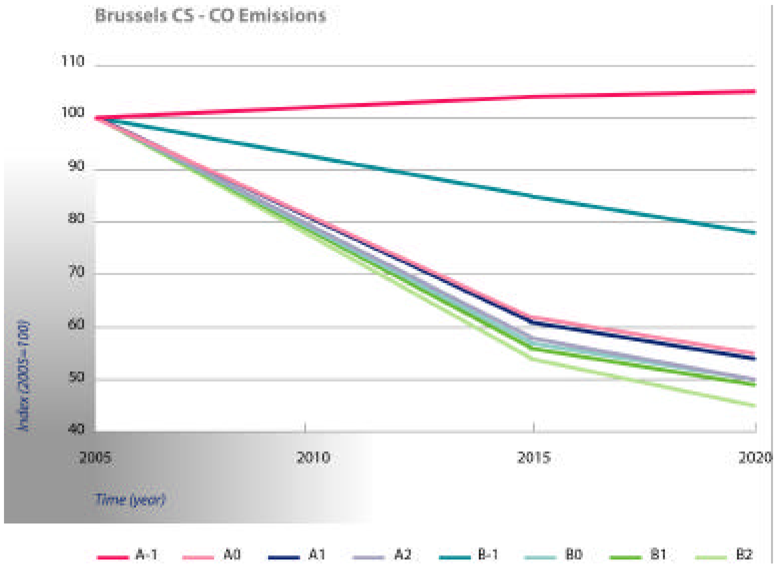
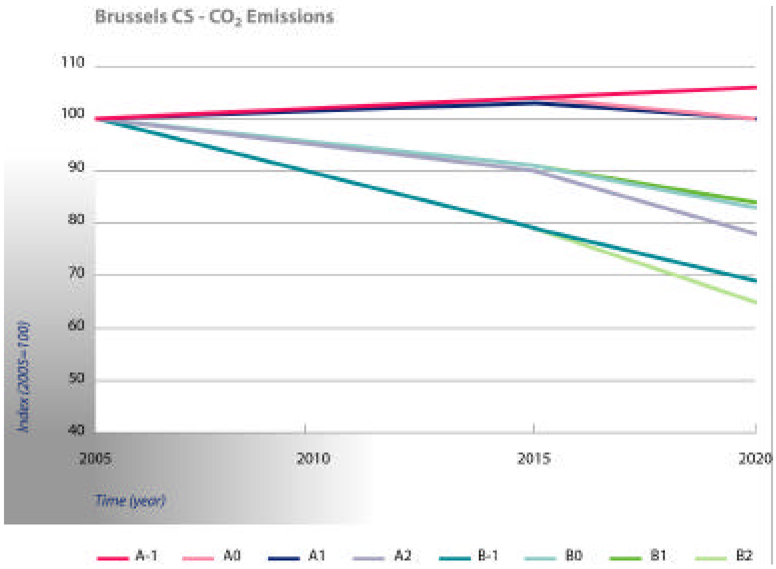


Figure 7.6: Brussels model results: CO_2 emissions (period 6PM-10PM) index for the 8 scenarios and the time horizon 2005, 2015 and 2020



7.2 The Dortmund model results

Implementation of the scenarios in the Dortmund model

The Dortmund model was used to simulate all the fifteen modelling scenarios defined, i.e. including the scenarios defined to examine the effects of more comprehensive policy combinations (A3, B3 and C3) and those including even stronger fuel price increases (C scenarios). In the Dortmund model, like in the SASI model, the assumptions concerning the fuel price increment have been applied to the fuel pump price and not on fuel resource price (i.e. net of taxes). In this way, the impact of the increment is larger as, implicitly, also a proportional increment of fuel taxes is considered.

All scenarios simulated with the Dortmund model were linked to the results of the SASI model (see Section 6.3) 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.

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, the same network scenario was used for all scenarios. Instead, different assumptions about general changes of travel times and travel costs were made for each scenario according to the scenario assumptions and these were applied to the travel times and travel costs derived from the common network scenario.

Main results from the Dortmund model

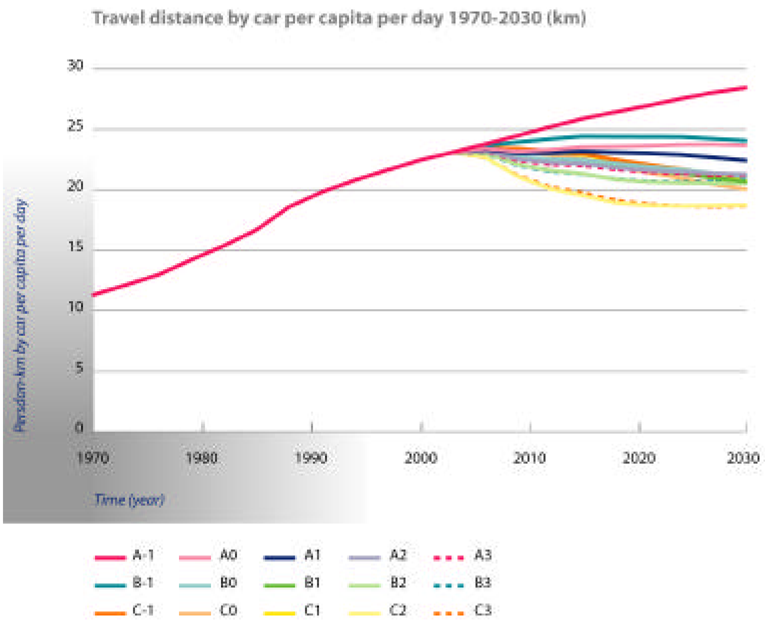
Transport

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.

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 in the urban area (Figure 7.7) have more than doubled since 1970. Compared to this growth, the reductions in distance travelled predicted by the model appear rather small.

Figures 7.8 and 7.9 show that in all scenarios the proportion of public transport trips go up and the proportion of car trips goes down compared with the Scenario A-1. 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.

Figure 7.7: Dortmund model results: Travel distance by car per capita per day 1970-2030 (km)



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 fuel pump price per litre is forecasted to be 22 Euro (in 2005 Euros) whereas household incomes should grow by about ten percent less than in the Scenario A-1. The distance-reducing effects of fuel price increases can also be seen.

Figure 7.8: Dortmund model results: Share of public transport trips 1970-2030 (%)

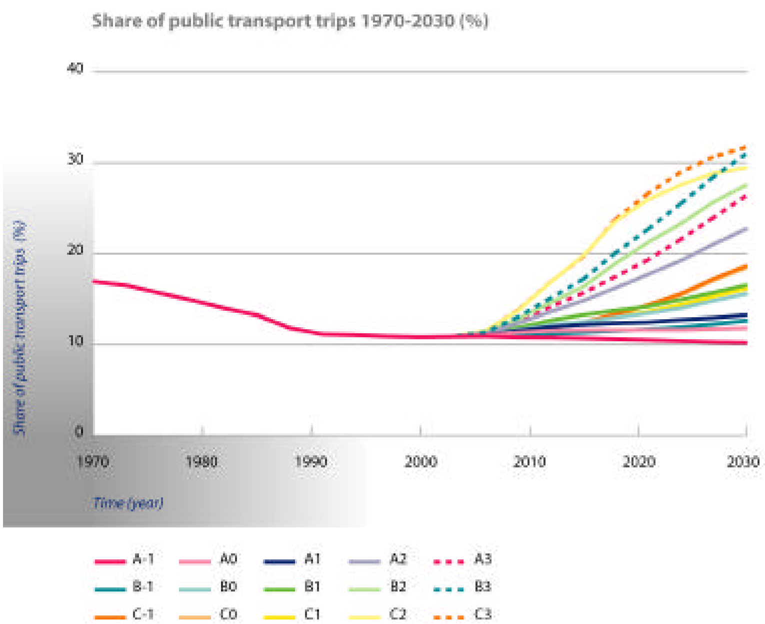
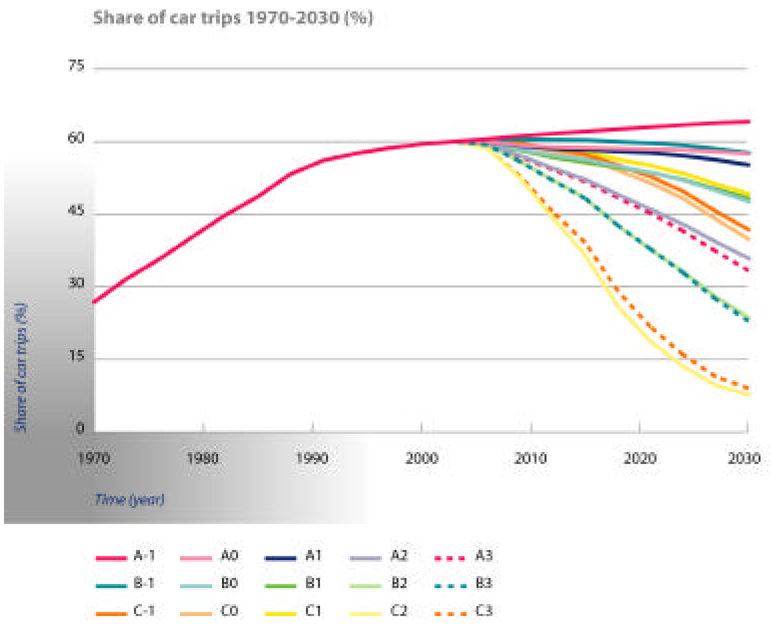


Figure 7.9: Dortmund model results: Share of car trips 1970-2030 (%)



Energy and environment

Again the major factor influencing fuel savings is fuel price (Figure 7.10). 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. 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).

All scenarios have significant impacts on future CO_2 emissions, i.e. lead to strong reductions (Figure 7.11). 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. Whereas there is no further reduction in NOx emissions in the A-1 Scenario, PM emission will further decline through the more restrictive regulations for diesel cars. The reductions of NOx and PM emissions through fuel cost increases and related policies are similar to those of CO_2.

Figure 7.10: Dortmund model results: Car fuel consumption per capita per day 1970 -2030 (l)

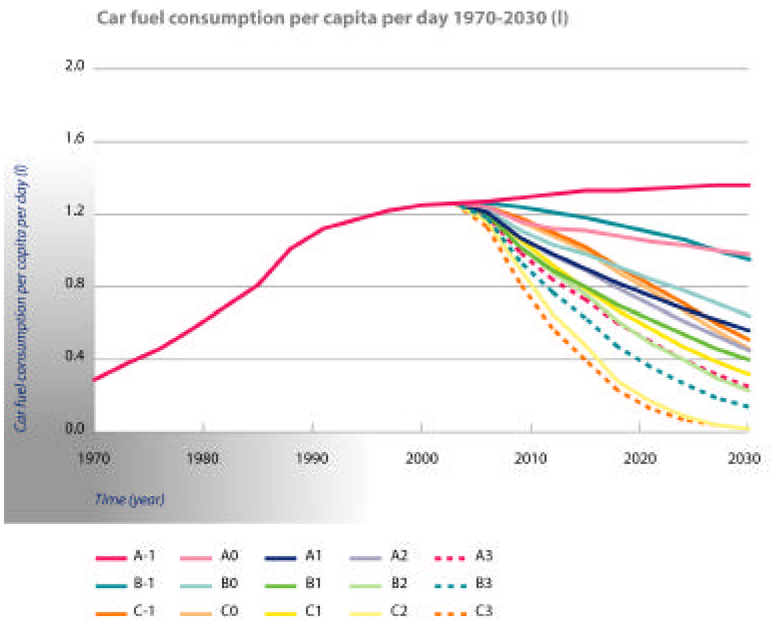
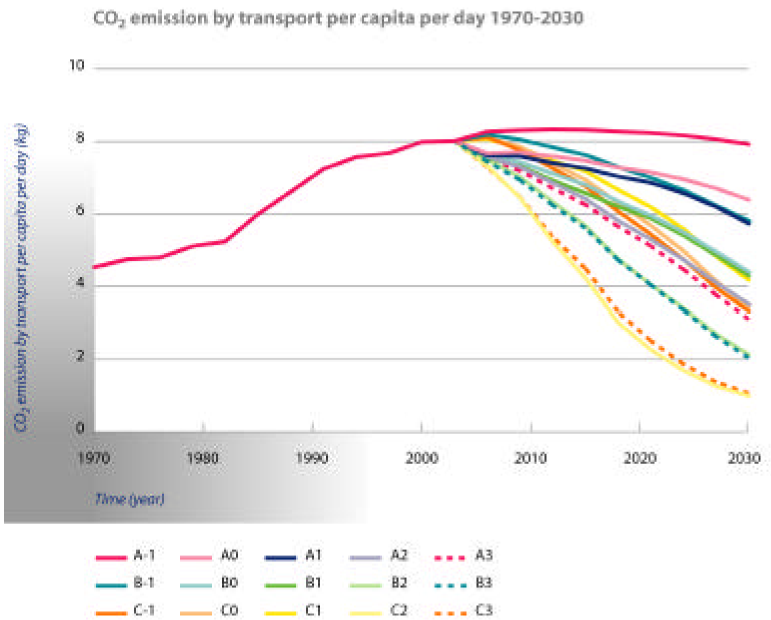


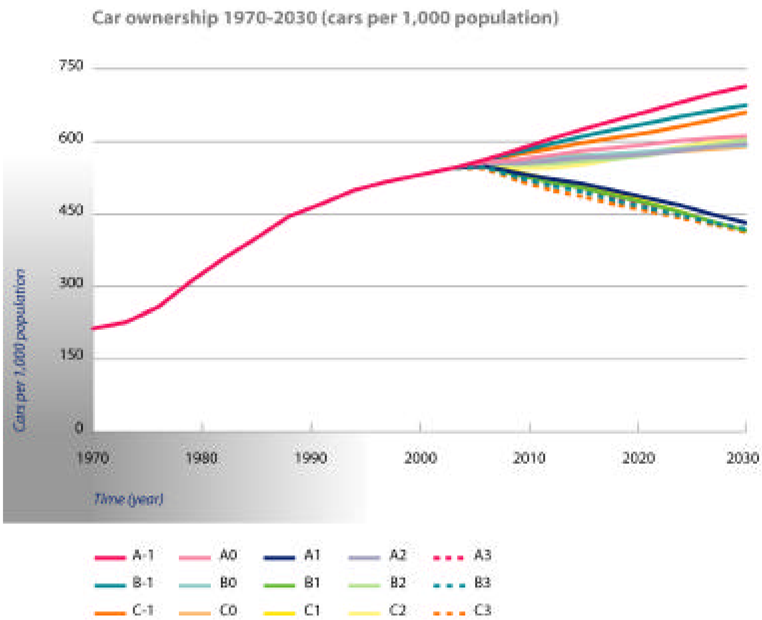
Figure 7.11: Dortmund model results: CO_2 emission by transport per capita per day 1970 -2030



Society

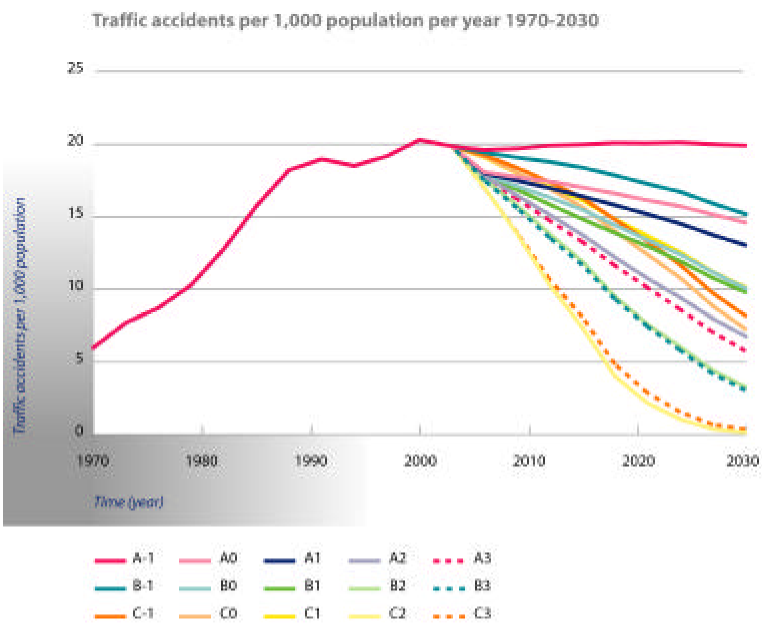
The fuel price increases and policies assumed in the scenarios have significant impacts also on the economic situation and quality of life of households. In all scenarios car ownership is lower than in the Scenario A-1 (Figure 7.12). Even in the demand regulation scenarios car ownership remains at a 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) the higher costs of alternative vehicles are assumed to affect 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.

Figure 7.12: Dortmund model results: Car ownership 1970-2030 (cars per 1,000 population)



As far as safety is concerned, one of the few positive side-effects of increasing fuel prices is that with declining car traffic roads become safer (Figures 7.13).

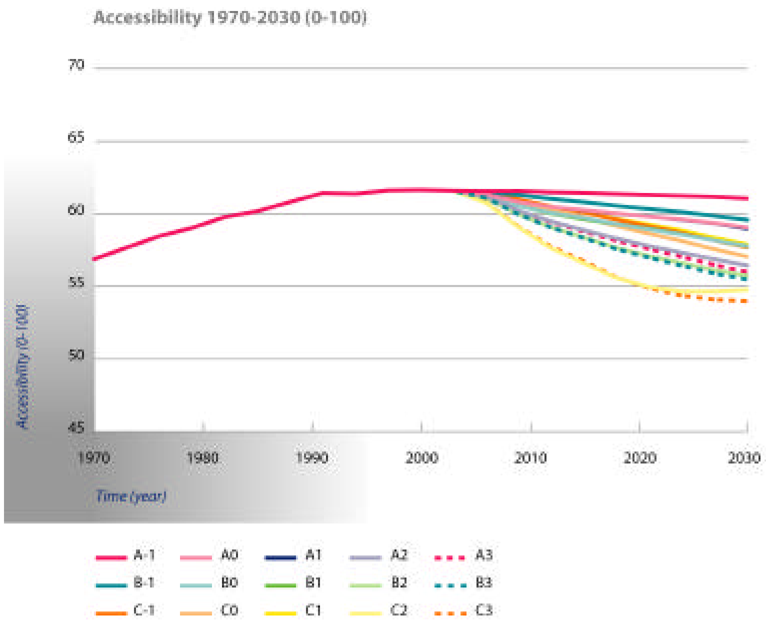
Figure 7.13: Dortmund model results: Traffic accidents per 1,000 population per year 1970-2030



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 7.14 shows the development of the 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 and the resulting decline in average trip speeds. The decline in accessibility would be even larger without the massive shifts to more nearby destinations. 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.

Figure 7.14: Dortmund model results: Accessibility 2005-2030 (0-100)



Land use

The massive outflow of people to the suburbs in the last decades would not have been possible without the automobile and cheap fuel. 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 not 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. 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 7.15 and 7.16 show the development of the shares of population and employment in three subregions of the Dortmund metropolitan area: the central area, the inner suburbs and the outer suburbs. In the 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 from the outer suburbs to the inner suburbs and the central area.

Figure 7.15: Dortmund model results: Share of population in subregions 1970-2030 (%)

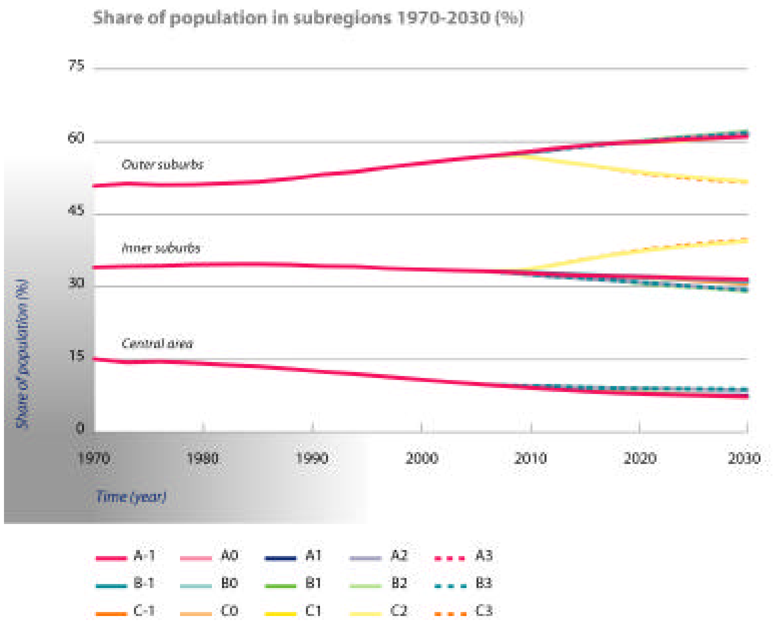
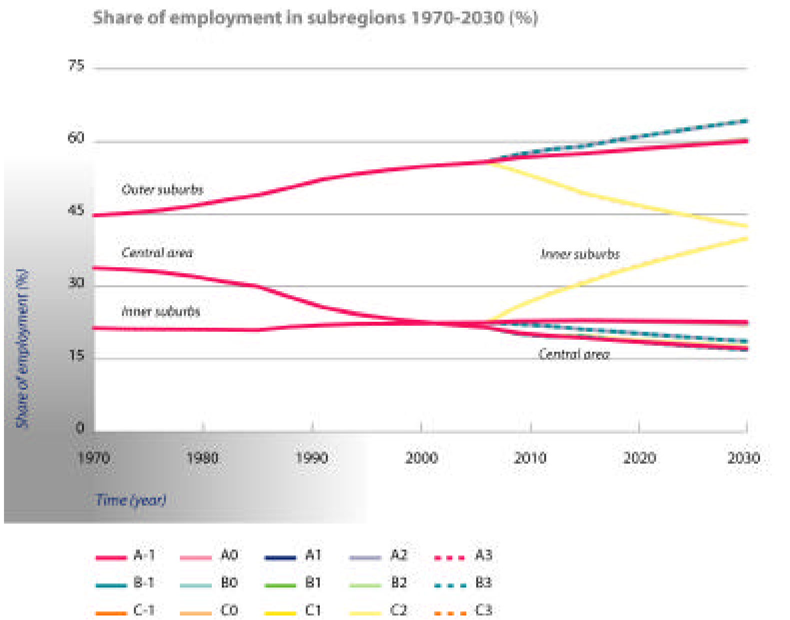


Figure 7.16: Dortmund model results: Share of employment in subregions 1970-2030 (%)



7.3 The Edinburgh model results

Implementation of the scenarios in the Edinburgh model

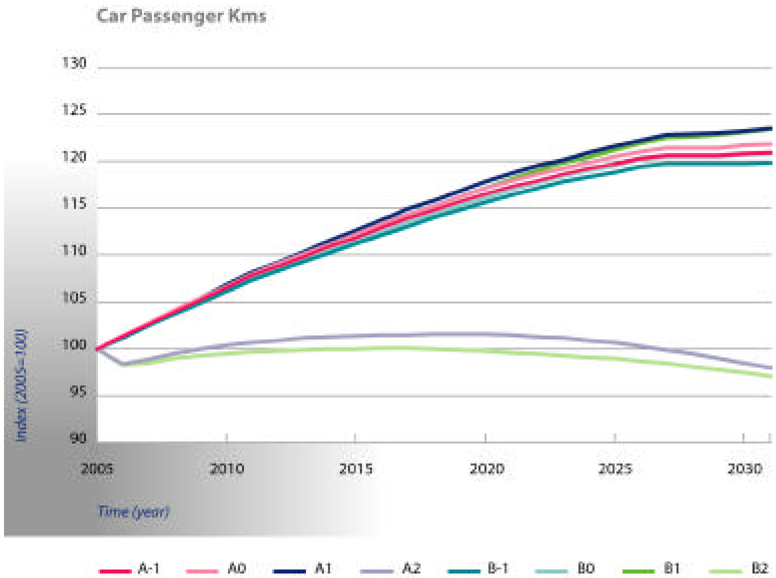
The Edinburgh model has taken the resulting fleet composition and emission factors from the POLES/ASTRA runs for each scenario. As can be seen from the following analysis, the resulting fleet composition differs from the suggested fleet shares (from Chapter 3) and responds not only to the technology 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.

Main results from the Edinburgh model

Demand and mode shares

Figure 7.17 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.

Figure 7.17: Edinburgh model results: Car passenger-km Index over time



As expected the impact on mode share can be viewed in pairs of scenarios (Figures 7.18 and 7.19). 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. 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 7.18: Edinburgh model results: Trip mode share trajectories for car

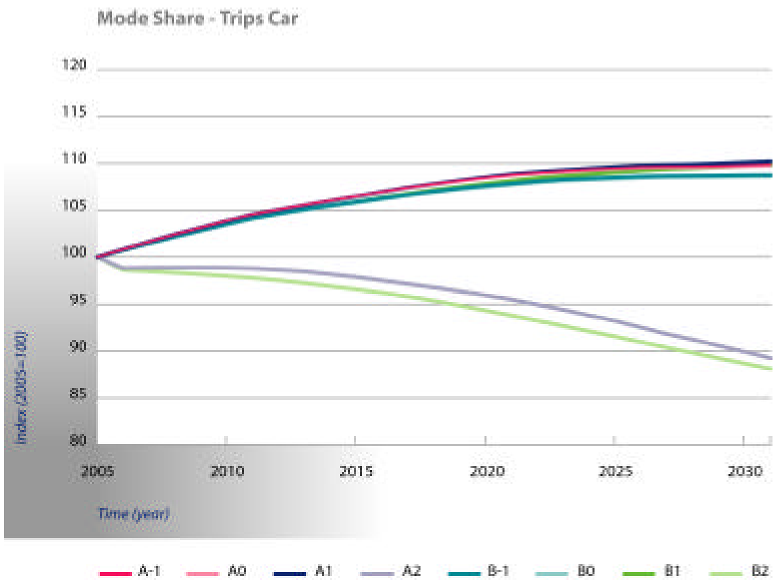
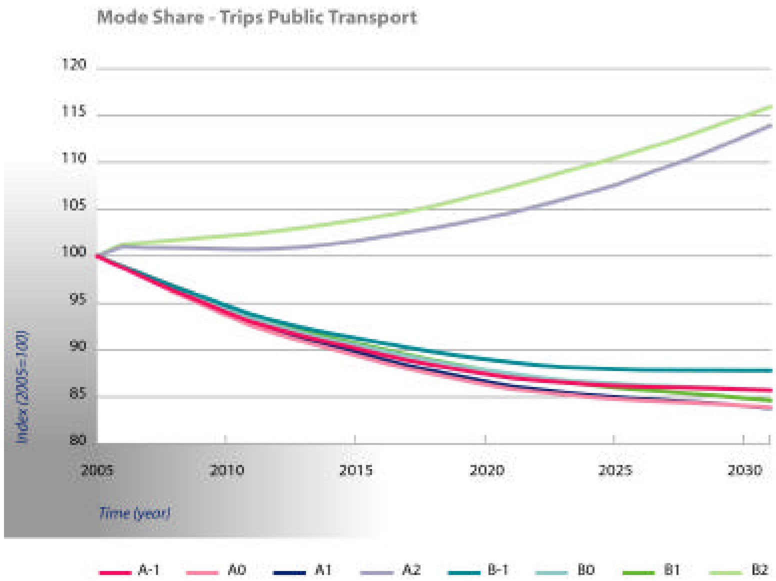


Figure 7.19: Edinburgh model results: Trip mode share trajectories for public transport.



Average speeds

Figures below show the average speeds for public transport and car trips. These are door-to-door speeds and include all access, egress, waiting and parking search tmes. 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. Within the technology investments scenarios A1/B1 the increased speed for public transport in the peak results in similar speeds as for car use. Under the demand regulation scenarios A2/B2 speeds are actually increased slightly compared to 2005. 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.

Figure 7.20: Edinburgh model results: Average car speed peak period

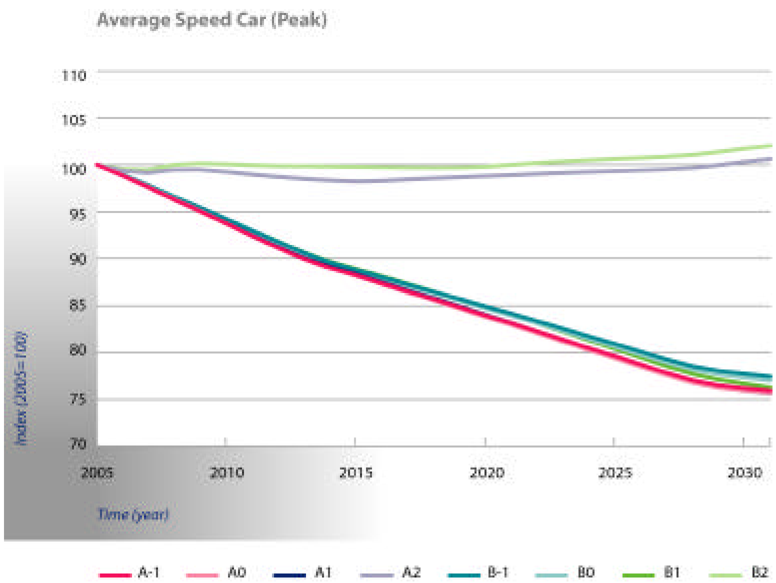
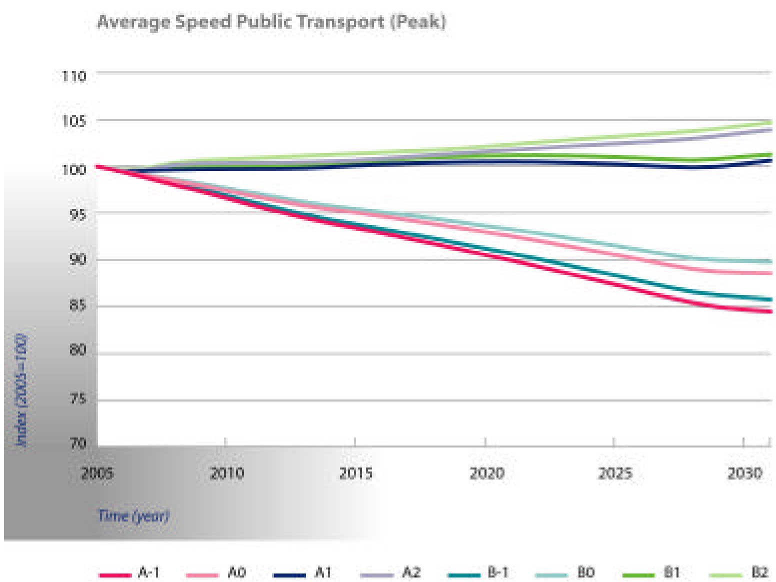


Figure 7.21: Edinburgh model results: Average speed public transport peak period



Average trip lengths

Table 7.3 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.

Table 7.3: Edinburgh model results: 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
Car	14.2	14.6	14.6	14.6	13.1	14.5	14.4	14.6	13.0

Energy and environment

Even 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 2030 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.

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. Also the trajectories for PM 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 7.4: Edinburgh model results: Emissions of CO_2, NO_X and PMs.

	2005	2030							
		A-1	A0	A1	A2	B-1	B0	B1	B2
CO_2 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
Total NOx Pump-Wheel (tons/year)	2628	935	938	771	727	826	829	613	650
Total PM Pump-Wheel (tons/year)	123	55	55	46	42	48	49	36	37

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 7.5: Edinburgh model results: 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
Accidents per year	1791	2005	2014	2044	1691	1992	2002	2040	1666

Revenue from charges on car use

Table 7.6 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-asusual 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. 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 7.6: Edinburgh model results: 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
Revenue Road charge	54.8	60.6	60.9	61.7	461.2	60.1	60.5	61.5	452.3

7.4 The Helsinki model results

Implementation of the scenarios in the Helsinki model

Helsinki model tests have been defined based on the scenarios 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 improvements in public transport services have 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 consists of a resource costs part (€ /litre) and an 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).

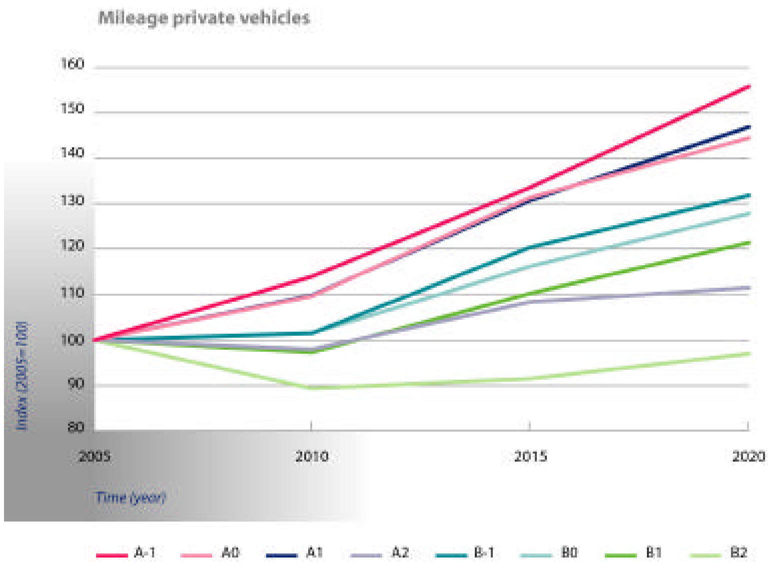
The fixed emission factors for Finland provided by ASTRA/POLES results for an average vehicle of the car fleet and the fuel price (comprehensive of pure fuel cost and fuel taxes) have been used for each technology and road type pair. The division of the fleet into different technologies follow also the 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.

Main results from the Helsinki model

Transport demand and modal shares

The growth of passenger kilometres 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.

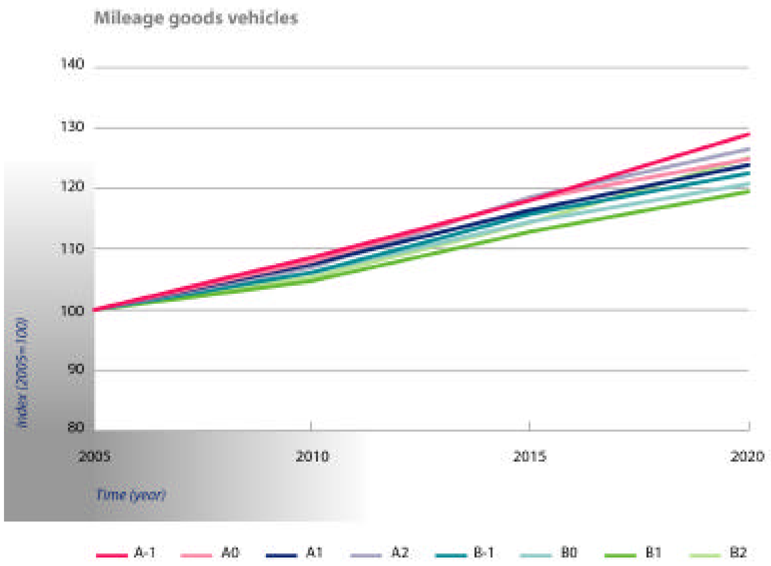
Figure 7.22: Helsinki model results: Total private vehicles mileage index in the eight scenarios



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 7.23), 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 transport.

Figure 7.23: Helsinki model results: Mileage index for goods vehicles in the eight scenarios



Change of modal shares for public transport and private cars are illustrated in Figure 7.24 and. Figure 7.25. 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.

Figure 7.24: Helsinki model results: Modal share development for public transport

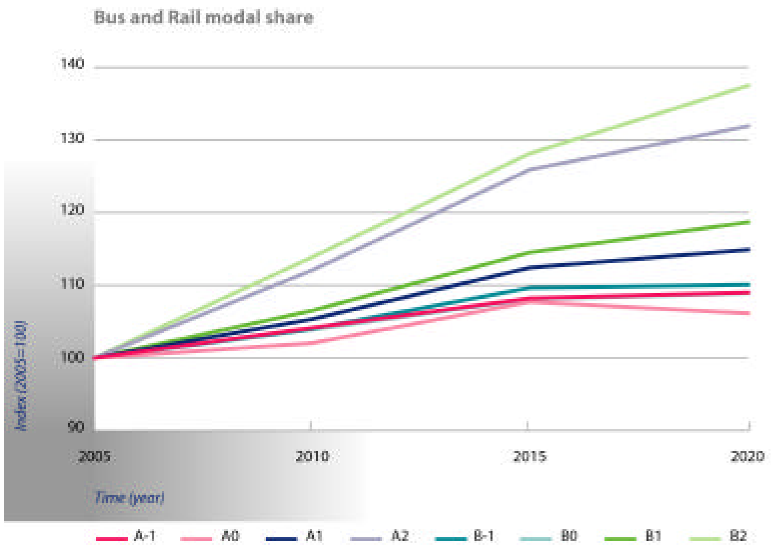
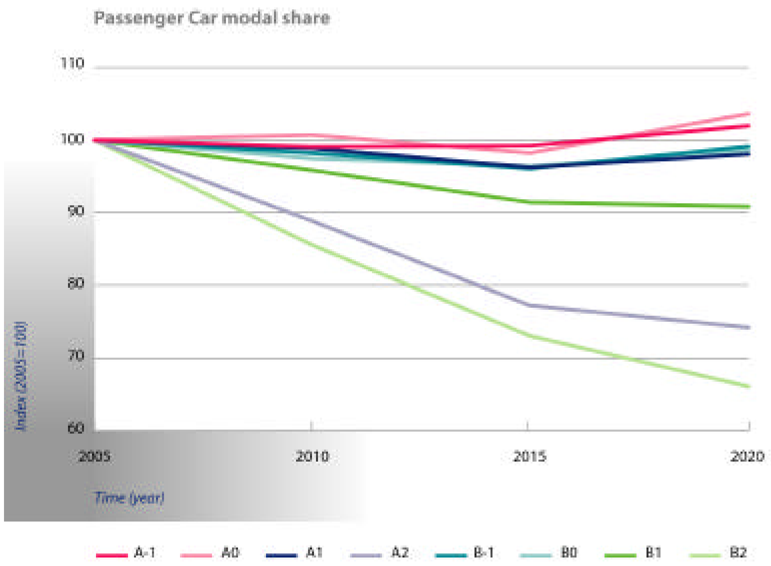


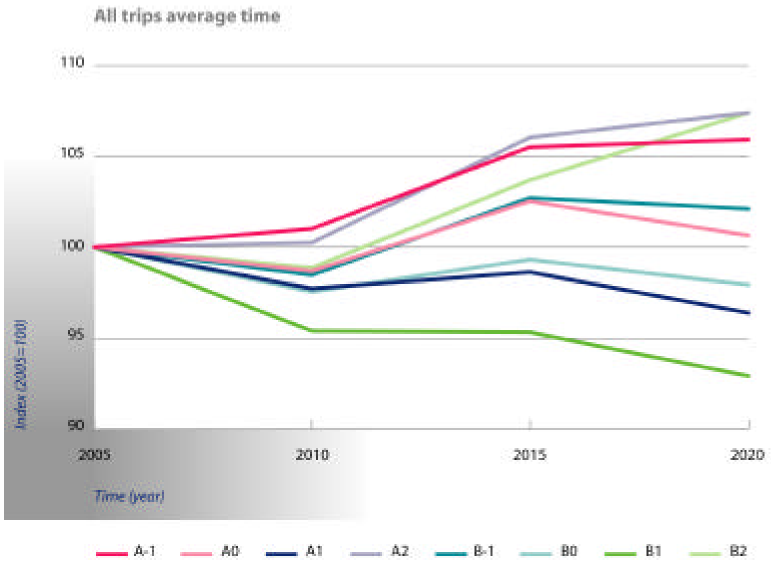
Figure 7.25: Helsinki model results: Modal share development for private cars



Trip length and travel time

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. The figure below 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.

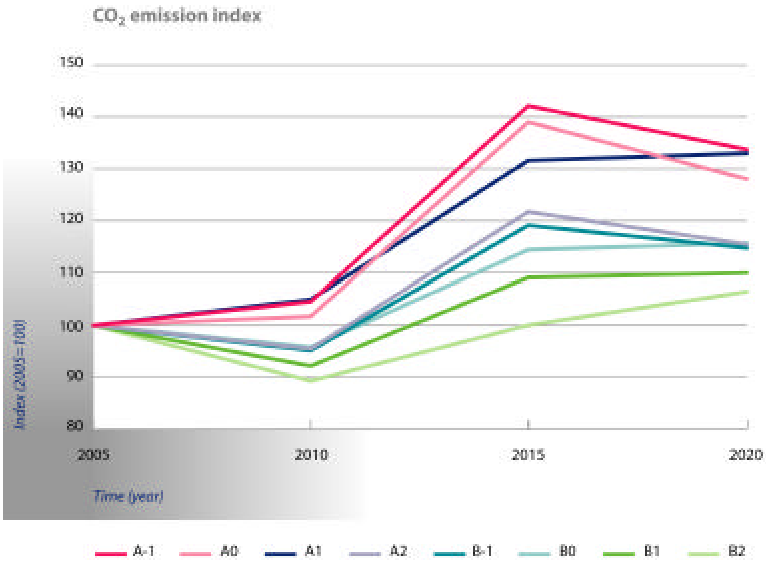
Figure 7.26: Helsinki model results: Average travel time index for all trips



Environment

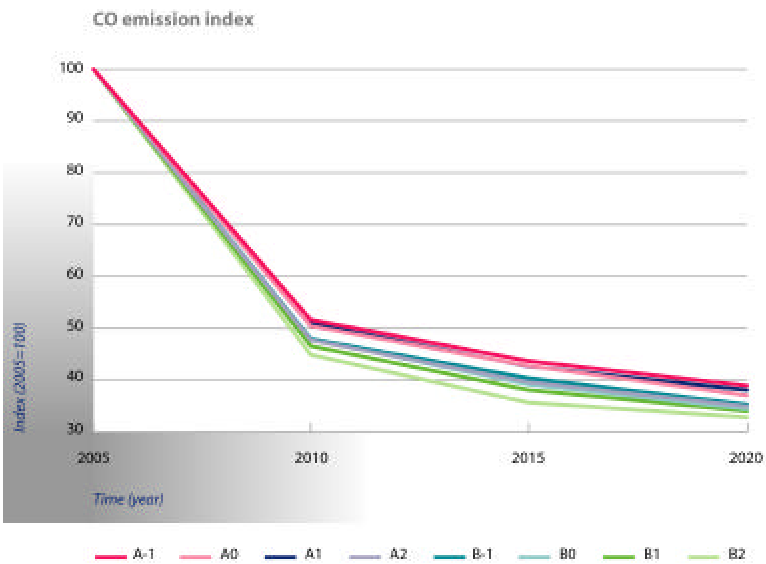
The CO_2 emissions are growing in each scenario but the growth per inhabitant is less or at the same level as the population growth for scenarios A2 and all B scenarios. The demand regulation scenarios are more efficient in reducing CO_2 emissions than the technology investments scenarios.

Figure 7.27: Helsinki model results: Total CO_2 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. The PM emissions are reduced by 30 –35% in all scenarios by the year 2020. The reduction is at maximum level in the year 2015 after which a slight increase starts.

Figure 7.28: Helsinki model results: *CO emission index*

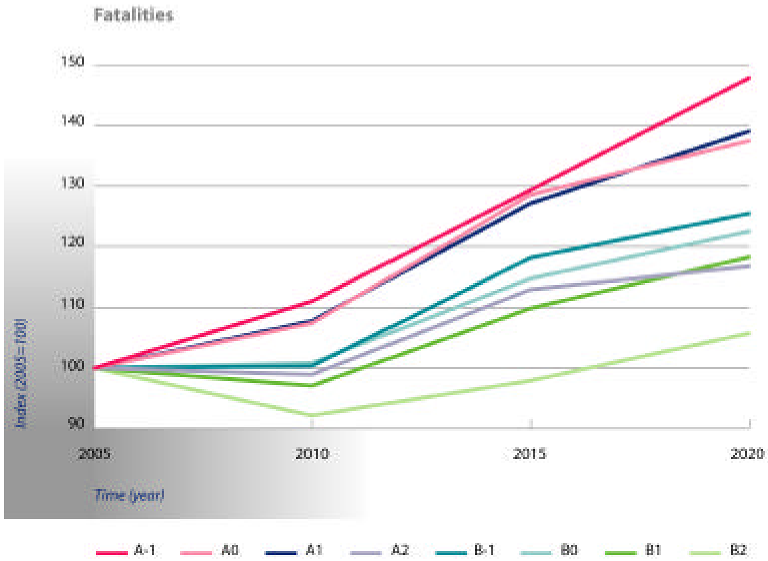


Society

Figure 7.29 shows the number of fatalities 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.

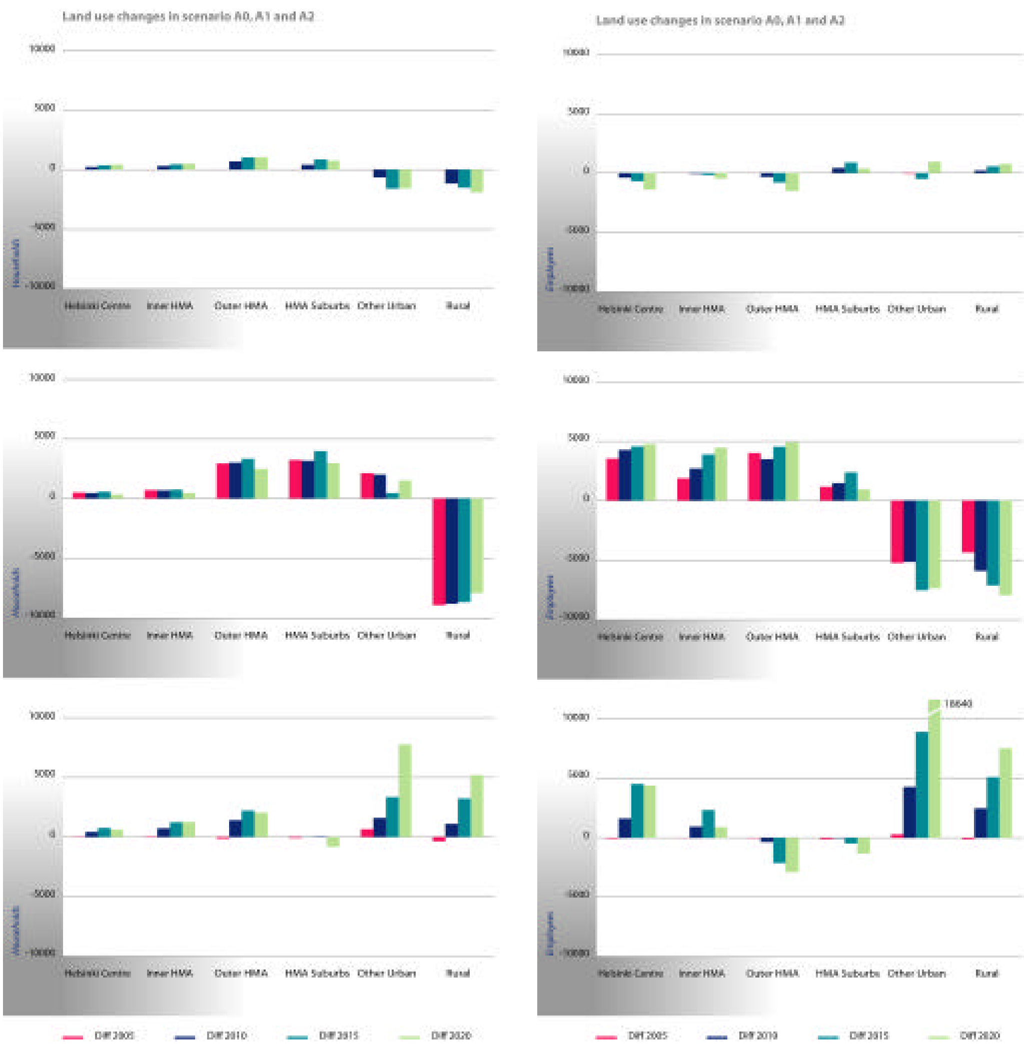
Figure 7.29: Helsinki model results: Fatalities index



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 7.30: 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.

7.5 The South Tyrol model results

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 (inclusive of pure fuel resource 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 weights 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.

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.

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, and by reducing the time spent for a trip on public transport.

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 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.

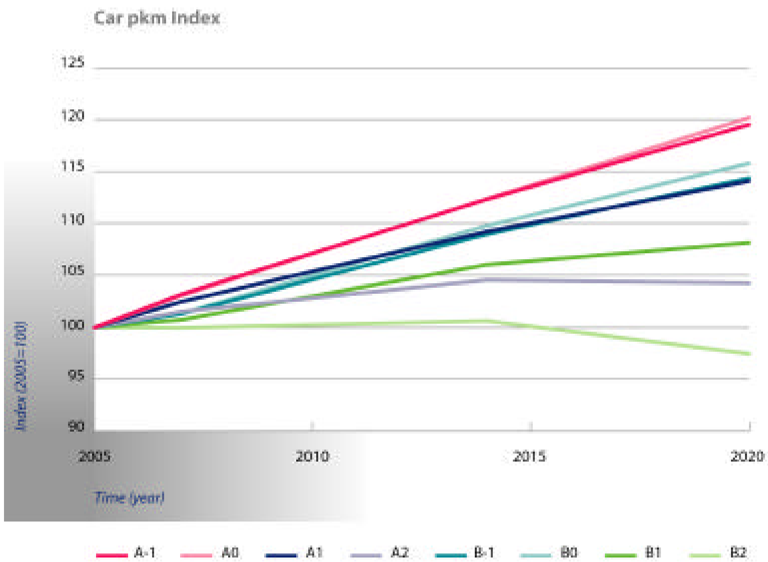
Main results from the South Tyrol model.

Transport demand and mode shares

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 the demand regulation scenarios (A2 and B2) have a more visible effect. In the ‘B’ scenarios where fuel price is assumed to grow faster, demand is always reduced with respect to the correspondent ‘A’ scenarios .In the South-Tyrol model the population is fixed and the number of generated trips does not changing in a given year, the different amount of passenger-km is due not to suppressed trips, but to lower average distances.

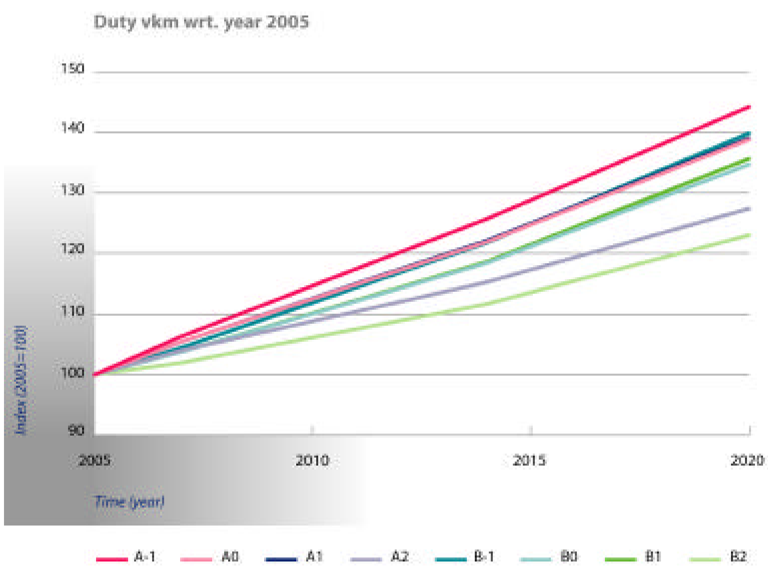
When focusing on the usage of private cars, the differences among the scenarios are larger. In Figure 7.31 it can be seen that in the demand regulation scenarios the growth of passenger-km by car is significantly lowered. When the high oil price growth assumption is associated with the measures implemented in the demand regulation policy (i.e. in the scenario B2), the total number of vehicle-kms by car at 2020 is lower than in 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 7.31: South Tyrol model results: Car passenger km 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 grows by 23% with respect to 2005 (see Figure 7.32).

Figure 7.32: South Tyrol model results: Freight vehicles per km with respect to year 2005 in the eight scenarios



Mode shares are interesting only for passenger traffic as, locally, freight is shipped and distributed almost totally by road given the relatively low distances. From Table 7.7 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 an increase in the car share in future years.

Table 7.7: South Tyrol model results: 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%

Average speed and trip lengths

The average road speed is quite high in 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. The 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.

Table 7.8: South Tyrol model results: 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.

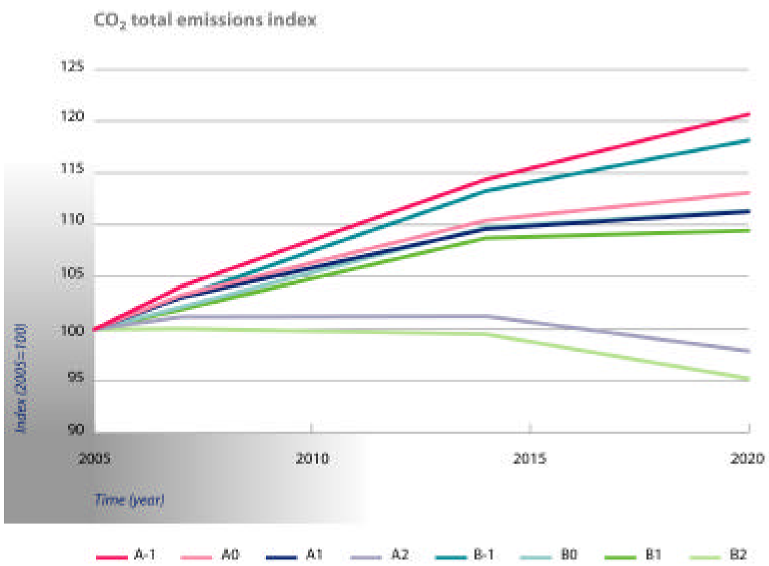
Car distance is always slightly lower at 2020 with respect to the base year. Even in scenarios where specific land-use measures are implemented (‘2’ scenarios), the difference compared to 2005 is very small. As explained above, the scale of the model does not allow to simulate this type of land use measures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

Environment

The South Tyrol model produce forecasts for the emissions of five different pollutants: CO_2, 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.

CO_2 emissions are basically growing during the time simulation period in each scenario, 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 7.33). 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 by 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 7.33: South Tyrol model results: CO_2 total emissions index (all modes)

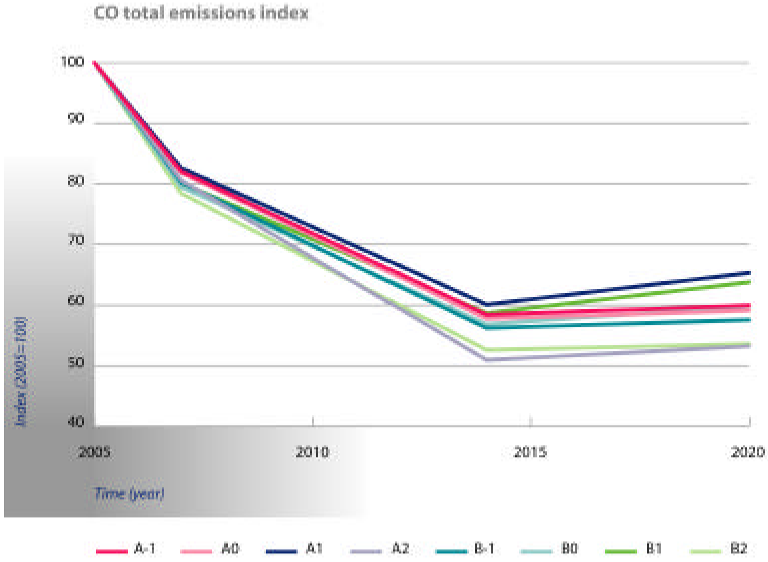


Instead, looking at the Figure 7.34 the development of the CO emissions index is quite different and shows a consistent reduction in all the scenarios. The minimum reduction amounts to 35% with respect to the year 2005 in the A1 scenario. However, in all scenarios the maximum reduction takes place in 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 veh kms growth more quickly than the average emissions are reduced.

The same development can be observed for the VOC, while for PM and NOx 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.

For the other pollutants the reduction of emissions is more significant with the demand regulation scenarios (A2/B2) matching the forecasts for CO_2 emissions.

Figure 7.34: South Tyrol model results: CO total emissions index (all modes)



CHAPTER 8: Summary of model results

8.1 Introduction

In this chapter the main outcomes of the simulation of the STEPs scenarios are presented. Detailed results for each model have been described in the previous chapters 6 and 7, concerning European models and local models respectively. Here the attempt is to provide an overall picture using results from all models. As explained previously, 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, differences exist between the models, as well as in the strategies used to implement the scenarios, meaning one can only compare the outcomes between models in broad terms. Also the demographic and economic trends of the study areas analysed in the models are significantly different (e.g. in Dortmund the population is decreasing while in Helsinki it is growing), so that the outputs of the common indicators produced could be considerably influenced. 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 8.2, 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 8.3;

- the impacts of the policy measures, i.e. the results of the scenarios A1, A2, B1 and B2 are reported in section 8.4;

- section 8.5 deals with the final conclusions.

8.2 Future trends assuming low oil price growth

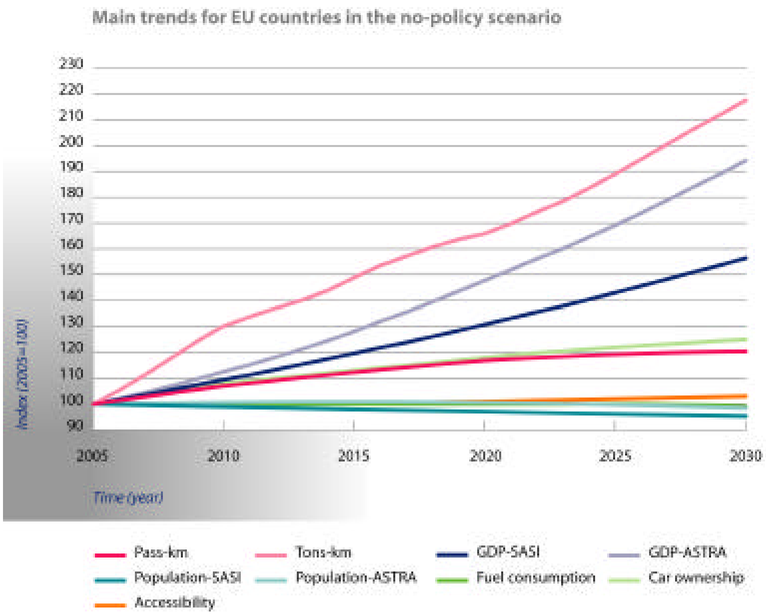
In the A-1 scenario, where only the lower growth rate of oil price is modelled, transport demand is clearly growing both for passengers and for freight. Such a trend of growing demand for the future years is common to Europe-wide models as well as to regional models. Even if population in the EU25 is forecasted as stable or even decreasing in future years, the modelling results suggest that the mobility of people will continue to grow in terms of passengers-km beyond 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,

[2] See for instance EU energy and Transport in figures 2004 page 3.1.3

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 dfferent 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 beyond 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, sea shipping also 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.

Figure 8.1: 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 8.1). Polluting emissions are sharply decreasing already in the no-policy scenario (A-1), with the only exception, though relevant, 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 to the extent that the absolute value of emission in the future year will be significantly lower despite the traffic growth.

Table 8.1: 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

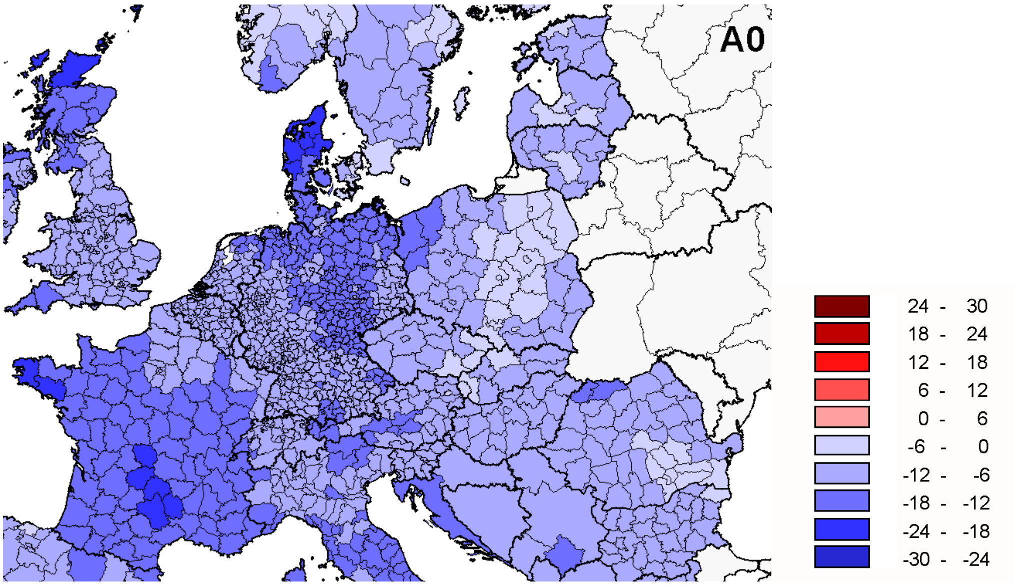
[1] Data of Brussels, Helsinki and South Tyrol models concerns year 2020.
[2] CO_2 emissions for the Edinburgh models are computed as well-to-wheel emissions.

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 is forecast 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 8.2).

Figure 8.2: Accessibility road/rail/air travel, Scenario AO with respect to Scenario A-1 2031 (SASI model results)



8.3 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 8.2).

Table 8.2: 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.	□	□

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.

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 travel is still growing but at a lower rate and the growth of cars, especially, is limited and falls below the base year (2005) value at the end of the simulation period. However, freight demand is more insensitive 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 by 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 8.3).

Table 8.3: 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	□	□	□	□

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 8.4: 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	□	□	□	□

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 8.5: 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
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.

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

Model	CO_2		CO		NO_x		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]	□	□	□	□	□	□	□	□	□	□

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

8.4 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 save energy and reduce harmful transport emissions, but a full assessment of their effects has to take into account other dimensions also such as the effect on the economy and on accessibility.

First, both strategies do not dramatically affect 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 growth of transport demand (see Tables 8.7 and 8.8). 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 8.7: European models: Change of passengers-Km and tonnes-Km 2005-2030: comparison between demand regulation and technology investment scenarios

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 8.8: 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]	☐	☐	☐	☐	☐	☐

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 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 8.9).

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

Table 8.9: Change of GDP and employment 2005-2030: comparison between demand regulation and technology investment scenarios

Model	A-1	A1	A2	B-1	B1	B2
GDP						
ASTRA	□	□	□	□	□	□
SASI	□	□	□	□	□	□
Employment						
ASTRA	□	□	□	□	□	□
SASI	□	□	○	○	○	□

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 8.10 and 8.11). 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 with the high oil price growth assumption, direct CO_2 emissions could be reduced by 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 only the effect of higher oil price growth.

Table 8.10: Change of emissions 2005-2030: comparison between demand regulation and technology investments scenarios under the low oil price growth assumption

Model	CO_2		CO		NO_x		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 8.11: Change of emissions 2005-2030: comparison between demand regulation and technology investments scenarios under the high oil price growth assumption

Model	CO_2		CO		NO_x		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 [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.

On the accessibility side (Table 8.12), 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 depend heavily on road modes for freight transport, this result is as expected. However, 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 8.12: Change of accessibility and cohesion 2005-2030: comparison between demand regulation and technology investments scenarios

Model	A1	A2	B1	B2
Passenger Accessibility				
ASTRA	○	□	□	□
Relative Cohesion (GDP)				
SASI	□	□	□	□

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

8.5 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 8.13 and Table 8.14 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. However, negative effects can be found on accessibility.

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

Table 8.13: European models: Summary of scenario B-1 results with respect to A-1 at year 2030

Model	CO_2 emissions	NO_x emissions	Energy consump-tion	% innovative vehicles	GDP	Accessi-bility	Relative Cohesion (GDP)
ASTRA	□	□	□	□	□	n.a	n.a.
SASI	n.a	n.a.	n.a.	n.a.	□	□	□

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 8.14: Local models: Summary of scenario B-1 results with respect to A-1 at year 2030

Model	CO_2 emissions	NO_x emissions	Energy consumption	Av. time per trip	Accessibility
Brussels [1]	□	□	□	n.a	n.a.
Dortmund	□	□	□	○	□
Edinburgh [2]	□	□	□	□	□
Helsinki	□	□	n.a	○	n.a
South Tyrol [1]	□	□	n.a	□	□

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

From Table 8.15 and Table 8.16 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 8.17 and Table 8.18 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 8.19 to Table 8.22 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 8.15: European models: Summary of scenario A1 results with respect to A-1 at 2030

Model	CO_2 emissions	NO_x emissions	Energy consump-tion	% innovative vehicles	GDP	Accessi-bility	Relative Cohesion (GDP)
ASTRA	□	□	□	□	□	n.a	n.a.
SASI	n.a	n.a.	n.a.	n.a.	□	□	□

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 8.16: Local models: Summary of scenario A1 results with respect to A-1 at 2030

Model	CO_2 emissions	NO_x emissions	Energy consumption	Av. time per trip	Accessibility
Brussels [1]	○	□	○	n.a	n.a.
Dortmund	□	□	□	□	□
Edinburgh [2]	□	□	□	□	□
Helsinki	□	□	n.a	□	n.a
South Tyrol [1]	□	□	n.a	○	□

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

Table 8.17: European models: Summary of scenario A2 results with respect to A-1 at 2030

Model	CO_2 emissions	NO_x emissions	Energy consump-tion	% innovative vehicles	GDP	Accessi-bility	Relative Cohesion (GDP)
ASTRA	□	□	□	○	□	n.a	n.a.
SASI	n.a	n.a.	n.a.	n.a.	□	□	□

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 8.18: Local models: Summary of scenario A2 results with respect to A-1 at 2030

Model	CO_2 emissions	NO_x emissions	Energy consumption	Av. time per trip	Accessibility
Brussels [1]	□	□	□	n.a	n.a.
Dortmund	□	□	□	□	□
Edinburgh [2]	□	□	□	○	□
Helsinki	□	□	n.a	○	n.a
South Tyrol [1]	□	□	n.a	○	□

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

Table 8.19: European models: Summary of scenario B1 results with respect to A-1 at 2030

Model	CO_2 emissions	NO_x emissions	Energy consumption	% innovative vehicles	GDP	Accessibility	Relative Cohesion (GDP)
ASTRA	□	□	□	□	□	n.a	n.a.
SASI	n.a	n.a.	n.a.	n.a.	□	□	□

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 8.20: Local models: Summary of scenario B1 results with respect to A-1 at 2030

Model	CO_2 emissions	NO_x emissions	Energy consumption	Av. time per trip	Accessibility
Brussels [1]	□	□	□	n.a	n.a.
Dortmund	□	□	□	□	□
Edinburgh [2]	□	□	□	□	□
Helsinki	□	□	n.a	□	n.a
South Tyrol [1]	□	□	n.a	○	□

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

Table 8.21: European models: Summary of scenario B2 results with respect to A-1 at 2030

Model	CO_2 emissions	NO_x emissions	Energy consumption	% innovative vehicles	GDP	Accessibility	Relative Cohesion (GDP)
ASTRA	□	□	□	□	□	n.a	n.a.
SASI	n.a	n.a.	n.a.	n.a.	□	□	□

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 8.22: Local models: Summary of scenario B2 results with respect to A-1 at 2030

Model	CO_2 emissions	NO_x emissions	Energy consumption	Av. time per trip	Accessibility
Brussels [1]	□	□	□	n.a	n.a.
Dortmund	□	□	□	□	□
Edinburgh [2]	□	□	□	○	□
Helsinki	□	□	n.a	○	n.a
South Tyrol [1]	□	□	n.a	□	□

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

Part IV: Scenario Assessment

Part IV: Summary

This Part includes the main STEPs assessment results.

Firstly, Chapter 9 includes a preliminary and complementary analysis to the application of the Multicriteria Analysis (MCA) procedure. In this Chapter the results of the six models applied in STEPs are compared with respect to their internal and mutual consistency. The comparison starts with a meta analysis of the results. After the meta analysis the internal and mutual consistency of the scenario results are discussed. The examination leads to conclusions about the validity and transferability of the results.

Chapter 10 includes an assessment of the results obtained in each scenario as a result of the application of the MCA methodology. The analysis was focused on the comparison of the scores obtained, in each model, in each of the four main criteria groups (energy, environment, social and competitiveness) with those of the reference scenario. The resulting scores have allowed conclusions to be drawn about the effect of the modelled oil price increases and policy measures driving each scenario. Assessment results show, on the one hand, that energy and environment criteria improve with both fuel price increases and modelled policies. On the other, social criteria show a mix of both positive and negative effects, while competitiveness criteria deteriorate when oil price increases and modelled policies are implemented.

Finally, Chapter 11 includes a broad comparison of the results obtained by the different models. The objective was to test the models' coherence in terms of the direction of the predicted effect of fuel price increases and modelled policies. This comparison generated general remarks valid for all the models considered in STEPs.

The analysis carried out in Part IV is intended to provide a useful starting point for Part V, in which recommendations for transport and energy policy making are made.

CHAPTER 9: Meta-analysis and consistency of model results

The modelling part of STEPs has been a unique collaborative modelling exercise. The coordinated application of several complex socio-economic models to a common task presents a unique opportunity to *cross-validate* the models, i.e. to check their validity by comparing their results. There is significant agreement between the models with respect to major trends and policy options and the general conclusions to be drawn from them. However, there are also differences in detail between the models, which are of interest for the validity of the models and the transferability of their results. In this chapter the results of the six models applied in STEPs are compared with respect to their internal and mutual consistency, before, in the following chapters they are evaluated by multicriteria analysis.

The comparison starts with a meta analysis of the results, i.e. an analysis in which the scenario results are objects of a cross-cutting statistical analysis. After the meta analysis the internal and mutual consistency of the scenario results are discussed. The examination leads to conclusions about the validity and transferability of the results.

9.1 Meta Analysis of Scenario Results

The energy scenarios examined in STEPs were designed to follow common criteria that led to a commonly agreed set of assumptions regarding energy supply, market response and policy options in the field of vehicle technology and transport demand management. These assumptions were laid down in STEPs Deliverable D3. All modelling teams in the project adopted these common assumptions in the specification of their scenarios. So ideally the results of the model simulations of the scenarios should be directly comparable.

However, in practice, a direct comparison of the results produced by the different models proved to be difficult. Three aspects of the modelling exercise seem to be of critical importance for the comparability of the model results: scenario specification, model mechanism and model output indicators.

Scenario Specification

Although all models in principle conformed to the scenario definitions laid down in STEPs Deliverable D3, there remained significant differences between the scenario definitions of the six models for the eight 'obligatory' scenarios:

- Four models (ASTRA, Brussels, Helsinki, and South Tyrol) adopted POLES-ASTRA forecasts of fuel price, fuel taxes, fuel consumption, car ownership, car fleet composition and emission factors by country. Because POLES models market response based on the different fuel demand of each scenario, this resulted in different fuel prices (after taxes) for each scenario in each country.

- Two models (SASI and Dortmund) assumed average fuel price increases at the pump of 1% p.a. for all A scenarios and 4% p.a. for all B scenarios. To represent changes to the fuel tax policies they used the average travel/ transport cost increases of 0.5% and 3.0% p.a., respectively, recommended in STEPs Deliverable D3.

- The Edinburgh model applied the growth rates of 1% and 4% p.a. to fuel resource costs and assumed fuel tax increases of 0.7% p.a. for petrol and 1.5% p.a. for diesel for the business-as-usual and technology scenarios A0/A1 and B0/B1 and 4.7% p.a. for both petrol and diesel for the demand regulation scenarios A2 and B2.

- More important is the fact that the equilibration mechanisms in the POLES model behind the POLES-ASTRA results lead to much smaller increases in pump fuel prices than the unmodified growth rates of 1% p.a. for the A scenarios and 4% p.a. for the B scenarios. Together with the response of POLES with respect to fuel efficiency they result in much lower car travel cost increases than if the fuel efficiency gains specified in D 3 are applied[1]

There are numerous other differences in the interpretation of the scenario specifications between the models (see Spiekermann & Wegener, 2006a), which may be of minor importance compared to the fundamental differences in fuel prices discussed above but contribute to the difficulty of comparing the model results.

Model Mechanisms

Because the models applied in the STEPs project were not developed specifically for STEPs but built on existing model applications for regions for which they were already calibrated with existing data, there were significant differences between the models:

- The six models work at different scales.
- The modelled study areas/regions have different characteristics.
- The time horizons of the simulations were different.
- The models cover different subsystems and have different theoretical underpinnings.

These differences were unavoidable in this project. However, they made comparing the model results difficult. A reduction in total greenhouse gas emissions, for instance, has a different meaning in a growing city as Helsinki than in a declining city as Dortmund. Other differences are related to internal model mechanisms. For instance, the way travel time and travel costs are treated in the models has far-reaching consequences for the predicted behavioural response to certain policies.

Model Output Indicators

A final important aspect of comparability between model results are the model output indicators – not only the selection of output indicators but also the form in which they are presented. The comparability of output indicators is the more important as the model results are to be evaluated in a common multicriteria analysis (see Chapter 10).

Ideally, all relevant indicators should be produced by all models and should be formulated in a way independent from the size and socio-economic characteristics of the different study areas (e.g. demographic or economic growth or decline) and the length of the study period (e.g. forecasting horizon 2020 or 2030).

In STEPs all efforts were made to fulfil the above requirements. A *reference scenario* was defined (Scenario A-1), which served as benchmark against which all policy scenarios are compared. A reference scenario is a powerful mechanism to make model results as robust as possible against data errors, model errors, regional characteristics and different forecasting periods: as all these are the same in the reference scenario and each policy scenario, it can be expected (hoped) that the differences between the reference and scenario a policy scenario reflect only the impact of the policy.

[1] The Deliverable 3 specifications were set before the results of the POLES model were available.

Meta Analysis Method

A meta analysis is a form of scientific inquiry in which not empirical phenomena but the results of scientific research are the objects of investigation. Meta analysis is a way of cross validation of models to enhance the reliability and credibility of model forecasts by systematically comparing the results of different models based on similar assumptions.

In an ideal cross validation meta analysis the models to be compared work with rigorously identical assumptions. However, where, as in STEPs, rigorously comparable scenario specifications were not possible, it is still possible to conduct a cross-validation meta analysis by comparing *not scenarios with identical names* but *scenarios with similar specifications* irrespective of their name.

The meta analysis results proceeds by linking model output and model input by univariate or multivariate statistical estimation techniques. This approach attempts to identify and isolate the specific contribution of relevant trends or policy packages to changes in the output variables observed in the model results. As in empirical research, it is attempting to explain observed changes of phenomena by statistically linking them to potential causal factors. In both cases it is concluded that, if the statistical properties of the link (e.g. expected sign or confidence level) appear sound, the statistical link can be interpreted as a causal one, i.e. the output indicators can be interpreted as *impacts* and the input variables as *causes*.

To achieve this, a meta analysis experiment was conducted, in which the scenarios modelled by the six models (see Chapters 6 to 8) were taken as observations. Preliminary results of a meta analysis were already presented in STEPs Deliverable D 5 (Section 2.5). After these preliminary tests the modelling teams were asked to provide for each of the modelled scenarios two sets of rigorously standardised input and output indicators:

- *Input indicators, or possible causes*. One group of indicators are model *input variables* set exogenously by the model user, such as assumptions about exogenous global developments, such as fuel price changes or technological progress, or explicit policy measures, such as fuel taxes, road pricing, speed limits or land use controls. In the statistical analysis these variables are independent or explanatory variables.

- *Output indicators, or possible impacts*. The other group of indicators are model *output indicators* of scientific and policy interest for which one would like to know which policies and other assumptions caused their changes in the models. For this, the causal chain is followed backwards until it is possible to identify the input variables (policies or assumptions) that caused those changes. This is done by statistical estimation methods, such as univariate or multivariate regression, with the output indicators as dependent variables.

Table 9.1 contains the input and output indicators collected for all six models and the variable names used in the meta analysis.

Table 9.1: Input and output indicators for the meta analysis

Indicator				Unit
Input	1	gdpc	GDP per capita	€
	2	fcpl	fuel cost for car users including taxes	€ per l
	3	twrk	telework (share of non-telework jobs)	%
	4	luc	land use control (1=none, 2=weak, 3=strong)	dummy
	5	devl	developed land per capita	sqm
	6	apts	average public transport speed	km/h
	7	acs	average car speed	km/h
	8	cptt	cost of a public transport trip	€
	9	afcc	average car fuel consumption	l/100 km
	10	palt	share of alternative vehicles	%
	11	cc	cost of car ownership per car per month	€
	12	ctc	car travel cost	€/km
	13	ctcp	car travel cost including road pricing	€/km
Output	14	tdpc	total distance travelled per capita per day	km
	15	cdpc	distance travelled by car per capita per day	km
	16	adt	average distance per trip	km
	17	adct	average distance per car trip	km
	18	swct	share of walking and cycling trips	%
	19	sptt	share of public transport trips	%
	20	sct	share of car trips	%
	21	fcpc	car fuel consumption per capita per day (l)	l
	22	co2	CO_2 emissions by transport per capita per day (kg)	kg
	23	nox	NOx emissions by transport per capita per day (g)	g
	24	pm	PM emissions by transport per capita per day (mg)	mg
	25	cown	car ownership per 1,000 population	#
	26	tdpm	traffic deaths per million population per year	#
	27	acc	accessibility	index

Of the 56 scenarios modelled by the six models, 54 were selected for the meta analysis. Scenarios C2 and C3 of Dortmund were excluded as they are too extreme to be compared with the other scenarios.

The 27 indicators listed in Table 9.1 of the 54 selected scenarios were subsequently transformed into index form, i.e. expressed as percent of the corresponding values in the Reference Scenario A-1 in the target year of the model 2020 or 2030, respectively.

In the following sections, selected results of the meta analysis are presented, first the results of univariate regressions and then the results of multivariate regressions. (The complete data used for the meta analysis are contained in Spiekermann & Wegener, 2006b)

Univariate Regressions

Univariate regressions explore the *correlation* between *two* scenario attributes based on a *hypothesis* about a cause-effect relationship between them. If the coefficient of determination (r^2) is high, the agreement between the models about the cause-effect relationship is high. The effects explored can be classified as *direct* or *indirect* effects.

Direct Effects

Direct effects of energy trends or policies are behavioural responses to changes in transport options due to energy trends or policies, such as changes in fuel prices, fuel taxes public transport fares, road charges, parking fees, vehicle technology, fuel consumption, travel speed, traffic regulations or land use regulations.

One example of a behavioural response is choice of mode. Figure 9.1 shows the share of trips by car predicted by the six models as a function of car travel cost including road pricing. The scatter diagram shows the large differences in scenario definitions.

In a perfect world, all scenarios with the same name should have the same assumptions on car travel costs, i.e. lie on the same vertical line. However, the assumptions about car travel cost increases differ substantially in the scenarios: In the Brussels and South Tyrol models, for instance, car travel cost in the worst-case scenario B2 increase by 42 and 27 percent, respectively, whereas in the Dortmund model they increase by 450 percent.

However, the scatter diagram shows also that the simulation results of the six models, despite their differences in scenario specification, are more similar than they appear at first sight. If one compares not scenarios with identical names but scenarios with similar assumptions about car travel cost increases, the six models show much agreement: they all show a consistent reduction in the share of car trips in response to car travel cost increases.

Similar conclusions can be drawn from Figure 9.2, which shows car distance as a function of car travel cost. Here too the same differences in scenario specification are visible, but also a similar agreement about the likely response of car drivers to rising car travel costs. The dotted regression line indicates that the price elasticities assumed by the models, if taken together, are relatively low and closer to -0.2 than the proverbial price elasticity of -0.3 usually found in transport behaviour. This may reflect the fact that many people, in particular long-distance commuters, depend on the car and cannot easily switch to other modes – in fact a non-linear regression line would represent the data even better.

Indirect Effects

Indirect effects of energy trends or policies are changes caused by behavioural responses to changes in transport options due to energy trends or policies, such as CO_2 emissions, NO_x emissions, PM emissions, traffic deaths, traffic injuries and accessibility.

Figures 9.3 and 9.4 show two examples of indirect effects: CO_2 emissions and traffic deaths as functions of car distance travelled. Here the agreement between the models is even better. It appears that the modellers used the same or very similar emission and accident probability functions. Figure 9.4 is based on the results of only three models because the other three models did not predict traffic accidents.

Figure 9.1: Share of car trips v. car travel cost including road pricing

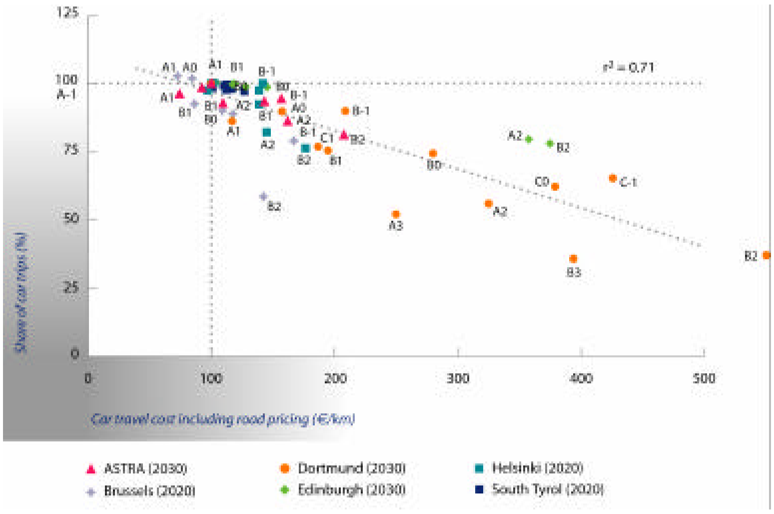


Figure 9.2: Car distance per capita per day v. car travel cost including road pricing

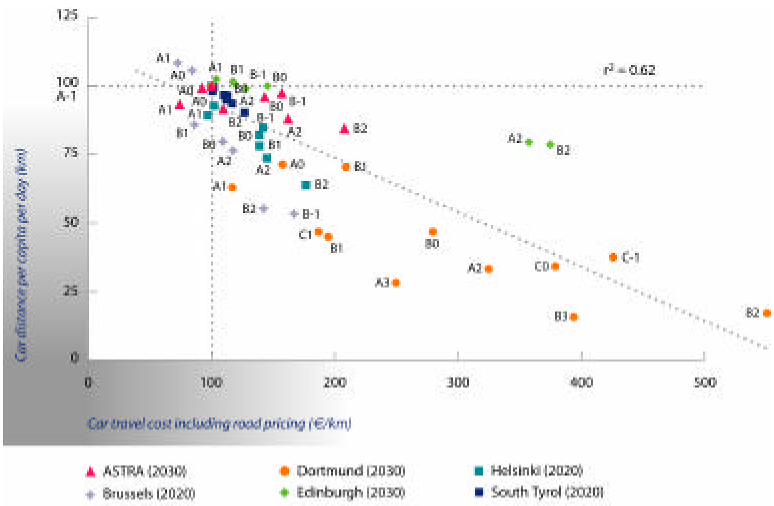


Figure 9.3: CO_2 emissions v. car distance per capita per day

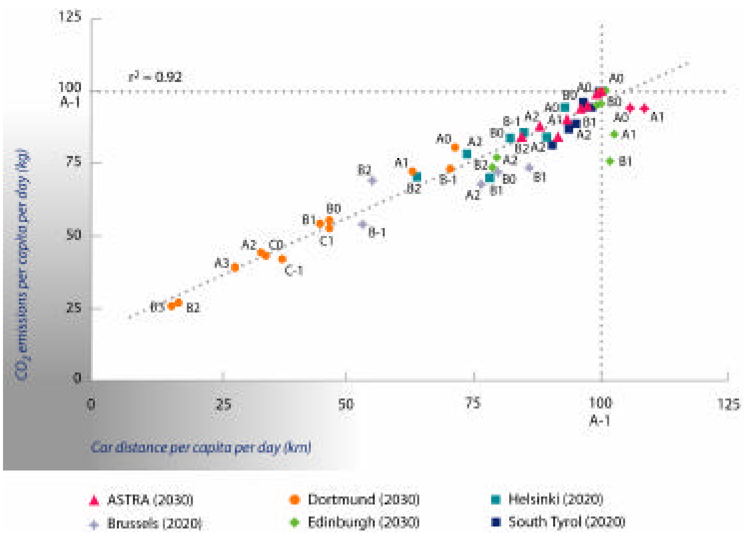
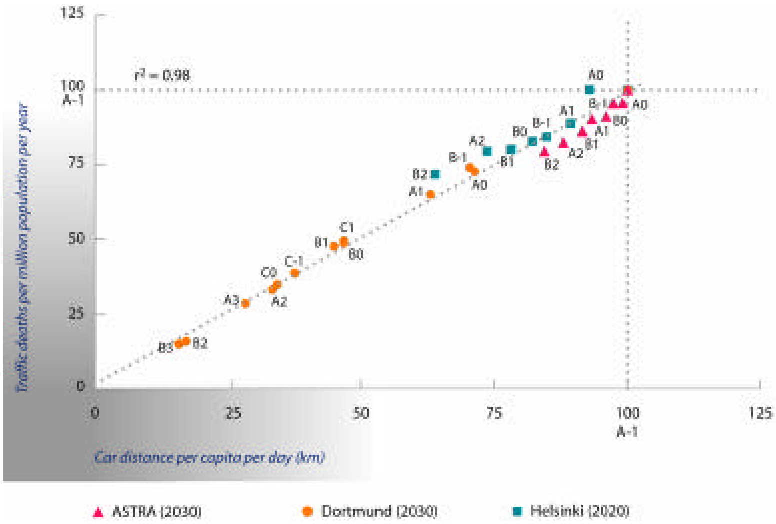


Figure 9.4: Traffic deaths v. car distance per capita per day



Multivariate Regressions

Multivariate regressions explore the correlation between three or more scenario attributes based on *hypotheses* about cause-effect relationships between them. One of the scenario attributes is the *dependent* variable to be explained. The other attributes are the *independent* or *explanatory* variables. Multivariate regressions have the advantage over univariate regressions that they take account of interactions between explanatory variables. If the coefficient of determination (r^2) is high, the agreement between the models about the cause-effect relationships is high. A problem with multivariate regressions is that only scenarios can be included in the analysis for which all relevant dependent variables were provided.

Figure 9.5 shows the same dependent variable as Figure 9.1, share of car trips. The indicator values along the horizontal axis of Figure 9.5 correspond to those along the vertical axis of Figure 9.1. Only 46 of the 54 scenarios could be included in the regression because the Brussels model did not provide travel speed indicators. It is obvious that the predictive power of the statistical model improves if more than one explanatory variables are considered as indicated by the higher r^2 value.

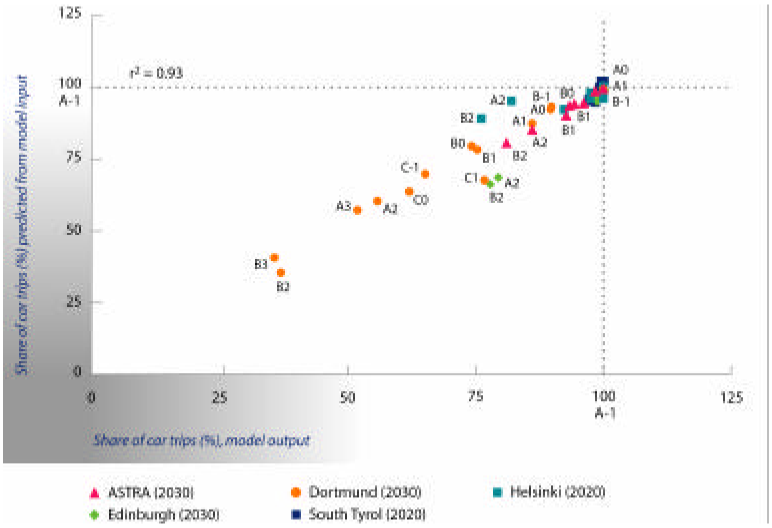
The table under the scatter diagram shows the list of input indicators or explanatory variables that were selected by the regression procedure to predict the output indicator share of car trips. The signs of the regression coefficients of the explanatory variables indicate that the share of car trips grows if public transport becomes slower and/or more expensive and/or car travel becomes faster and/or cheaper. Interestingly, car use goes down if the share of alte rnative vehicles in the car fleet grows, presumably because alternative vehicles are assumed to be more expensive than conventional cars.

Figure 9.6 shows the same dependent variable as Figure 9.2, car distance per capita per day. Again the results of the Brussels model had to be excluded because no travel speed indicators were available for Brussels. The signs of the coefficients indicate that car distances grow if public transport becomes slower and car travel less expensive. Again car use declines if the share of alternative vehicles in the car fleet grows.

Figure 9.7 shows the same dependent variable as Figure 93, traffic deaths per million population per year, again only for those models that predict traffic accidents. As this is an indirect effect, the dependent variables are output variables of the models, such as distance travelled by car or share of car trips.

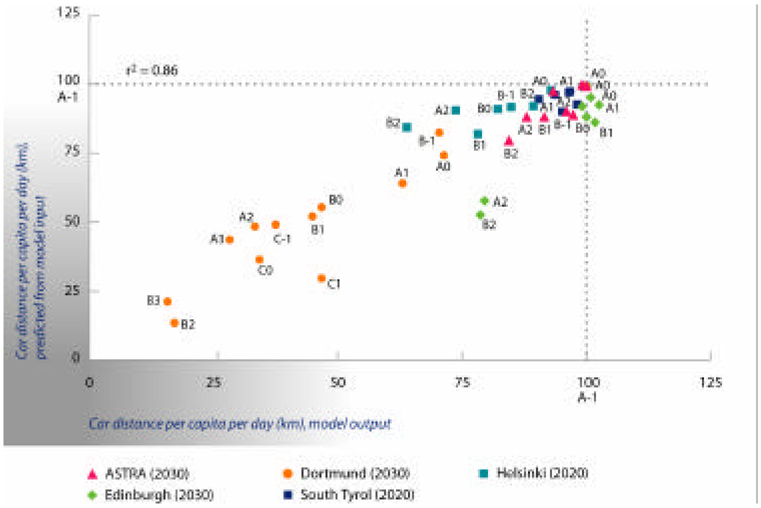
As to be expected, the regression models select exactly those variables which were used in the model to calculate the number of traffic deaths. And as not only one explanatory variable is considered, the estimation is almost perfect, better than that of the univariate regression shown in Figure 9.4. The result also shows that relatively simple accident probability functions are used by the models, probability functions that do not take account of the significant achievement in traffic safety made in the last years.

Figure 9.5: Multiple regression of share of car trips (%)



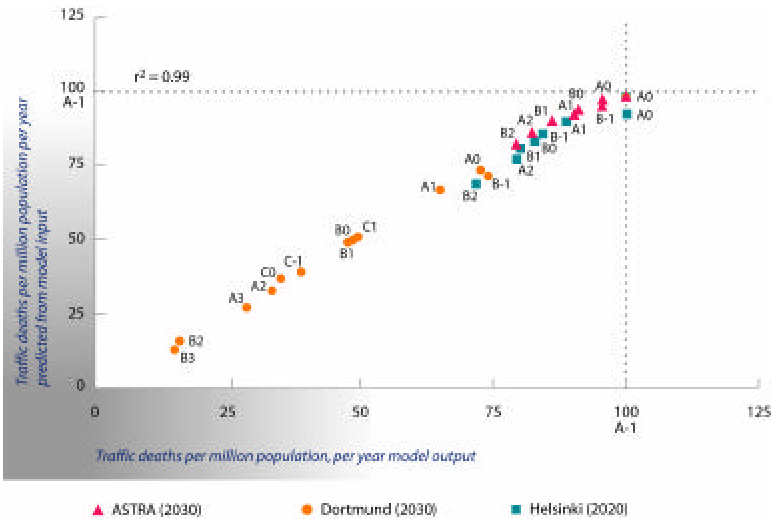
Explanatory variables			Coefficient
6	apts	Average public transport speed (km/h)	-0.35609
7	acs	Average car speed (km/h)	1.06922
8	cptt	Cost of a public transport trip (€)	0.23018
10	palt	Share of alternative vehicles (%)	-0.00910
12	ctc	Car travel cost (€/km)	-0.10308
		Constant	16.28384
Number of scenarios			46
F level			-0.43898
Standard deviation of estimate			4.97826
Multiple correlation coefficient			0.96253
Coefficient of determination (r^2)			0.92647

Figure 9.6: Multiple regression of car distance per capita per day (km)



Explanatory variables			Coefficient
6	apts	Average public transport speed (km/h)	-0.23280
10	palt	Share of alternative vehicles (%)	-0.03106
13	ctcp	Car travel cost including road pricing (€/km)	-0.15433
		Constant	141.03989
Number of scenarios			46
F level			1.19170
Standard deviation of estimate			9.83328
Multiple correlation coefficient			0.92731
Coefficient of determination (r^2)			0.85990

Figure 9.7: Multiple regression of traffic deaths per million population per year



Explanatory variables	Coefficient
Distance travelled by car per day (km)	0.75100
Average distance per trip (km)	0.17353
Share of public transport (%)	-0.10058
Constant	15.77382
Number of scenarios	30
F level	2.32100
Standard deviation of estimate	2.53968
Multiple correlation coefficient	0.99594
Coefficient of determination (r^2)	0.99189

9.2 Consistency and Relevance of Results

As previously described in this chapter, there have been problems of obtaining comparable data outputs and the reasons for this have been discussed elsewhere. Nevertheless the data are sufficient to assess the relevance and applicability of the outputs for the purposes of the STEPS project - that is, as an input to an assessment process, where scenarios are assessed against a series of criteria (see Chapter 5). However before the model outputs can be deemed suitable they must be checked to ensure that the results are both internally consistent and that they are credible and a valid reflection of the likely impacts of the scenarios in those areas modelled.

Are the results internally consistent?

Before we can consider using them in an evaluation exercise, the STEPS models results should be both internally consistent and believable. There has been much discussion so far on the problems of definitions of costs and demand and of the different interpretation of the scenario assumptions, as well as relevant data from some of the models. Because of these uncertainties any assessment of the results across both models and scenarios will have a high degree of uncertainty.

Section 9.1 above comments that, whilst common scenarios were run on each of the model systems, differences in the way each scenario was interpreted for the individual model, has meant that common scenarios do not led to common changes in such inputs as car fuel prices or intermediate outputs such as car 'costs' and public transport times. Graphs of outputs against input factors such as Figures 9.1 and 9.2 show a scatter of points rather than a simple relationship. Differences in definitions are only one reason for this scatter and other factors, which vary between model runs are also important. The impact of this is explored for a limited selection of outputs through the use of multivariate regression in section 9.1.3 above. Even allowing for other unexplained differences in inputs such as different changes in network speeds and fuel tax regimes, one would still expect some scatter because the areas modelled are very different, ranging from a conurbation (Dortmund) to a semi-rural region (South Tyrol), as well as a trans-EU model (ASTRA). Each of the models used also has slightly different modelling assumptions so common changes in inputs can be expected to give rise to different changes in outputs.

Nevertheless, the meta analysis described above and the analysis described in section 2 of Deliverable 5.2, which considers some of the seemingly outlying results, both suggest that if one treats each scenario/model run as an individual result then most of the results can be explained with respect to changes in the 'cost' of travel by car, leading to changes in car travel distance and so to changes in emissions. In each test a number of cases stand out from the rest indicating that other factors do have an influence but it has not been possible to find definitive explanations for all these 'outliers' from the general trends.

Implications for validation and credibility

The discussion above suggests that most results are internally consistent, and that the main driving force for differences between the scenarios is the implication that the scenarios have for the costs of travelling by car (particularly fuel and running costs, but also network speeds). The validation and credibility of the forecasts therefore rely on the credibility of the forecasts of such increases in travel costs. The setting up of the scenarios has assumed, quite rightly from a modelling viewpoint, that the particular combination of measures would all be implemented at, or nearly at, the same time. In reality, household behaviour, and politics, are rarely that simple.

Over the past 20 years or so car fuel costs have not increased successively over a large number of years, and car ownership has tended to increase year on year in nearly all countries (Finland 1990-1994 being the exception). The consequence of this is that many of the models' forecasts are predicting trends in car travel costs, and car ownership that have not been experienced in the past and so have not been present in the data-sets on which the models have been calibrated. This should inevitably cast some uncertainty on the behaviour of households faced with such trends in car costs. In all EU countries the data will only contain a few examples of rapidly rising car costs and none where the increase has gone on for a number of years, allowing many longer-term decisions to be influenced by the increasing costs, such as car ownership and household location.

The second issue that the results raise is the political credibility of the forecasts. In this case the issue is less to do with the travellers as with the likelihood that politicians will implement all the different elements of the various scenarios even if the Multiple-Criteria-Analysis (MCA) discussed in the next chapter is favourable for a scenario. This is especially important in the case of the more severe scenarios involving demand management.

The costs of car travel in demand management scenarios such as scenario B2, arise through a combination of high resource petrol prices, rapidly increasing fuel taxes and road user charges, as well as improvements in public transport. The ability of politicians to push through increases in fuel taxes and increased road changes in a regime of rapidly increasing petrol prices must be doubted in the light of the experience in many European countries during recent rises in oil prices, when compensating decreases (or the postponement of increases) in fuel taxes were made in responses to the oil prices rises.

This political action, in the face of a previous oil prices rise, suggests that it would be worthwhile to research the possible impact of the rises in oil prices under two different political scenarios;

- where countries compensate for exogenous oil prices rise by deferring fuel tax rises, or reducing them, and
- the affect of a trend towards the harmonisation of fuel taxes across the EU, under the different oil price rise scenarios.

9.3 Conclusions

The experience with the meta analysis has shown that the models applied in STEPs are in reasonable agreement about the major behavioural responses and environmental effects of the energy trends and policies examined: Higher fuel prices will have a significant effect on trip distances and modal choice, reductions in car distance will significantly reduce air pollution, greenhouse gas emissions, traffic accidents and traffic deaths, and reductions in car use will have negative effects on accessibility unless public transport is significantly improved.

If one considers that the scenarios differ not only in their assumptions about fuel prices but also in their policies in the fields of technology, infrastructure and demand regulation, this result supports the hypothesis that car travel cost, or more specifically fuel price, is indeed the most important policy variable and that all other policies fields, such as alternative vehicles, traffic regulation (in particular travel speed), but also land use policies, are of lesser importance – a result in accordance with those of recent EU empirical and modelling studies, such as the PROPOLIS project (Lautso et al., 2004). In the future, road pricing, where it is introduced as a substitute for current vehicle taxes could also become an important policy instrument.

For future studies there is considerable potential for improving the validity and transferability of model results with respect to scenario specification, model mechanism and model output indicators by a cross-validation of the results with respect to important output indicators as standard practice. Such a meta analysis would contribute much to establishing the credibility of the models and to improve their policy relevance and acceptance of their results in the policy arena.

The experience with the meta analysis has also shown that there exists a demand for more research. Forecasting energy price increases seems to be more difficult than forecasting their effects. Research should therefore address the issue of market responses to energy price shocks. Related to this, and not taken into account in the setting of the scenarios (and so in the modelling), are the political reactions to the changes that these scenarios forecast. This would also be a fruitful source of research, building on the STEPS modelling results.

Whilst much of the discussion has centred on the indicators that have been chosen in Chapter 5 to reflect the EU policies on the environment, large changes in the costs of travel, and in some cases accessibility, have implications both for the individual travellers welfare, and the economic viability of some of the regions. Changes in the relative political pressures for sustainability issues and competitive issues may also change the acceptability of the scenarios.

It should not be forgotten in relation to the last issue that the STEPS project is not concerned with the costs of implementing any particular scenario. The costs of implementing any particular scenario could materially affect the economic and political rationale for that scenario.

CHAPTER 10: Assessment of scenarios

10.1 Introduction

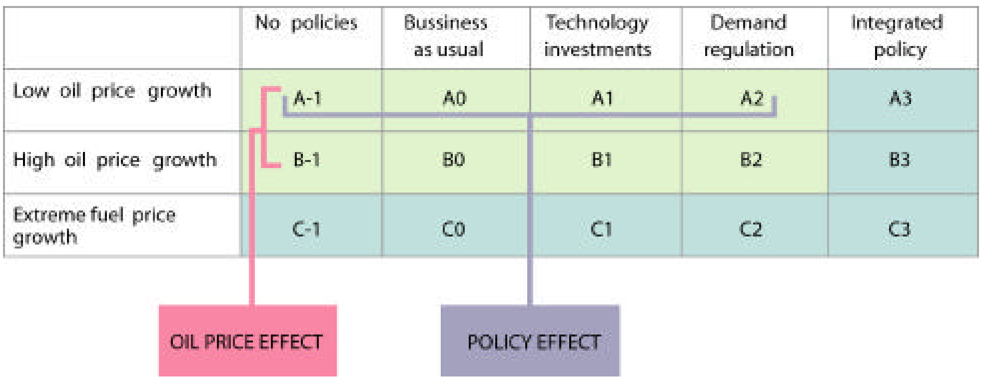
The subsequent sections of this chapter include an assessment of the results obtained in each scenario as a result of the application of the MCA methodology. The results are presented, split in two groups: European (Section 10.2) and regional/local models (Section 10.3). The analysis is focused in the comparison of the scores obtained, in each model, in each of the four main criteria groups: energy, environment, social and competitiveness. This analysis is completed in Chapter 11, which includes a broad comparison of the results obtained across models, therefore allowing for a global view of the assessment carried out in STEPs.

In order to carry out any comparison among scenarios, it is firstly necessary to define the 'reference scenario'. The scenario A-1 was chosen, where a modest fuel price rise is combined with a continuation of past trends and no new polices. Hence, in order to facilitate the interpretation of results, in what follows the performance of each scenario is compared with that obtained in the A-1 scenario.

The focus of the analysis is to assess the performance of the different STEPs scenarios, based on the rationale from which these scenarios have been developed. From the different possible approaches to comparing across scenarios, Figure 10.1 represents the one selected in this Chapter for its clarity and ease of interpretation[2] :

- On the one hand, the effect of an increase in fuel price is isolated if the reference scenario is assessed against scenario B-1.
- On the other, the effect of the different policy packages present in each scenario is more easily highlighted when the reference scenario is compared against policy scenarios with the same fuel price assumptions, i.e. A0, A1 y A2.

Figure 10.1: Effects analysed: fuel price and policies



[2] Figure 10.1 includes the additional scenarios (C-1, A3, B3 and C3), implemented in SASI and Dortmund models

The comparison of the reference scenario with another scenario combining different fuel price and the implementation of policy measures provides an idea of the overall effect obtained, although it makes it more difficult to identify which part of the effect is caused by each of the aforementioned factors. These 'diagonal' comparisons (e.g. A-1 vs. B1) make little additional contribution to the analysis. Hence, and for the sake of simplicity, the tables included in this Chapter include the results obtained in all scenarios, whilst the graphs have focused on the comparison of scenarios located in the same row and/or column of the reference scenario A-1.

Finally, a clarification about the location of data in this Chapter. For the sake of simplicity, some information has been included only in the original Deliverables, in two Annexes. Annex 4.I of Deliverable 5.2 includes, for each model, the corresponding performance matrix, with the values of the performance indicators for all scenarios. Annex 4.II of Deliverable 5.2 includes, also for each model, bar charts decomposing the resulting four global scores (energy, environment, social and competitiveness) into each criterion weighted scores.

10.2 European models

ASTRA

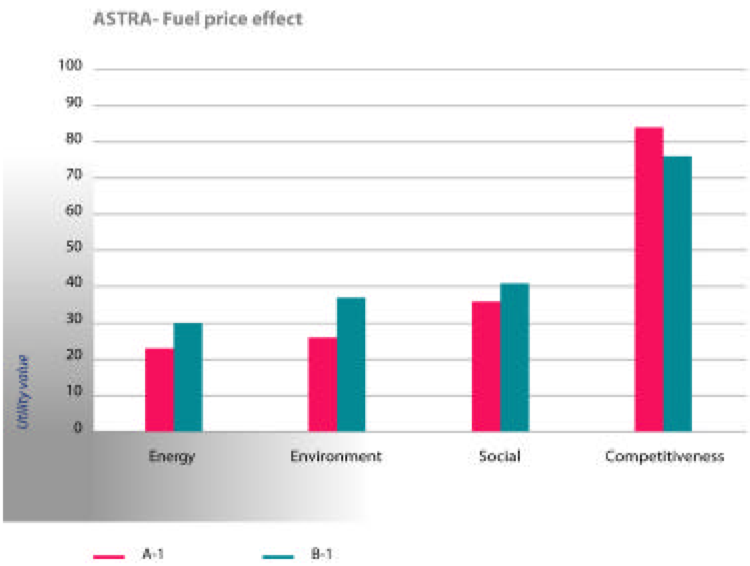
Table 10.1 includes a summary of the assessment results of scenarios according to the ASTRA model. In this case, the model provides indicators for the four criteria categories, although it has to be kept in mind that ASTRA does not (none of the models used in STEPs does) provide results for all the STEPs list of performance indicators.

Table 10.1: ASTRA assessment results

Criteria	Sub-Criteria	Base indicator	Indicator	Detail, unit	Time	A-1	A0	A1	A2	B-1	B0	B1	B2
ENERGY GLOBAL SCORE						**22,99**	**43,04**	**64,99**	**77,01**	**30,00**	**51,00**	**74,00**	**81,99**
Efficiency and security of energy supply	Reducing total energy consumption	Total energy consumption (toE)		ToE/year	2020	10,08	22,39	31,24	44,96	14,51	27,23	36,21	47,63
	Reducing import dependence	% of energy from imports				–	–	–	–	–	–	–	–
	Increasing % of renewables	% of energy from renewable sources				–	–	–	–	–	–	–	–
	Reducing energy consumption per unit of transport/economic activity	toE/trip		ToE/trips	2020	7,62	9,78	17,09	12,36	6,27	10,59	18,67	12,85
		toE/GDP		ToE/euro	2020	5,29	10,87	16,66	19,69	7,22	13,18	19,12	21,51
ENVIRONMENTAL GLOBAL SCORE						**26,01**	**37,98**	**48,98**	**72,02**	**36,99**	**49,03**	**61,00**	**79,00**
Environmental	Global warming	CO_2/pers-km, t-km		g CO2/pass*km	2020	17,21	19,01	26,09	30,22	23,24	24,86	32,85	34,52
		Total CO_2		t/year	2020	8,80	18,97	22,89	41,80	13,75	24,17	28,15	44,68
	Emissions of PM/NO_x	Atmospheric emissions				–	–	–	–	–	–	–	–
	Emissions of traffic noise	Noise emitted				–	–	–	–	–	–	–	–
SOCIAL GLOBAL SCORE						**35,95**	**42,00**	**43,94**	**67,94**	**40,94**	**47,06**	**49,99**	**73,01**
Social	Increasing transport safety	Total deaths/injuries	# Deaths			–	–	–	–	–	–	–	–
			# Injuries	cases/year	2020	20,32	23,40	26,78	40,50	25,91	29,10	33,02	45,59
	Improving equity	Territorial cohesion indicators of accessibility, GDP & employment	Accessibility			–	–	–	–	–	–	–	–
			GDP	Variation coefficient	2020	2,41	2,55	2,46	2,72	2,60	2,71	2,69	2,92
				Gini index	2020	2,52	2,61	2,56	2,71	2,53	2,63	2,63	2,79
				Correlation coefficient relative change vs level	2020	1,73	2,86	2,59	3,95	1,02	2,20	3,09	3,60
				Correlation coefficient absolute change vs level	2020	2,16	2,26	2,12	2,82	2,47	2,61	2,41	3,26
			Employment	Variation coefficient	2020	2,46	2,56	2,51	2,72	2,49	2,56	2,57	2,83
				Gini index	2020	2,51	2,58	2,54	2,76	2,49	2,56	2,59	2,80
				Correlation coefficient relative change vs level	2020	1,24	2,13	1,87	4,57	0,24	1,18	1,13	4,23
				Correlation coefficient absolute change vs level	2020	0,58	1,05	0,51	5,21	1,18	1,49	0,86	4,99
COMPETITIVENESS GLOBAL SCORE						**86,00**	**65,01**	**72,97**	**11,00**	**75,99**	**59,99**	**69,00**	**14,00**
Competitiveness	Changes in accessibility	% change (each mode)				–	–	–	–	–	–	–	–
	Increasing regional GDP	% change GDP			2020	45,58	37,61	47,93	4,24	42,29	35,56	46,40	6,92
	Increasing employment rates	% change unemployment rates			2020	–	–	–	–	–	–	–	–
	Decoupling transport and GDP growth	%GDP growth-%transport growth			2020	38,42	27,40	25,04	6,76	33,78	24,43	22,80	7,08

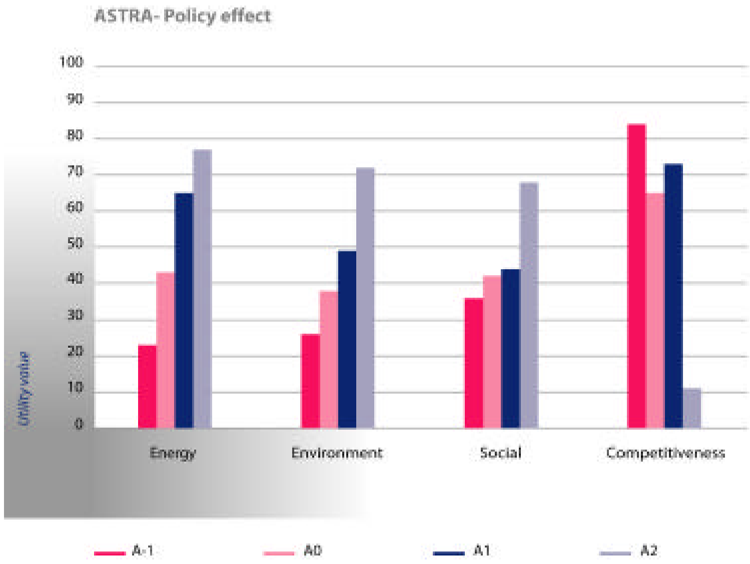
Figure 10.2 shows ASTRA's predicted effects of a fuel price increase: scenarios with higher fuel prices achieve higher scores both in terms of energy, environment and social criteria categories. The opposite effect appears for the competitiveness category, in which drastic reductions are observed as fuel price increases. This result is consistent with what Chapter 6 pointed out: fuel price increases lead to reductions in travel demand, which are associated with lower energy use and emissions, along with a deceleration of economic growth. This conflict among the scores obtained in the aforementioned criteria will appear in the interpretation of the resulting scenario scores of the other models used in STEPs, as the following sections will show.

Figure 10.2: ASTRA-Fuel price effect



If we now move to the effect caused by the different policy measures, which Figure 10.3 is intended to highlight, it can be observed that a similar effect appears when Business-as-usual (BAU), technology investments and demand regulation policies are implemented: an improvement in energy, environmental and social terms, along with a decrease in competitiveness. Among the different policies implemented, demand regulation have proven to be more effective than technology investment, i.e. scenario A2 results in higher scores than A1 in the three aforementioned categories. This observation is consistent with the ones included in the analysis of ASTRA outputs: measures constraining car use result in higher energy and emission savings than technology leading to vehicle energy efficiency improvements.

Figure 10.3: ASTRA-Policy effect



The same conclusions can be derived if the scores obtained in the different B scenarios are compared. The complete assessment results, included in Table 10.1, show how the scenario combining both fuel price increase and demand regulation measures (scenario B2), obtains the highest scores in energy, environment and social criteria, along with the lowest competitiveness score.

The main reason, by far, for the drastic reduction in B scenarios compared to A ones for the competitiveness score is quite obvious from the model's characteristics: ASTRA translates the increase in fuel price into a reduction of GDP growth rates. The same holds for the application of technology investment and demand regulation measures. In summary, at an EU scale, improvements in the first three categories lead to a deterioration of competitiveness results.

POLES

POLES is basically an energy model and therefore it only provides results under the ‘energy’ criterion. It is the only model in STEPs providing results on two of the indicators selected for their importance in European energy policy, such as the Green Book (EC, 2000): the share of energy from renewable sources and from imports. POLES scenario assessment results are included in Table 10.2. Due to the model characteristics, POLES is not sensitive to the different underlying assumptions of scenarios ‘-1’ and ‘0’. Therefore neither A0 nor B0 results are included, as they are identical to A-1 and B-1, respectively.

Table 10.2: POLES assessment results

Criteria	Sub-Criteria	Base indicator	Indicator	Detail, unit	Time	A-1	A0	A1	A2	B-1	B0	B1	B2
ENERGY GLOBAL SCORE						**–**	**23.44**	**33.08**	**46.59**	**–**	**44.46**	**58.73**	**73.27**
Efficiency and security of energy supply	Reducing total energy consumption	Total energy consumption (toE)				–	–	–	–	–	–	–	–
	Reducing import dependence	% of energy from imports		%	2030	–	17.70	20.46	22.09	–	21.71	25.52	26.15
	Increasing % of renewables	% of energy from renewable sources		%	2030	–	5.74	12.62	24.59	–	22.75	33.21	47.12
	Reducing energy consumption per unit of transport/economic activity	toE/trip				–	–	–	–	–	–	–	–
		toE/GDP				–	–	–	–	–	–	–	–
ENVIRONMENTAL GLOBAL SCORE						–	–	–	–	–	–	–	–
Environmental	Global warming	CO_2/pers-km, t-km				–	–	–	–	–	–	–	–
		Total CO_2				–	–	–	–	–	–	–	–
	Emissions of PM/NO_x	Atmospheric emissions				–	–	–	–	–	–	–	–
	Emissions of traffic noise	Noise emitted				–	–	–	–	–	–	–	–
SOCIAL GLOBAL SCORE						–	–	–	–	–	–	–	–
Social	Increasing transport safety	Total deaths/Injuries				–	–	–	–	–	–	–	–
	Improving equity	Territorial cohesion indicators of accessibility, GDP & employment				–	–	–	–	–	–	–	–
COMPETITIVENESS GLOBAL SCORE						–	–	–	–	–	–	–	–
Competitiveness	Changes in accessibility	% change (each model)				–	–	–	–	–	–	–	–
	Increasing regional GDP	% change GDP				–	–	–	–	–	–	–	–
	Increasing employment rates	% change unemployment rates				–	–	–	–	–	–	–	–
	Decoupling transport and GDP growth	%GDP growth-%transport growth				–	–	–	–	–	–	–	–

As expected, a higher fuel price gives rise, in POLES, to an increase in the share of energy coming from renewable sources and a reduction in the percentage of energy coming from imports, as the comparison of A-1 and B-1 results -represented in Figure 10.4 - shows. A similar effect appears when technology investment policies (A1) and/or demand regulation measures (A2) are implemented (see Figure 10.5). The higher score obtained by A2 when compared to A1 confirms that demand regulation measures are more efficient than technology investment ones in terms of the indicators computed by POLES.

Figure 10.4: POLES-Fuel price effect

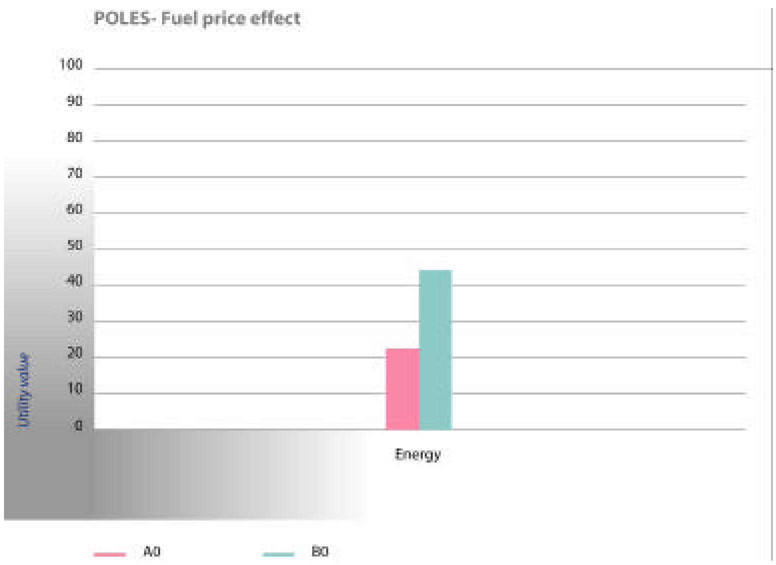
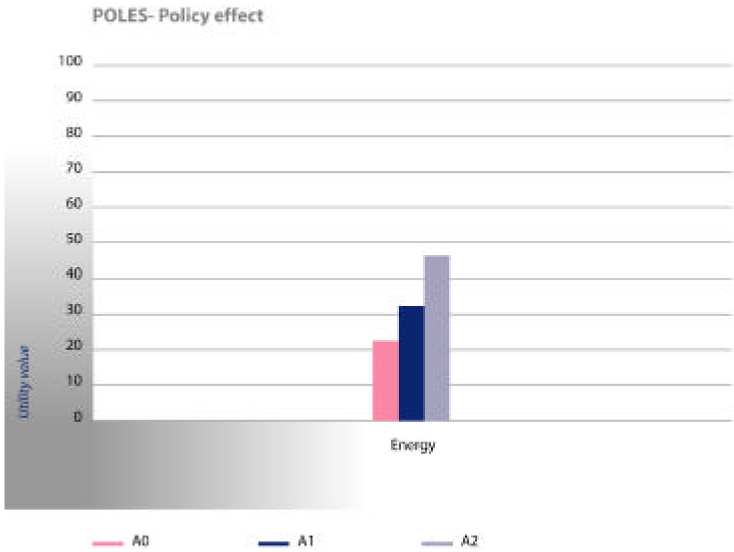


Figure 10.5: POLES-Policy effect



In summary, from the energy-biased POLES approach, both fuel price increases and policy measures have a positive effect, i.e. scenario A-1/A0, no policies, fuel price as past trends predict, is the one performing worse among all scenarios.

SASI

The inclusion of additional scenarios in the SASI model allows for a more complete analysis of the effect of extreme assumptions on fuel price increases and the integrated implementation of modelled policies.

SASI computes indicators in two criteria categories: social and competitiveness. The scores obtained in each scenario in the aforementioned categories have been included in Table 10.3 (for main STEPs scenarios) and Table 10.4(additional scenarios).

Table 10.3: SASI assessment results. Main scenarios

Criteria	Sub-Criteria	Base indicator	Indicator	Detail, unit	Time	A-1	A0	A1	A2	B-1	B0	B1	B2
ENERGY GLOBAL SCORE						–	–	–	–	–	–	–	–
Efficiency and security of energy supply	Reducing total energy consumption	Total energy consumption (toE)				–	–	–	–	–	–	–	–
	Reducing import dependence	% of energy from imports				–	–	–	–	–	–	–	–
	Increasing % of renewables	% of energy from renewable sources				–	–	–	–	–	–	–	–
	Reducing energy consumption per unit of transport/economic activity	toE/trip				–	–	–	–	–	–	–	–
		toE/GDP				–	–	–	–	–	–	–	–
ENVIRONMENTAL GLOBAL SCORE						–	–	–	–	–	–	–	–
Environmental	Global warming	CO_2/pers-km, t-km				–	–	–	–	–	–	–	–
		Total CO_2				–	–	–	–	–	–	–	–
	Emissions of PM/NO_x	Atmospheric emissions				–	–	–	–	–	–	–	–
	Emissions of traffic noise	Noise emitted				–	–	–	–	–	–	–	–
SOCIAL GLOBAL SCORE						**53,07**	**58,87**	**63,90**	**50,64**	**54,94**	**54,81**	**60,49**	**52,65**
Social	Increasing transport safety	Total deaths/injuries				–	–	–	–	–	–	–	–
	Improving equity	Territorial cohesion indicators of accessibility, GDP & employment	Accessibility	CoV (0-100)	2030	–	–	–	–	–	–	–	–
				Gini coefficient (0-100)	2030	8,01	6,47	7,67	–	3,99	0,32	4,00	–
				Relative convergence (0-1)	2030	9,75	11,80	11,78	8,70	10,71	9,36	10,57	7,82
				Abs. convergence (0-1)	2030	10,00	1,98	4,52	3,90	0,41	2,26	3,65	5,71
			GDP	CoV (0-100)	2030	–	–	–	–	–	–	–	–
				Gini coefficient (0-100)	2030	8,60	13,35	12,39	14,03	13,67	14,74	13,63	14,03
				Relative convergence (0-1)	2030	6,71	10,59	9,73	11,43	10,86	11,85	10,79	11,48
				Abs. convergence (0-1)	2030	10,00	14,68	18,01	12,58	15,30	16,28	17,85	13,61
			Employment			–	–	–	–	–	–	–	–
COMPETITIVENESS GLOBAL SCORE						**83,59**	**60,70**	**68,61**	**42,79**	**49,20**	**31,40**	**40,59**	**24,51**
Competitiveness	Changes in accessibility	% change in accessibility		Travel road/rail	2030	–	–	–	–	–	–	–	–
				Travel road/rail/air	2030	14,41	10,21	12,79	9,48	9,33	5,69	8,20	6,13
				Freight road	2030	14,41	11,74	13,68	8,38	7,80	5,07	6,96	3,90
				Freight road/rail	2030	14,41	4,33	3,92	–	4,37	–	–	–
	Increasing regional GDP	% change GDP		%	2030	–	–	–	–	–	–	–	–
	Increasing employment rates	% employment		%	2030	40,36	34,42	38,22	24,93	27,70	20,64	25,43	14,48
	Decoupling transport and GDP growth	%GDP growth-%transport growth				–	–	–	–	–	–	–	–

Table 10.4: SASI assessment results. Additional scenarios

Criteria	Sub-Criteria	Base indicator	Indicator	Detail, unit	Time	A-1	A0	A1	A2	B-1	B0	B1	B2
ENERGY GLOBAL SCORE						–	–	–	–	–	–	–	–
Efficiency and security of energy supply	Reducing total energy consumption	Total energy consumption (toE)				–	–	–	–	–	–	–	–
	Reducing import dependence	% of energy from imports				–	–	–	–	–	–	–	–
	Increasing % of renewables	% of energy from renewable sources				–	–	–	–	–	–	–	–
	Reducing energy consumption per unit of transport/economic activity	toE/trip				–	–	–	–	–	–	–	–
		toE/GDP				–	–	–	–	–	–	–	–
ENVIRONMENTAL GLOBAL SCORE						**33,00**	**40,99**	**44,00**	**70,02**	**38,01**	**43,98**	**45,02**	**77,00**
Environmental	Global warming	CO_2/prs-km,t-km		(t CO_2/pass*km)	2020	7,84	7,29	11,80	15,79	9,90	9,21	14,67	18,96
		Total CO_2		(t)	2020	7,16	9,89	11,21	17,48	8,47	10,71	12,37	19,02
	Emissions of PM/NO_x	Atmospheric emissions	PM	(t)		10,74	12,58	9,13	18,40	12,12	12,84	6,19	20,13
			NO_x	(t)		7,26	11,23	11,86	18,35	7,52	11,22	11,79	18,89
	Emissions of traffic noise	Noise emitted				–	–	–	–	–	–	–	–
SOCIAL GLOBAL SCORE						**48,00**	**47,99**	**51,03**	**51,01**	**50,04**	**50,00**	**51,00**	**52,00**
Social	Increasing transport safety	Total deaths/injuries				–	–	–	–	–	–	–	–
	Improving equity	Territorial cohesion indicators of accessibility, GDP & employment	Accessibility	Variation coefficient	2020	12,74	12,90	13,34	13,93	13,96	13,35	13,87	14,16
				Gini index	2020	12,89	13,02	13,30	13,85	13,42	13,38	13,73	14,00
				Corr. coeff. relative change vs. level	2020	9,20	9,06	10,27	13,04	11,07	11,16	12,27	14,55
				Corr. coeff. relative change vs. level	2020	13,17	13,01	14,12	10,19	12,19	12,11	13,13	9,29
			GDP			–	–	–	–	–	–	–	–
			Employment			–	–	–	–	–	–	–	–
COMPETITIVENESS GLOBAL SCORE						**100,00**	**55,01**	**79,99**	**75,99**	**48,01**	**9,01**	**32,01**	**32,01**
Competitiveness	Changes in accessibility	% change (each mode)	Multimodal			100,00	55,01	79,99	75,99	48,01	9,01	32,01	32,01
			Bus			–	–	–	–	–	–	–	–
			Train			–	–	–	–	–	–	–	–
			Car			–	–	–	–	–	–	–	–
			Water			–	–	–	–	–	–	–	–
			Air			–	–	–	–	–	–	–	–
	Increasing regional GDP	% change GDP				–	–	–	–	–	–	–	–
	Increasing employment rates	% change unemployment rates				–	–	–	–	–	–	–	–
	Decoupling transport and GDP growth	%GDP growth-%transport growth				–	–	–	–	–	–	–	–

The effects of an increase in fuel price, if compared to the reference scenario (A-1 vs B-1 and C-1, see Figure 10.6), as well as those derived from the implementation of policies (A-1 vs A0, A1, A2 and A3, see Figure 10.7) point in the same direction: a slight improvement in social criteria and a severe deterioration of competitiveness.

Figure 10.6: SASI- Fuel price effect

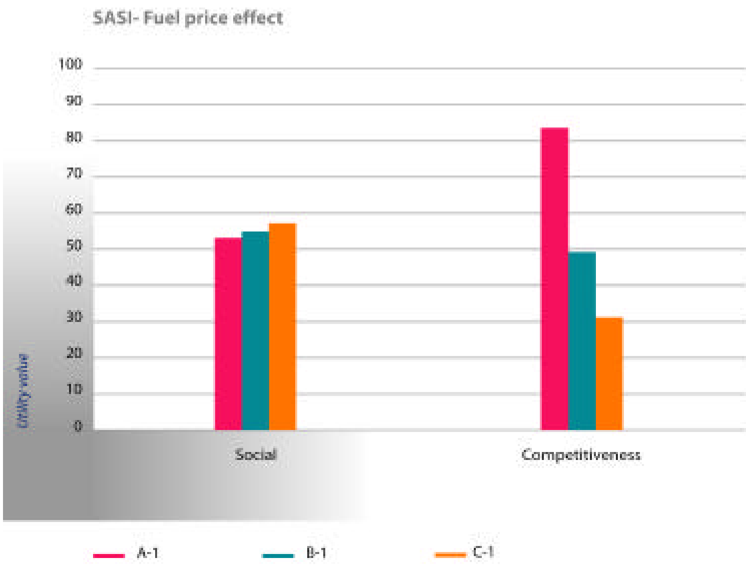
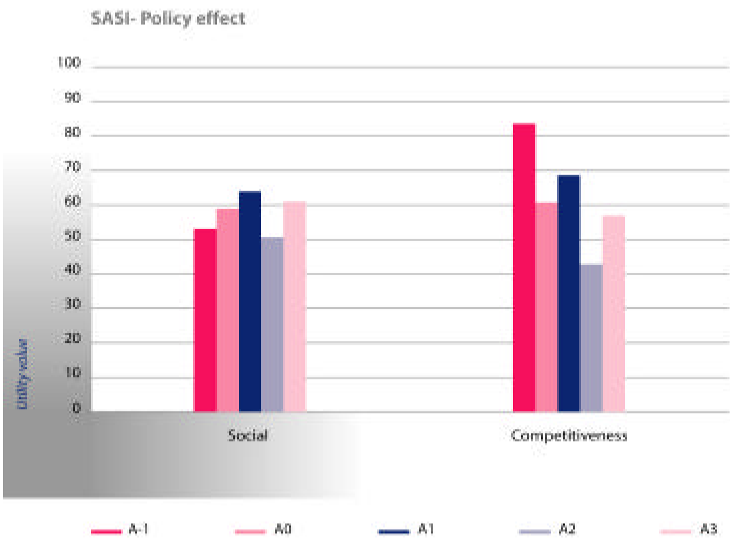


Figure 10.7: SASI- Policy effect



This result is consistent with the concerns stated in SASI's corresponding section of Chapter 6. On the one hand, a slightly more balanced spatial structure is achieved when fuel price increases, but on the other hand, there is a warning about the serious implications for a competitive economy of an increase in fuel price and/or the implementation of modelled policies, due to the drastic reductions in accessibility they lead to.

This effect is particularly strong in the scenario with extreme fuel price increase (C-1). In this case, the increase in generalised costs brought about by higher fuel prices gives rise to significant competitiveness losses: up to a reduction of near 75% of the competitiveness score of the reference scenario A-1. Regarding the reduction of competitiveness caused by the modelled policy measures, again all scenarios perform worse than the reference scenario, i.e. any of the modelled policies aimed at improving energy efficiency or environment conditions appear to result in a serious threat to economic growth, although they seem to slightly improve spatial cohesion in the EU. If compared to the values obtained by the reference scenario, the combination of technology investment and demand regulation policies (A3) result in a 25% increase in social terms, along with a 50% reduction of competitiveness.

10.3 Regional/local models

BRUSSELS

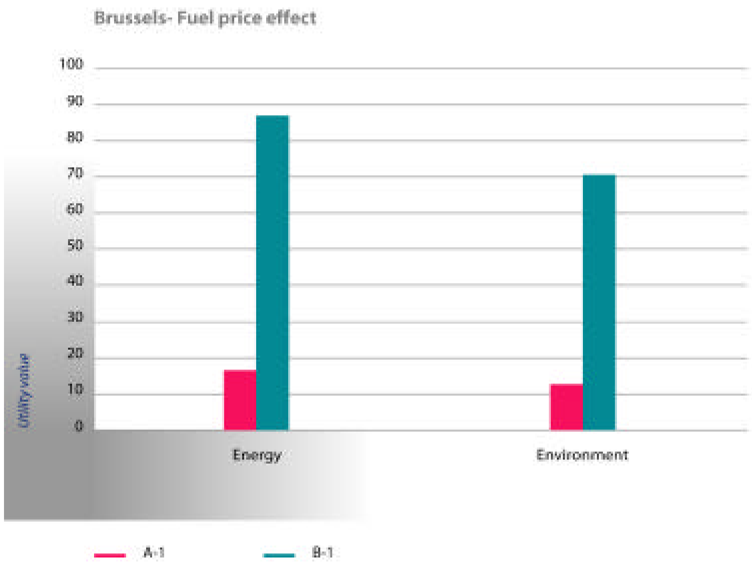
The Brussels model only provides indicators for the energy and environment categories, based on energy consumptions and GHG and NO_x emmissions. The corresponding scores are included in Table 10.5.

Table 10.5: Brussels assessment results

Criteria	Sub-Criteria	Base indicator	Indicator	Detail, unit	Time	A-1	A0	A1	A2	B-1	B0	B1	B2
ENERGY GLOBAL SCORE						**16,00**	**18,02**	**29,00**	**56,99**	**84,00**	**55,00**	**59,99**	**87,01**
Efficiency and security of energy supply	Reducing total energy consumption	Total energy consumption (toE)		morning peak (06:00-10:00)	2020	7,59	8,23	13,32	28,56	42,67	27,43	29,35	44,00
	Reducing import dependence	% of energy from imports				–	–	–	–	–	–	–	–
	Increasing % of renewables	% of energy from renewable sources				–	–	–	–	–	–	–	–
	Reducing energy consumption per unit of transport/economic activity	toE/trip		per car trip	2020	8,41	9,79	15,68	28,43	41,33	27,57	30,64	43,01
		toE/GDP				–	–	–	–	–	–	–	–
ENVIRONMENTAL GLOBAL SCORE						**13,00**	**59,99**	**61,00**	**84,01**	**74,00**	**80,00**	**78,98**	**100,0**
Environmental	Global warming	CO_2/pers-km, t-km				–	–	–	–	–	–	–	–
		Total CO_2		kg morning peak (06:00-10:00)	2020	7,91	12,56	12,76	33,93	45,26	30,46	29,20	48,24
	Emissions of PM/NO_x	Atmospheric emissions	PM			–	–	–	–	–	–	–	–
			NO_x	kg morning peak (06:00-10:00)	2020	5,09	47,43	48,24	50,08	28,74	49,54	49,78	51,76
	Emissions of traffic noise	Noise emitted				–	–	–	–	–	–	–	–
SOCIAL GLOBAL SCORE						–	–	–	–	–	–	–	–
Social	Increasing transport safety	Total deaths/Injuries				–	–	–	–	–	–	–	–
	Improving equity	Territorial cohesion Indicators of accessibility, GDP & employment				–	–	–	–	–	–	–	–
COMPETITIVENESS GLOBAL SCORE						–	–	–	–	–	–	–	–
Competitiveness	Changes in accessibility	% change (each mode)				–	–	–	–	–	–	–	–
	Increasing regional GDP	% change GDP				–	–	–	–	–	–	–	–
	Increasing employment rates	% change unemployment rates				–	–	–	–	–	–	–	–
	Decoupling transport and GDP growth	%GDP growth-%transport growth				–	–	–	–	–	–	–	–

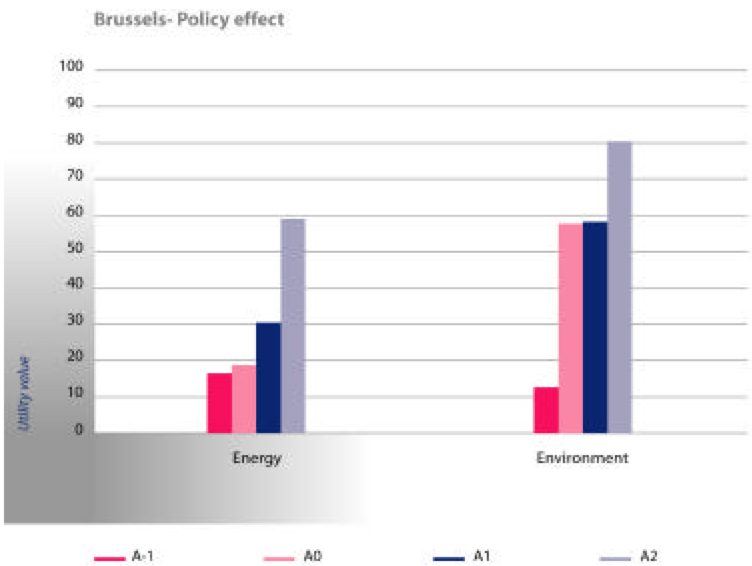
The effect of fuel price increases on the assessment results is highlighted in Figure 10.8. The assessment results confirm what Chapter 7 pointed out: the model is extremely sensitive to changes in fuel price, both in energy and environmental terms. In particular, the fuel price increases included in the B-1 scenario bring about a 520% and a 560% improvement, respectively, in terms of the corresponding scores on the reference scenario.

Figure 10.8: Brussels- Fuel price effect



The observed policy effect is also relevant, as showed in Figure 10.9. In this case, demand management policies perform considerably better than technology oriented policies in the aforementioned two criteria categories. This observation is consistent with what the other European models showed: policies leading to a reduction in car use are more effective than improved technology for the reduction of energy consumption and related emissions.

Figure 10.9: Brussels- Policy effect



DORTMUND

Dortmund results show a clear pattern: both fuel price increases and the implementation of policies are translated into an improvement in energy, environment and social criteria, at the expense of severe loses in competitiveness. Table 10.6 (main scenarios) and Table 10.7 (additional scenarios) include the assessment results obtained. These scores are consistent with the conclusions taken from the model outputs in Chapter 7.

Table 10.6: Dortmund assessment results. Main scenarios

Criteria	Sub-Criteria	Base indicator	Indicator	Detail, unit	Time	A-1	A0	A1	A2	B-1	B0	B1	B2
ENERGY GLOBAL SCORE						**15,81**	**38,71**	**72,31**	**71,51**	**43,58**	**62,41**	**84,91**	**89,5**
Efficiency and security of energy supply	Reducing total energy consumption	Total energy consumption (toE)		car fuel/capita/day (l)	2030	4,99	18,58	33,59	37,48	19,62	30,70	39,27	45,38
	Reducing import dependence	% of energy from imports				–	–	–	–	–	–	–	–
	Increasing % of renewables	% of energy from renewable sources				–	–	–	–	–	–	–	–
	Reducing energy consumption per unit of transport/economic activity	toE/trip		car fuel/car trip/traveller (l)	2030	10,82	20,13	38,72	34,03	23,96	51,71	45,64	44,12
		toE/GDP				–	–	–	–	–	–	–	–
ENVIRONMENTAL GLOBAL SCORE						**33,99**	**43,58**	**47,51**	**62,99**	**47,71**	**56,76**	**57,11**	**71,58**
Environmental	Global warming	CO_2 emission		kg/capita/day	2030	15,98	24,27	28,72	43,77	28,25	37,75	38,36	52,89
		Total CO_2				–	–	–	–	–	–	–	–
	Emissions of PM/NO_x	Atmospheric emissions	PM	mg/capita/day	2030	-	0,89	2,10	7,83	4,24	5,72	5,74	11,31
			NO_x	g/capita/day	2030	20,01	18,62	16,69	10,99	15,22	13,29	13,01	7,38
	Emissions of traffic noise	Noise emitted				–	–	–	–	–	–	–	–
SOCIAL GLOBAL SCORE						**37,14**	**48,35**	**43,94**	**63,77**	**52,47**	**62,67**	**60,22**	**73,84**
Social	Increasing transport safety	Total deaths/injuries	Deaths	deaths/million pop/year	2030	4,20	10,22	11,93	18,93	9,93	15,57	15,76	22,77
			Injuries	injuries/million pop/year	2030	8,75	13,46	14,85	20,40	13,14	17,63	17,79	23,44
	Improving equity	Territorial cohesion indicators of accessibility, GDP & employment	Accessibility	CoV (0-100)	2030	3,01	2,82	2,60	1,55	3,15	2,91	2,76	1,25
				Gini coefficient (0-100)	2030	2,07	1,95	1,68	0,53	2,33	2,17	1,95	0,16
				Relative convergence (0-1)	2030	1,97	1,77	–	1,38	3,94	3,55	2,36	2,57
				Abs. convergence (0-1)	2030	1,97	3,54	1,77	2,56	3,94	3,95	3,94	3,55
			Income	CoV (0-100)	2030	1,75	1,65	1,50	2,17	1,68	1,67	1,64	2,24
				Gini coefficient (0-100)	2030	0,99	0,83	0,69	1,30	0,85	0,81	0,79	1,52
				Relative convergence (0-1)	2030	1,97	1,77	0,59	2,58	2,17	2,37	1,97	2,98
				Abs. convergence (0-1)	2030	1,97	2,36	0,59	2,56	2,76	3,35	2,76	3,16
			Segregation	High-income h.h. (0-100)	2030	0,79	1,05	0,89	1,04	1,02	1,34	1,27	1,35
				Low-income h.h. (0-100)	2030	1,96	1,86	1,84	2,62	1,88	1,91	1,93	2,70
				Old people (0-100)	2030	2,96	2,71	2,60	2,95	2,91	2,88	2,69	2,73
				Foreign population (0-100)	2030	2,78	2,36	2,41	3,22	2,77	2,56	2,61	3,04
COMPETITIVENESS GLOBAL SCORE						**100,01**	**57,72**	**78,13**	**46,01**	**65,90**	**30,58**	**44,60**	**18,40**
Competitiveness	Changes in accessibility	% change in accessibility		Population (%)	2030	7,41	7,41	6,74	6,37	7,40	7,40	6,74	6,37
				Employment (%)	2030	7,41	5,55	5,41	3,56	6,52	4,96	4,59	3,26
				Shops (%)	2030	7,41	6,00	6,08	3,19	6,74	5,63	5,56	3,04
				Retail purchase power (%)	2030	7,41	5,70	5,95	2,98	6,44	5,18	5,28	2,81
				High schools (%)	2030	7,41	5,41	5,34	2,89	6,52	4,59	4,52	2,30
				CBD (%)	2030	7,41	4,32	4,42	1,28	4,54	1,38	1,88	–
	Increasing regional GDP	% change GDP		%	2030	33,53	23,33	26,68	14,67	16,66	6,00	10,00	–
	Incremployment rates	% change unemployment		%	2030	22,22	15,38	17,52	11,11	11,28	3,46	6,05	0,62
	Decoupling transport and GDP growth	%GDP growth-%transport growth				–	–	–	–	–	–	–	–

Table 10.7: Dortmund assessment results. Additional scenarios

Criteria	Sub-Criteria	Base indicator	Indicator	Detail, unit	Time	A-1	A3	B3	C-1	C0	C1	C2	C3
ENERGY GLOBAL SCORE						**15,81**	**91,10**	**95,00**	**73,28**	**74,30**	**88,60**	**99,30**	**99,30**
Efficiency and security of energy supply	Reducing total energy consumption	Total energy consumption (toE)		car fuel/capita/day (l)	2030	4,99	44,66	48,57	35,36	37,15	42,16	52,86	52,86
	Reducing import dependence	% of energy from imports				–	–	–	–	–	–	–	–
	Increasing % of renewables	% of energy from renewable sources				–	–	–	–	–	–	–	–
	Reducing energy consumption per unit of transport/economic activity	toE/trip		car fuel/car trip/traveller (l)	2030	10,82	46,44	46,43	37,82	37,15	46,44	46,44	46,44
		toE/GDP				–	–	–	–	–	–	–	–
ENVIRONMENTAL GLOBAL SCORE						**33,99**	**64,95**	**72,11**	**65,98**	**63,10**	**57,81**	**72,40**	**72,40**
Environmental	Global warming	CO_2 emission		kg/capita/day	2030	15,98	46,41	53,53	44,93	44,90	39,24	53,83	53,83
		Total CO_2				–	–	–	–	–	–	–	–
	Emissions of PM/NO_x	Atmospheric emissions	PM	mg/capita/day	2030	–	8,67	11,47	9,46	7,90	6,48	14,23	14,05
			NO_x	g/capita/day	2030	20,01	9,87	7,11	9,59	10,90	12,09	4,34	4,52
	Emissions of traffic noise	Noise emitted				–	–	–	–	–	–	–	–
SOCIAL GLOBAL SCORE						**45,73**	**62,82**	**70,60**	**68,56**	**68,99**	**59,30**	**77,06**	**75,25**
Social	Increasing transport safety	Total deaths/injuries	Deaths	deaths/million pop/year	2030	4,20	19,87	23,01	17,72	18,56	15,38	26,14	25,91
			Injuries	injuries/million pop/year	2030	8,75	21,22	23,65	19,30	20,04	17,54	26,15	25,96
	Improving equity	Territorial cohesion indicators of accessibility, GDP & employment	Accessibility	CoV (0-100)	2030	3,01	1,46	1,28	3,11	2,82	2,74	0,35	0,27
				Gini coefficient (0-100)	2030	2,07	0,43	0,22	2,46	2,13	1,90	–	–
				Relative convergence (0-1)	2030	3,88	0,79	1,78	3,94	3,94	2,17	2,37	1,58
				Abs. convergence (0-1)	2030	1,97	2,36	3,16	3,94	3,94	3,95	3,55	2,96
			Income	CoV (0-100)	2030	1,75	2,04	2,11	1,72	1,66	1,64	1,90	1,95
				Gini coefficient (0-100)	2030	0,99	1,18	1,20	0,85	0,79	0,77	0,79	0,87
				Relative convergence (0-1)	2030	1,97	1,97	2,57	2,76	2,37	1,78	2,37	2,56
				Abs. convergence (0-1)	2030	1,97	1,77	2,57	3,75	3,55	2,76	3,55	3,55
			Segregatio	High-income h.h. (0-100)	2030	0,79	0,80	1,10	1,51	1,65	1,55	1,55	1,32
				Low-income h.h. (0-100)	2030	1,96	2,51	2,58	1,99	1,93	2,02	2,22	2,24
				Old people (0-100)	2030	2,96	2,99	2,63	2,78	2,85	2,59	3,35	3,29
				Foreign population (0-100)	2030	2,76	3,33	2,74	2,73	2,76	2,51	2,77	2,79
COMPETITIVENESS GLOBAL SCORE						**100,01**	**55,19**	**28,00**	**30,02**	**26,30**	**32,61**	**15,31**	**9,40**
Competitiveness	Changes in accessibility	% change in accessibility		Population (%)	2030	7,41	5,26	5,19	7,42	7,41	6,67	6,58	5,55
				Employment (%)	2030	7,41	2,81	2,52	5,34	4,45	4,74	2,22	0,59
				Shops (%)	2030	7,41	2,52	2,37	6,08	5,41	5,63	3,03	1,63
				Retail purchase power (%)	2030	7,41	2,44	2,15	5,84	4,96	5,33	3,18	1,63
				High schools (%)	2030	7,41	2,22	1,78	5,12	4,07	4,74	0,90	–
				CBD (%)	2030	7,41	1,51	0,44	0,42	–	2,12	–	–
	Increasing regional GDP	% change GDP		%	2030	33,33	21,99	7,33	–	–	2,67	–	–
	Inc.employment rates	% change unemployment		%	2030	22,22	16,44	6,22	–	–	0,71	–	–
	Decoupling transport and GDP growth	%GDP growth-%transport growth				–	–	–	–	–	–	–	–

As with SASI, the inclusion of the additional scenarios in the Dortmund model allows for a more complete analysis of the effect of extreme assumptions on fuel price increases and the implementation of modelled policies. In these additional scenarios, the direction of the effects occurred in the 'basic' scenarios is intensified. In general, the scores obtained by scenarios 'C' and '3' in energy, environment and social criteria are higher than those corresponding to 'B', and '0-1-2', respectively. In other words, extreme hypothesis on fuel price growth, or the combination of technology investment and demand management policy measures tend to reinforce the positive effect on the first three assessment criteria.

Exactly the opposite holds for the fourth criteria category: competitiveness. Additional generalised cost increases present in scenarios 'C' and '3' give rise to increased mobility constraints, accessibility losses and, results in worse economic results, in terms of GDP and employment indicators, as the Dortmund model forecasts. In particular, scenario C-1 nearly halves the competitiveness score obtained in the reference scenario A-1, as Figure 10.10 shows. The policy effect is highlighted in Figure 10.11, where it is shown how a similar percentage of competitiveness reduction appears when comparing A3 –combining technology investment with demand regulation measures- with the reference scenario.

Figure 10.10: Dortmund- Fuel price effect

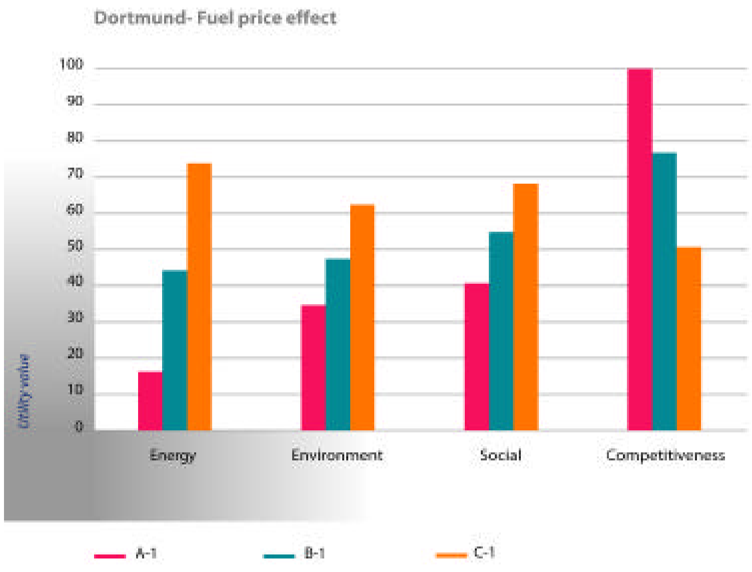
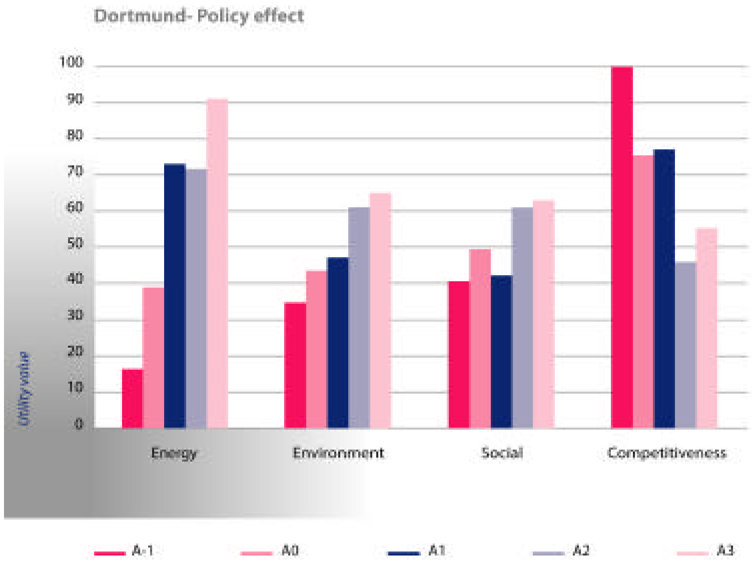


Figure 10.11: Dortmund- Policy effect



In general terms, it can also be concluded that demand regulation measures are more effective than technology investment measures in energy efficiency and environmental terms. Again, as the models analyzed so far have shown, the reduction in traffic brought about by the '2' scenarios goes beyond the enhanced energy efficiency of '1' scenarios.

In summary, the already commented trade-off between energy, environment and social criteria, on the one side, and competitiveness, on the other, is particularly apparent if one looks at the assessment results of the Dortmund model.

EDINBURGH

Table 10.8 includes the assessment results for the Edinburgh model, which computes indicators in the four criteria categories. In the Edinburgh case, the direction of the effect in the first two categories, energy and environment, is the same than in the previous models, i.e., those scenarios with higher fuel prices and/ore those in which policies are implemented obtain higher scores than the reference scenario.

Table 10.8: Edinburgh assessment results

Criteria	Sub-Criteria	Base indicator	Indicator	Detail, unit	Time	A-1	A0	A1	A2	B-1	B0	B1	B2
ENERGY GLOBAL SCORE						**25,7**	**39,1**	**53,9**	**57,11**	**61,18**	**61,7**	**79,7**	**72,89**
Efficiency and security of energy supply	Reducing total energy consumption	Total energy consumption (toE)		toE/year	2020	13,44	20,52	28,30	28,74	32,05	32,41	42,05	37,18
	Reducing import dependence	% of energy from imports				–	–	–	–	–	–	–	–
	Increasing % of renewables	% of energy from renewable sources				–	–	–	–	–	–	–	–
	Reducing energy consumption per unit of transport/economic activity	toE/trip		toE/trips	2020	12,26	18,58	25,60	28,37	29,13	29,29	37,65	35,71
		toE/GDP				–	–	–	–	–	–	–	–
ENVIRONMENTAL GLOBAL SCORE						**21,40**	**29,41**	**57,88**	**62,99**	**44,19**	**46,60**	**83,99**	**77,89**
Environmental	Global warming	CO_2/prs-km/t-km		g CO_2/pass*km	2020	6,06	7,17	15,62	20,20	10,92	10,58	22,49	23,47
		Total CO_2			2020	5,93	9,22	15,29	17,79	14,25	15,48	23,62	22,59
	Emissions of PM/NO_x	Atmospheric emissions	PM	t/year		4,97	6,21	13,84	12,78	9,00	9,67	18,62	16,35
			NO_x			4,44	6,81	13,13	12,22	10,04	10,87	19,26	15,48
	Emissions of traffic noise	Noise emitted				–	–	–	–	–	–	–	–
SOCIAL GLOBAL SCORE						**25,32**	**35,79**	**46,27**	**59,12**	**45,60**	**49,62**	**54,71**	**70,41**
Social	Increasing transport safety	Total deaths/Injuries	# Deaths		2020	6,11	10,38	12,94	17,77	15,37	16,58	18,36	22,46
			# Injuries		2020	6,02	9,18	11,55	18,85	11,55	13,31	15,91	22,58
	Improving equity	Territorial cohesion indicators of accessibility, GDP & employment	Accessibility	Gini index	2020	8,28	11,33	9,52	10,23	13,85	14,60	15,53	13,72
				Spearman's rank corr. coeff.	2020	4,91	4,90	12,26	12,27	4,91	4,91	4,91	19,65
			GDP			–	–	–	–	–	–	–	–
			Employment			–	–	–	–	–	–	–	–
COMPETITIVENESS GLOBAL SCORE						**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Competitiveness	Changes in accessibility	% change (each mode)				–	–	–	–	–	–	–	–
	Increasing regional GDP	% change GDP				–	–	–	–	–	–	–	–
	Increasing employment rates	% change unemployment rates				–	–	–	–	–	–	–	–
	Decoupling transport and GDP growth	%GDP growth-%transport growth				–	–	–	–	–	–	–	–

In terms of social criteria, the increase in fuel price provokes, on the one hand, a reduction in travel demand which is obviously translated into a reduced number of injuries. On the other, it results in an increase in spatial accessibility disparities, i.e. equity is negatively influenced. As showed in Figure 10.12, the combination of both effects using the MCA methodology finally leads to a higher score of B-1 scenario vs A-1 in the social category.

Regarding the policy effects, the implementation of policies driving scenario A2 is translated into a large reduction in the number of injuries, capable of overcoming the negative equity impact of scenario A2. Subsequently, as shown in Figure 10.13, in social terms, A2 performs noticeable better than the rest of A scenarios.

In the competitiveness category, the effect of an increase in fuel price also leads to reductions in competitiveness scores. The effect is not that obvious if we move to the policy effects: BAU and demand regulation policies tend to reduce competitiveness, whereas technology investment measures increase it. The reasons for this result are not obvious and must be found in the indicators driving competitiveness final scores in the Edinburgh model. These indicators are changes in accessibility by slow modes, bus and car. The different combinations (via criteria weights and value functions) of the percentage change in the two latter modes are responsible for the final results. E.g. '2' scenarios result, on the one hand, in significant improvements in bus accessibility (due to lower bus fares and the reduced use of car and its consequent increase in bus speed). On the other hand, they also give rise to significant car accessibility losses. The integration of these results using the MCA methodology finally results in a slightly lower competitiveness score in the A2 vs A1 scenario. The same rationale lies behind the higher competitiveness score of A1 scenario. Given this result, a sensitivity analysis of the results to change in the weights assigned to accessibility by bus and car has been carried out (see Section 9.4).

Finally, it is also useful to compare the magnitude of the effect caused by fuel price increases versus those caused by the modelled policies. The Edinburgh model appears to be more sensitive to the latter ones. As the comparison of Figure 10.12 and Figure 10.13 suggests, different policies implemented, especially the demand regulation ones, have a stronger effect on energy and environmental category, of compared to the limited influence of fuel price increases.

Figure 10.12: Edinburgh- Fuel price effect

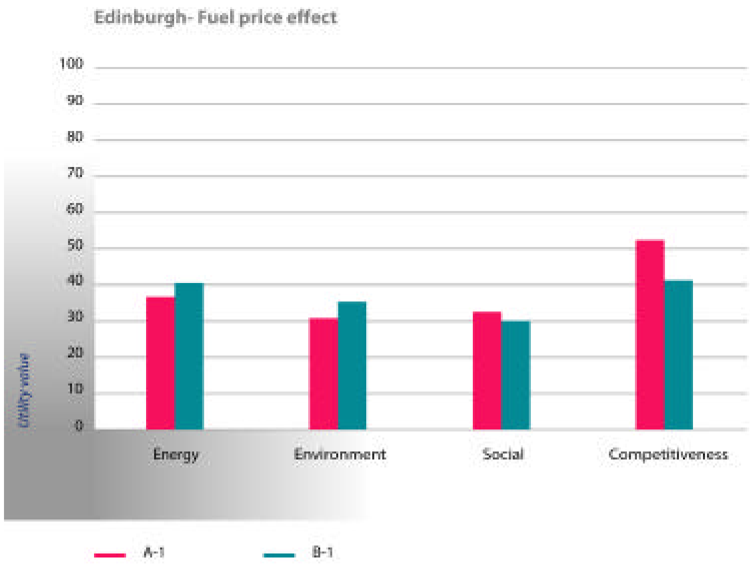
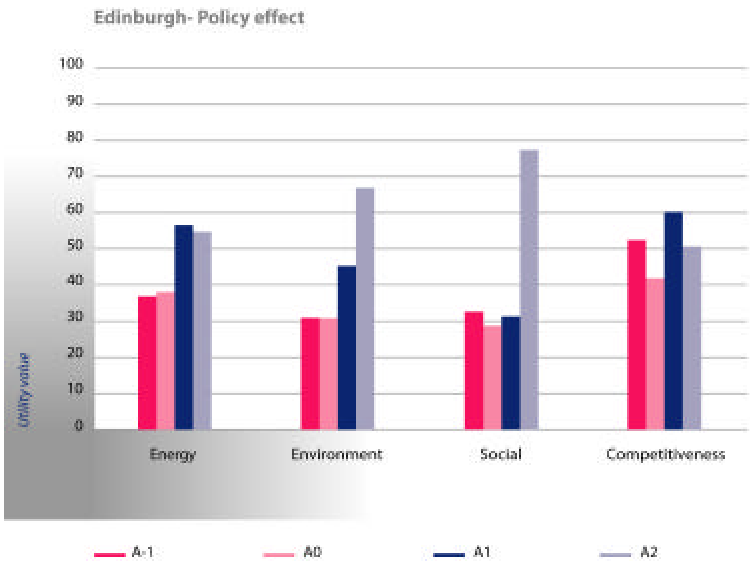


Figure 10.13: Edinburgh- Policy effect



HELSINKI

Table 10.9 includes the results obtained in the Helsinki model, which only computes indicators for energy, environment and social criteria. Therefore, the aforementioned conflict between these criteria categories and the competitiveness one is not present in this case. It is not surprising then to find that the reference scenario is the one showing worse scores in all cases, as both fuel price increases and modelled policies improve the situation in the three criteria categories analyzed.

Table 10.9: Helsinki assessment results

Criteria	Sub-Criteria	Base indicator	Indicator	Detail, unit	Time	A-1	A0	A1	A2	B-1	B0	B1	B2
ENERGY GLOBAL SCORE						**25,7**	**39,1**	**53,9**	**57,11**	**61,18**	**61,7**	**79,7**	**72,89**
Efficiency and security of energy supply	Reducing total energy consumption	Total energy consumption (toE)		toE/year	2020	13,44	20,52	28,30	28,74	32,05	32,41	42,05	37,18
	Reducing import dependence	% of energy from imports				–	–	–	–	–	–	–	–
	Increasing % of renewables	% of energy from renewable sources				–	–	–	–	–	–	–	–
	Reducing energy consumption per unit of transport/economic activity	toE/trip		toE/trips	2020	12,26	18,58	25,60	28,37	29,13	29,29	37,65	35,71
		toE/GDP				–	–	–	–	–	–	–	–
ENVIRONMENTAL GLOBAL SCORE						**21,40**	**29,41**	**57,88**	**62,99**	**44,19**	**46,60**	**83,99**	**77,89**
Environmental	Global warming	CO_2/pas-km;t-km		g CO_2/pass*km	2020	6,06	7,17	15,62	20,20	10,92	10,58	22,49	23,47
		Total CO_2			2020	5,93	8,22	15,29	17,79	14,25	15,48	23,62	22,59
	Emissions of PM/NO_x	Atmospheric emissions	PM	t/year		4,97	6,21	13,84	12,78	9,00	9,67	18,62	16,35
			NO_x			4,44	6,81	13,13	12,22	10,04	10,87	19,26	15,48
	Emissions of traffic noise	Noise emitted				–	–	–	–	–	–	–	–
SOCIAL GLOBAL SCORE						**25,32**	**35,79**	**46,27**	**59,12**	**45,60**	**49,62**	**54,71**	**78,41**
Social	Increasing transport safety	Total deaths/Injuries	# Deaths		2020	6,11	10,38	12,94	17,77	15,37	16,58	18,36	22,46
			# Injuries		2020	6,02	9,18	11,55	18,85	11,55	13,31	15,91	22,58
	Improving equity	Territorial cohesion indicators of accessibility, GDP & employment	Accessibility	Gini index	2020	8,28	11,33	9,52	10,23	13,85	14,62	15,53	13,72
				Spearman's rank corr. coeff.	2020	4,91	4,90	12,26	12,27	4,91	4,91	4,91	19,65
			GDP			–	–	–	–	–	–	–	–
			Employment			–	–	–	–	–	–	–	–
COMPETITIVENESS GLOBAL SCORE						**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Competitiveness	Changes in accessibility	% change (each mode)				–	–	–	–	–	–	–	–
	Increasing regional GDP	% change GDP				–	–	–	–	–	–	–	–
	Increasing employment rates	% change unemployment rates				–	–	–	–	–	–	–	–
	Decoupling transport and GDP growth	%GDP growth-%transport growth				–	–	–	–	–	–	–	–

Figure 10.14 shows how the assessment scores are affected by a fuel price increase as predicted by the Helsinki model: the result is positive in all criteria categories. Resulting values are in the range of doubling the corresponding reference scenario scores. The effect is particularly strong in the energy criteria, where the fuel price increase is equivalent to a 240% rise in the energy score of the reference scenario.

Figure 10.14: Helsinki – Fuel price effect

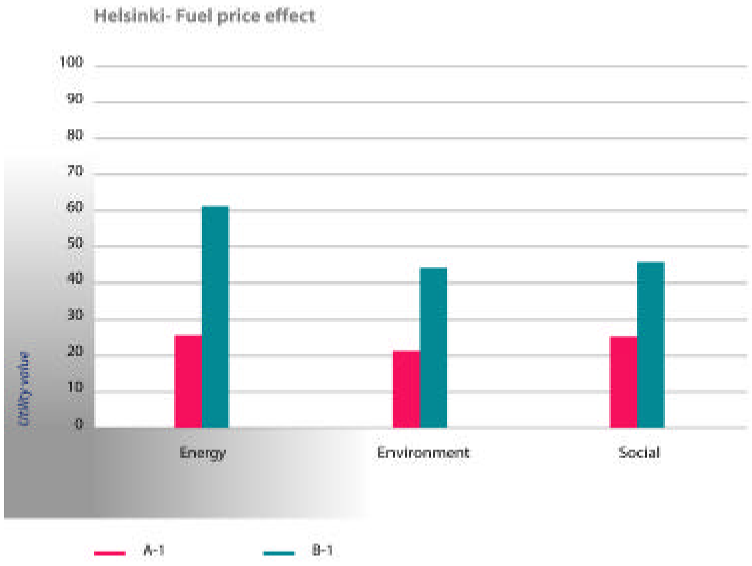
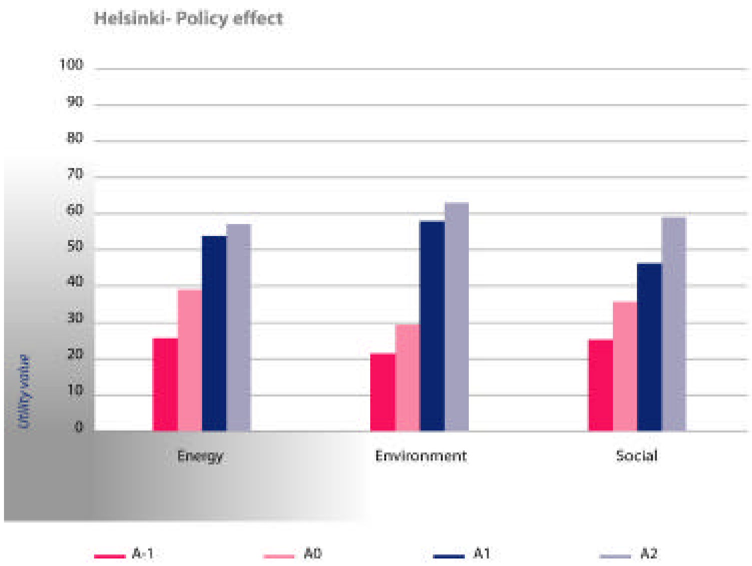


Figure 10.15: Helsinki – Policy effect



The policies effect, as it appears, in Figure 10.15, again shows that all the policy scenarios give rise to an improvement in all the criteria categories. In the Helsinki model, demand management scenarios perform better than technology investment scenarios, although differences between them are lower than in previous models.

SOUTH TYROL

In this case, the model does not compute any indicators under the energy category, as Table 10.10 shows.

Table 10.10: South Tyrol assessment results

Criteria	Sub-Criteria	Base indicator	Indicator	Detail, unit	Time	A-1	A0	A1	A2	B-1	B0	B1	B2
ENERGY GLOBAL SCORE						-	-	-	-	-	-	-	-
Efficiency and security of energy supply	Reducing total energy consumption	Total energy consumption (toE)				-	-	-	-	-	-	-	-
	Reducing import dependence	% of energy from imports				-	-	-	-	-	-	-	-
	Increasing % of renewables	% of energy from renewable sources				-	-	-	-	-	-	-	-
	Reducing energy consumption per unit of transport/economic activity	toE/trip				-	-	-	-	-	-	-	-
		toE/GDP				-	-	-	-	-	-	-	-
ENVIRONMENTAL GLOBAL SCORE						**33,00**	**40,99**	**44,00**	**70,02**	**38,01**	**43,98**	**45,02**	**77,00**
Environmental	Global warming	CO_2/pas-km,t-km		(t CO_2/pass*km)	2020	7,84	7,29	11,80	15,79	9,90	9,21	14,67	18,96
		Total CO_2		(t)	2020	7,16	9,89	11,21	17,48	8,47	10,71	12,37	19,02
	Emissions of PM/NO_x	Atmospheric emissions	PM	(t)		10,74	12,58	9,13	18,40	12,12	12,84	6,19	20,13
			NO_x	(t)		7,26	11,23	11,86	18,35	7,52	11,22	11,79	18,89
	Emissions of traffic noise	Noise emitted				-	-	-	-	-	-	-	-
SOCIAL GLOBAL SCORE						**48,00**	**47,99**	**51,03**	**51,01**	**50,04**	**50,00**	**53,00**	**52,00**
Social	Increasing transport safety	Total deaths/injuries				-	-	-	-	-	-	-	-
	Improving equity	Territorial cohesion indicators of accessibility, GDP & employment	Accessibility	Variation coefficient	2020	12,74	12,90	13,34	13,93	13,36	13,35	13,87	14,16
				Gini index	2020	12,89	13,02	13,30	13,85	13,42	13,58	13,73	14,00
				Corr. coeff. relative change vs. level	2020	9,20	9,06	10,27	13,04	11,07	11,16	12,27	14,55
				Corr. coeff. relative change vs. level	2020	13,17	13,01	14,12	10,19	12,19	12,11	13,13	9,29
			GDP			-	-	-	-	-	-	-	-
			Employment			-	-	-	-	-	-	-	-
COMPETITIVENESS GLOBAL SCORE						**100,00**	**59,01**	**79,99**	**75,99**	**48,01**	**9,01**	**32,01**	**32,01**
Competitiveness	Changes in accessibility	% change (each mode)	Multimodal			100,00	59,01	79,99	75,99	48,01	9,01	32,01	32,01
			Bus			-	-	-	-	-	-	-	-
			Train			-	-	-	-	-	-	-	-
			Car			-	-	-	-	-	-	-	-
			Water			-	-	-	-	-	-	-	-
			Air			-	-	-	-	-	-	-	-
	Increasing regional GDP	% change GDP				-	-	-	-	-	-	-	-
	Increasing employment rates	% change unemployment rates				-	-	-	-	-	-	-	-
	Decoupling transport and GDP growth	%GDP growth-%transport growth				-	-	-	-	-	-	-	-

Figure 10.16 and Figure 10.17 highlight the effect of fuel price increases and policy implementation on the assessment scores, respectively. If one compares both graphs, it can be noted that in the environment criteria, contrary to most models, it is the implementation of modelled policies and not a fuel price increase which provokes higher environmental benefits. Again, (see Figure 10.17 demand regulation policies appear as those with higher environmental scores, above the technology investment scenario.

Figure 10.16: South Tyrol- Fuel price effect

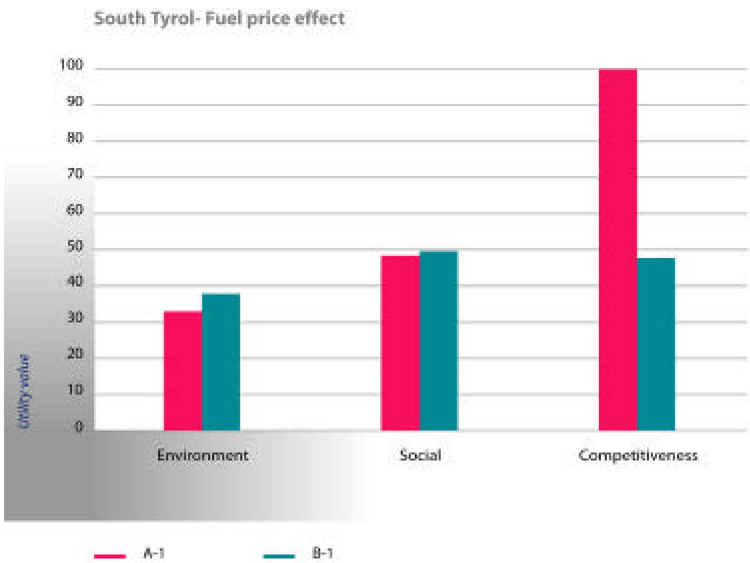
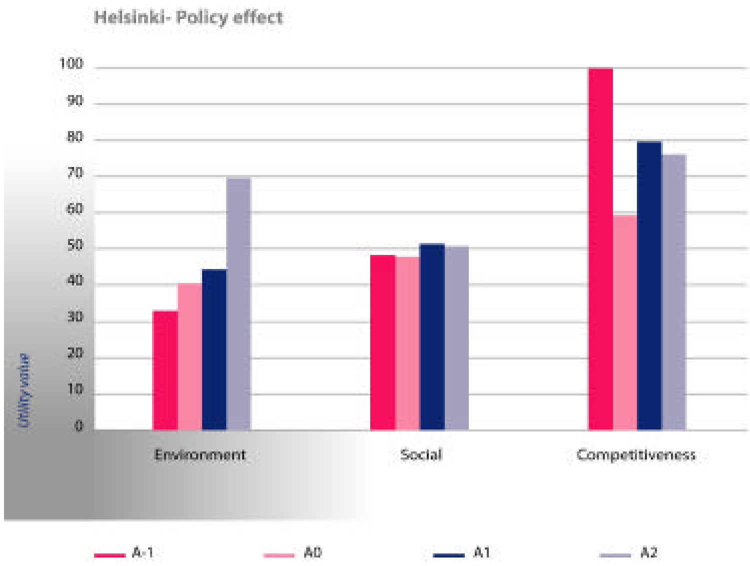


Figure 10.17: South Tyrol- Policy effect



In the social category, although both fuel price increases and the implementation of policies improve the resulting scores, differences between scenarios are lower than in the environment category. This is due to the fact that cohesion effects have an opposite direction depending on whether they are measured in absolute or relative terms, resulting in an almost neutral final effect on territorial equity.

Finally, in the competitiveness category, the observed effect of fuel price increases and policies is the opposite to that for the environment and social categories. The fuel price increase of B-1 scenario more than halves the score obtained in the reference scenario, while technology investment and demand regulation policy measures reduce competitiveness in a 20 and 25%, respectively. In summary, the trade-off which appears in the South Tyrol model is between environment and competitiveness: how much 'competitiveness' is the decision maker willing to give up in favor of improved environmental conditions?

10.4 Sensitivity analysis

Introduction

Sensitivity analysis is often involved in the assessment and choice processes, usually in the presence of risk and uncertainty (Dyer et al., 1992). Sensitivity analysis is a collection of methods used for evaluating how sensitive the assessment results are to small changes in the input values. The most important elements to consider in sensitivity analysis are *criterion (attribute) values* and *criterion weights* (Malczewski, 1999).

The first concern is sensitivity due to errors in estimating the criterion or attribute values: i.e. the values of the performance matrix in STEPs. The values obtained depend on many factors beyond the control of the decision maker. These uncontrollable factors are referred to as *states of nature or states of environment* (Malczewski, 1999). The states of nature, such as the state of the economy (e.g. recession, inflation) reflect the degree of uncertainty about decision outcomes. For each alternative there is a set of possible outcomes, depending on the corresponding state of nature.

One popular procedure to deal with different states of nature is the design of *scenarios*. This is the approach followed in STEPs, as detailed in Deliverables D3.1. and D3.2. A scenario represents a plausible assumption on the future development of external factors. i.e. it represents a particular state of nature. Scenario construction techniques allow isolating the impacts caused by transport infrastructure improvements from the ones stemming from the, unknown, future development of external variables to the assessment procedure (Rehfeld, 1998)

Therefore, in STEPs, as attribute value sensitivity is already dealt with the definition of scenarios, the sensitivity to criteria weights is more important, because of they are the essence of value judgments (Malczewski, 1999). Sensitivity analysis and the incorporation of vague or imprecise judgements of preferences and/or probabilities in multi-attribute situations and decisions under uncertainty constitutes one of the areas for future research in multi-criteria decision making (MCDM) (Dyer et al., 1992)

Methodology for the analysis

The sensitivity analysis has been carried out for each of the models and within each of the four criteria categories. The procedure consists in systematically vary the weights attached to each of the subcriteria included in each of the aforementioned criteria categories, and subsequently check if this change in the weights has ay influence in the resulting scenario ranking. In other words, this allows for the 'robustness' (Rehfeld, 1998) of the scenario rankings to criteria weights to be tested.

The analysis has been carried out using the model specific Excel spreadsheets developed for the multi-criteria analysis. It is not possible to include here all the results obtained in each model, therefore the results of only one European and one regional model are shown here as examples. Annex 5.I includes the Tables with the resulting scores obtained in each scenario when the different weights vary from 0 to 100 per cent. A comprehensive analysis of model-specific scenario rankings is out of the scope of this sensitivity analysis. However, the overall conclusion is that in general, results show that the scenario rankings are quite robust when weights change. The reader is referred to Annex 5.I for any additional numerical information.

The robustness is particularly clear in energy and environmental criteria categories, where slight changes in the scenario rankings occur only when particular weights take extreme values. For the social criteria category, as the differences between scenarios assessed using the MCA procedure are reduced, there is more variability in the resulting rankings when weights assigned to different criterions change. Finally, in the competitiveness category, scenario rankings also show robust results. There is, however, one significant remark to be made about Edinburgh results, which was already highlighted in the corresponding analysis of this model's MCA results in Section 10.3.3 and which is also shown below in the section Regional level.

European level

Table 10.11 includes the case of the sensitivity analysis of changes in the weight attached to changes in accessibility in the resulting competitiveness scores of the SASI model.

Table 10.11: Example of a sensitivity analysis. (SASI-competitiveness)

Accessibility weight	Scores/scenarios								Raking/scenarios							
	A-1	A0	A1	A2	B-1	B0	B1	B2	A-1	A0	A1	A2	B-1	B0	B1	B2
0	100,00	83,00	91,50	62,00	66,50	49,00	59,50	35,50	1	3	2	4	1	3	2	4
5	99,17	81,15	89,70	60,26	65,10	47,31	57,79	34,51	1	3	2	4	1	3	2	4
10	98,33	79,31	87,89	58,52	63,70	45,63	56,08	33,53	1	3	2	4	1	3	2	4
15	97,50	77,46	86,09	56,78	62,30	43,94	54,38	32,54	1	3	2	4	1	3	2	4
20	96,67	75,62	84,28	55,03	60,90	42,26	52,67	31,55	1	3	2	4	1	3	2	4
25	95,83	73,77	82,48	53,29	59,50	40,57	50,96	30,56	1	3	2	4	1	3	2	4
30	95,00	71,93	80,68	51,55	58,10	38,89	49,25	29,58	1	3	2	4	1	3	2	4
35	94,17	70,08	78,87	49,81	56,70	37,20	47,54	28,59	1	3	2	4	1	3	2	4
40	93,33	68,23	77,07	48,07	55,30	35,52	45,83	27,60	1	3	2	4	1	3	2	4
45	92,50	66,39	75,26	46,33	53,90	33,83	44,13	26,61	1	3	2	4	1	3	2	4
50	91,67	64,54	73,46	44,58	52,50	32,15	42,42	25,63	1	3	2	4	1	3	2	4
55	90,83	62,70	71,65	42,84	51,10	30,46	40,71	24,64	1	3	2	4	1	3	2	4
60	90,00	60,85	69,85	41,10	49,70	28,78	39,00	23,65	1	3	2	4	1	3	2	4
65	89,17	59,00	68,05	39,36	48,30	27,09	37,29	22,66	1	3	2	4	1	3	2	4
70	88,33	57,16	66,24	37,62	46,90	25,40	35,58	21,68	1	3	2	4	1	3	2	4
75	87,50	55,31	64,44	35,88	45,50	23,72	33,88	20,69	1	3	2	4	1	3	2	4
80	86,67	53,47	62,63	34,13	44,10	22,03	32,17	19,70	1	3	2	4	1	3	2	4
85	85,83	51,62	60,83	32,39	42,70	20,35	30,46	18,71	1	3	2	4	1	3	2	4
90	85,00	49,78	59,03	30,65	41,30	18,66	28,75	17,73	1	3	2	4	1	3	2	4
95	84,17	47,93	57,22	28,91	39,90	16,98	27,04	16,74	1	3	2	4	1	3	2	4
100	83,33	46,08	55,42	27,17	38,50	15,29	25,33	15,75	1	3	2	4	1	4	2	3

The numerical results are more easily interpreted if they are graphed. Figure 10.18 and Figure 10.19 graph the competitiveness scores and the resulting scenario rankings obtained in each of the 'A' scenarios, when the weight attached to the accessibility criterion changes from 0 to 100, respectively. It can be observed that the ranking of scenarios does not change, even for the extreme values of the weight attached to the accessibility criterion: A-1 obtains the higher score and A-2 the worse, independently to the accessibility weight. A similar picture is obtained in nearly all models and criteria categories.

Figure 10.18: Scores of 'A' scenarios. (SASI-competitiveness)

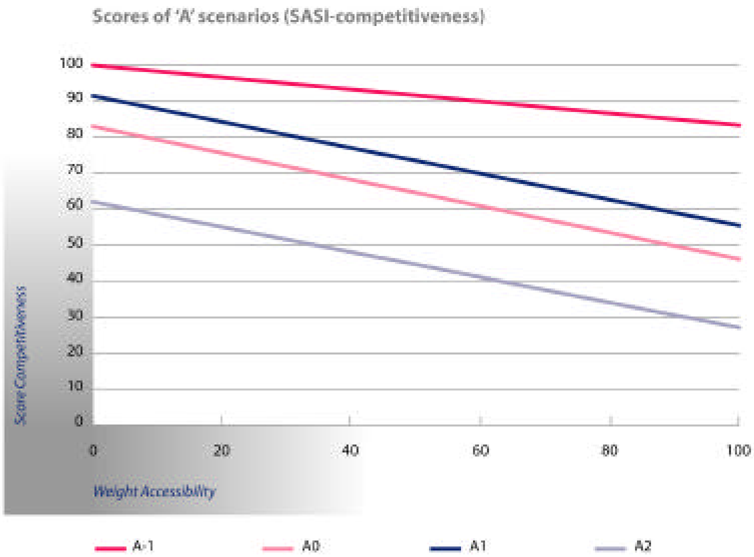
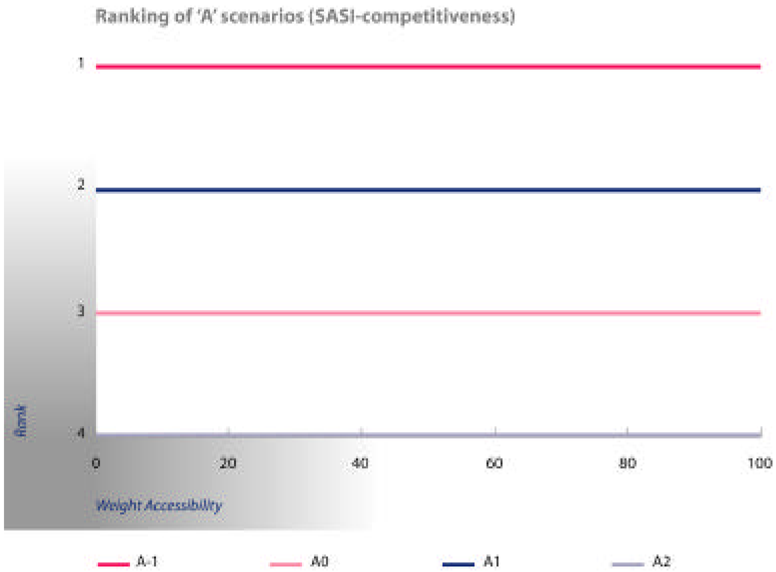


Figure 10.19: Ranking of ‘A’ scenarios. (SASI-competitiveness)



Regional level

The indicator for the category ‘competitiveness’, as it used in the Edinburgh case study, is only made up by car and bus accessibility. Therefore the possibility exists that scenario rankings would change if higher importance is assigned to car accessibility as opposed to bus accessibility. Table 10.12, Figure 10.20 and Figure 10.21 show how indeed, A2 scenario (demand regulation policies) obtains the best ranking if bus accessibility’ weight is higher than car accessibility, whereas it goes down in the ranking as the weight assigned to car accessibility increases. This is one remark which has been taken into account when drawing conclusions on the competitiveness implications of the modelled policies in the Edinburgh case study.

Table 10.12: Example of a sensitivity analysis. (Edinburgh-competitiveness)

Accessibility bus	Scores/scenarios								Raking/scenarios							
	A-1	A0	A1	A2	B-1	B0	B1	B2	A-1	A0	A1	A2	B-1	B0	B1	B2
0	99,27	85,65	91,33	12,25	73,25	64,06	86,59	9,69	1	3	2	4	2	3	1	4
5	94,75	81,42	88,33	15,94	70,16	61,01	83,88	13,80	1	3	2	4	2	3	1	4
10	90,23	77,19	85,32	19,64	67,06	57,96	81,18	17,92	1	3	2	4	2	3	1	4
15	85,71	72,96	82,32	23,34	63,97	54,92	78,48	22,03	1	3	2	4	2	3	1	4
20	81,19	68,73	79,32	27,04	60,88	51,87	75,77	26,14	1	3	2	4	2	3	1	4
25	76,67	64,50	76,31	30,73	57,79	48,83	73,07	30,26	1	3	2	4	2	3	1	4
30	72,15	60,27	73,31	34,43	54,69	45,78	70,37	34,37	2	3	1	4	2	3	1	4
35	67,63	56,04	70,31	38,13	51,60	42,73	67,67	38,48	2	3	1	4	2	3	1	4
40	63,11	51,81	67,30	41,83	48,51	39,69	64,96	42,60	2	3	1	4	2	4	1	3
45	58,60	47,58	64,30	45,52	45,41	36,64	62,26	46,71	2	3	1	4	3	4	1	2
50	54,08	43,35	61,30	49,22	42,32	33,60	59,56	50,82	2	4	1	3	3	4	1	2
55	49,56	39,12	58,30	52,92	39,23	30,55	56,86	54,93	3	4	1	2	3	4	1	2
60	45,04	34,89	55,29	56,62	36,14	27,50	54,15	59,05	3	4	2	1	3	4	2	1
65	40,52	30,66	52,29	60,31	33,04	24,46	51,45	63,16	3	4	2	1	3	4	2	1
70	36,00	26,43	49,29	64,01	29,95	21,41	48,75	67,27	3	4	2	1	3	4	2	1
75	31,48	22,19	46,28	67,71	26,86	18,37	46,05	71,39	3	4	2	1	3	4	2	1
80	26,96	17,96	43,28	71,41	23,77	15,32	43,34	75,50	3	4	2	1	3	4	2	1
85	22,44	13,73	40,28	75,10	20,67	12,27	40,64	79,61	3	4	2	1	3	4	2	1
90	17,92	9,50	37,28	78,80	17,58	9,23	37,94	83,73	3	4	2	1	3	4	2	1
95	13,41	5,27	34,27	82,50	14,49	6,18	35,23	87,84	3	4	2	1	3	4	2	1
100	8,89	1,04	31,27	86,19	11,40	3,14	32,53	91,95	3	4	2	1	3	4	2	1

Figure 10.20: Ranking of ‘A’ scenarios. (Edinburgh-competitiveness)

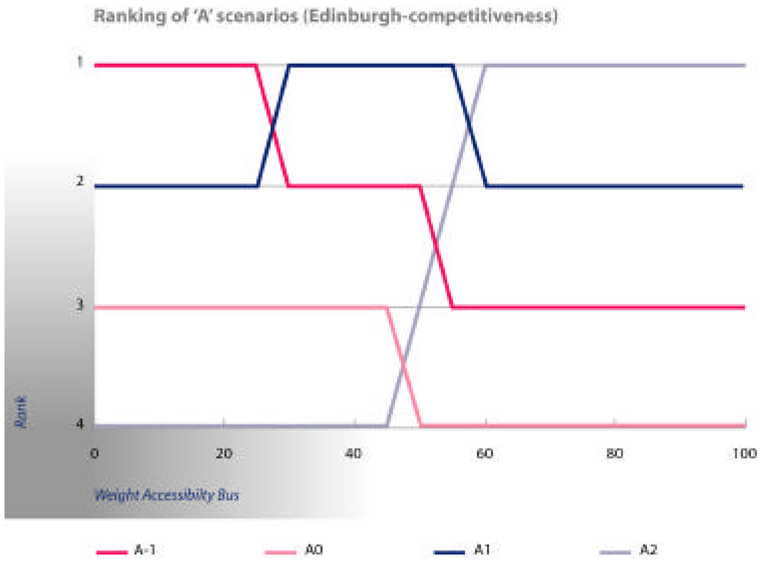
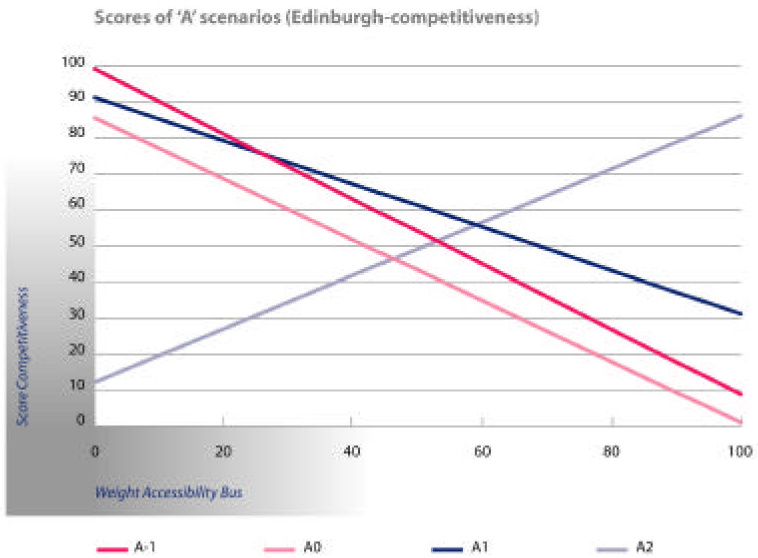


Figure 10.21: Scores of ‘A’ scenarios. (Edinburgh-competitiveness)



CHAPTER 11: Overall assessment of results

11.1 Introduction

As explained in Chapter 10, the different intrinsic characteristics of each of the models used in STEPS makes a direct comparison of their outputs and the utility values subsequently derived from them, difficult. Aware of this heterogeneity across models, this Chapter has intended to carry out only a broad comparison of their results. The values which are compared are the four criteria categories 'energy', 'environment', 'social' and 'competitiveness'.

The objective is to test the models' coherence in terms of the direction of the predicted effect of fuel price increases and modelled policies in each of the aforementioned four criteria categories. In order to allow for this comparison, the scores obtained in each model need to be normalized beforehand. In this case, the normalization has been carried out in terms of the corresponding value of the reference scenario A-1. Scenario-specific bar charts, comparing the resulting values with those of the reference scenario, have subsequently been derived based on these normalized values. This procedure facilitates the visualization of results and enables to draw general conclusions on the direction of predicted effect. Its magnitude is heavily dependant of the model under consideration; therefore no attempts have been made to derive any conclusions on this topic.

The analysis carried out in this Chapter is intended to provide a useful starting point for Chapter 12, in which recommendations for transport and energy policy making are to be included.

11.2 Comparison across models

In this Section, the performance of STEPs main scenarios in every model is tested against the reference scenario A-1, therefore allowing for a broad comparison of the results across models.

Each scenario's performance has been compared with that of the reference scenario. Each of the resulting 7 comparisons has been graphically represented and included in Figures 11.1 to 11.7. In the vertical axis the percentage change in utility values–in terms of the corresponding value of the A-1 scenario, in each of the four criteria categories, is included. The horizontal axis represents the four categories: energy, environment, social and competitiveness. Finally, each model's performance in each criteria category -in case the model provides the corresponding results, is represented by a vertical bar. Figure 11.1 includes the comparison carried out for scenario A0. Its analysis shows that all models are coherent in the direction of their predicted effect: they result in an improvement in energy and environmental categories, whereas they result in a deterioration of competitiveness. In social terms, the direction of the effect slightly differs across models[3], although in general the values of the positive social effects are higher than the negative ones.

However, within the same criteria category, the magnitude of the effect differs among greatly between models. This is partly due to the different responses of the models to the

[3] The reasons behind these results have been specifically treated in each model's corresponding section of Chapters 7 and 8.

changes in parameters behind each scenario, which is dependant, in turn, on each model's intrinsic structure, but also due to the already commented fact that each model measures different things under the same criteria category, and therefore the evaluation score of each model is built from a different set of performance indicators. The values composing each of these scores have been included in each model analysis (see Tables 10.1 to 10.10).

Figure 11.1: Comparison of policy effects across models. A0 vs A-1

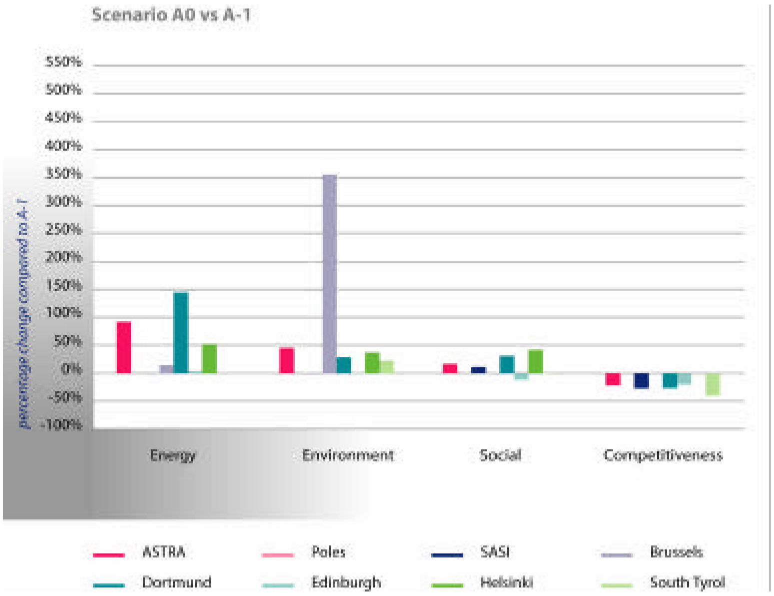
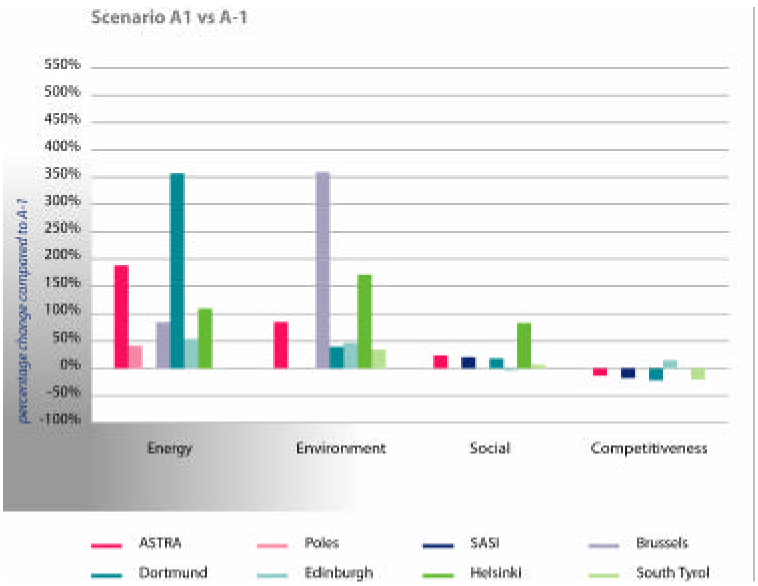
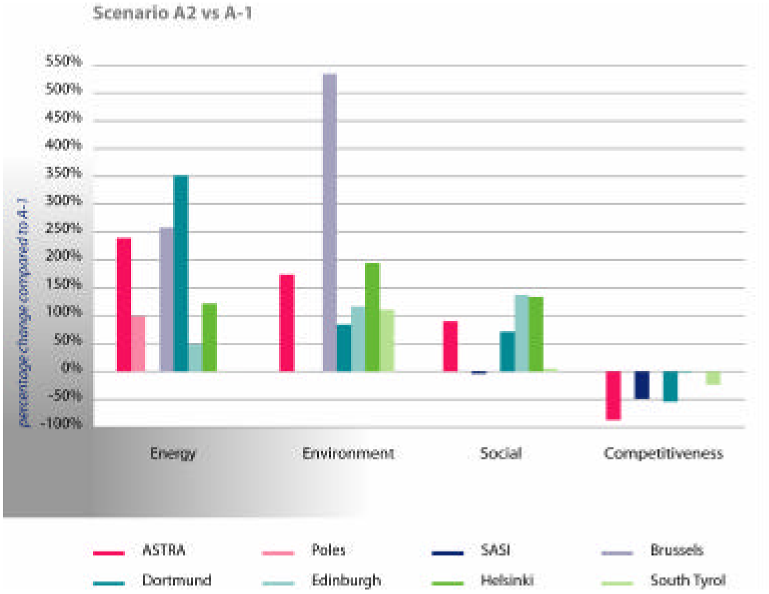


Figure 11.2: Comparison of policy effects across models. A1 vs A-1



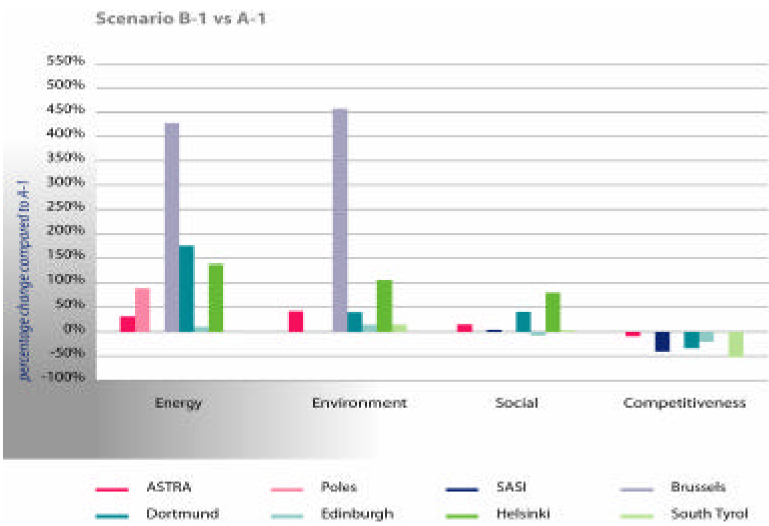
A similar conclusion can be drawn from the analysis of the effects of technology investment measures: the three first criteria categories improve their performance at the expense of a deterioration of their competitiveness. The exception is Edinburgh, where a slight improvement in competitiveness utility is observed, due to the increased accessibility by bus predicted by the model. As Section 10.4 (Sensitivity analysis) discusses, a change in the relative importance given to accessibility by bus vs by car changes the sign of this effect translating it into a deterioration of competitiveness in A1 scenario.

Figure 11.3: Comparison of policy effects across models. A2 vs A-1



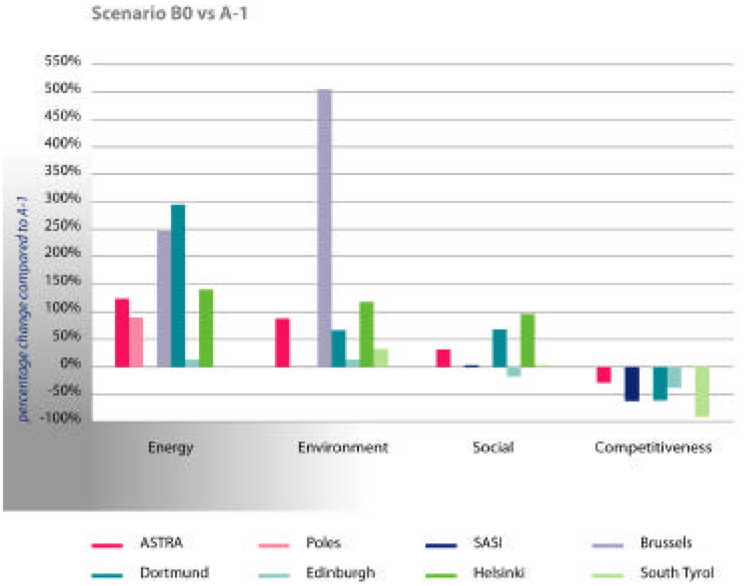
Similar results are obtained when demand regulation measures are tested against the reference scenario, included in Figure 11.3. All models coincide in predicting positive effects in energy, environmental and social terms. The only exception is SASI with an almost imperceptible reduction in its social score, which has already been justified in Chapter 7. In the competitiveness criteria category, the direction of the effect is the same across models: demand regulation policy measures result in a deterioration of economic performance, with severe utility reductions, up to an amount near to 100%, if measured in terms of ASTRA or 50%, if we refer to SASI or Dortmund results.

Figure 11.4: Comparison of fuel price effects across models. B-1 vs A-1



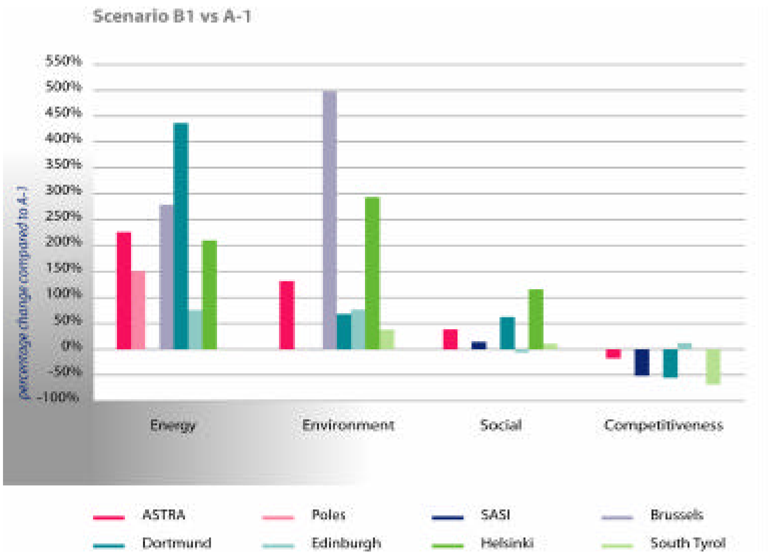
Again, conclusions are similar when assessing the effect of a fuel price increase, as Figure 11.4 shows: in general terms, all the models predict an improvement in energy, environment and social categories along with worse competitiveness values as fuel price increases. The only exception is Edinburgh, which obtains a slightly lower value under the social criteria[4].

Figure 11.5: Comparison of combined policy and oil price effects across models. B0 vs A-1



Similar conclusions can be drawn from the analysis of the resulting scores when assessing the combined effect of fuel price increases and BAU policies (scenario B0), represented in Figure 11.5.

Figure 11.6: Comparison of combined policy and oil price effects across models. B1 vs A-1

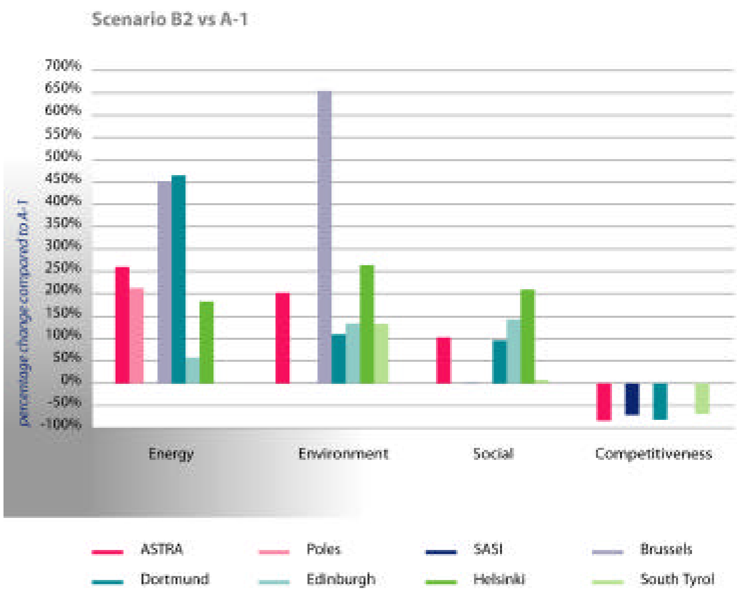


The picture is similar when technology investment measures are implemented in combination with fuel price increases (see Figure 11.6). The only exception is Edinburgh, which shows a slight improvement in competitiveness, in accordance with what happened

[4] Again, results under the social criterion show slight differences. In the case of Edinburgh, although the number of injured people decrease, the social balance is negative due to increasing disparities in the spatial distribution of accessibility, as explained in Chapter 8.

when assessing scenario A1 versus A-1 (see Figure 11.2). This is due to the improvements in bus accessibility brought about by the technology investment measures behind ‘1’ scenarios, capable to overcome the reductions in car accessibility. It is clear that this effect is due to the implicit trade-off between car and bus accessibility present in the MCA aggregation procedure. The implications of a change in the relative importance of these two criteria has been analysed in Section 10.4 (Sensitivity analysis).

Figure 11.7: Comparison of combined policy and oil price effects across models. B2 vs A-1



Finally, Figure 11.7 includes the comparison of the scores obtained by the different models when demand regulation measures are combined with fuel price increases. The results again follow the already commented dominant pattern: modelled policies and fuel price increases. and their combination, bring about important improvements in energy and environmental criteria, moderate improvements in social terms, and important reductions in competitiveness.

11.3 Final remarks

At this final stage of the assessment work, it may be useful to look back at the starting point of the assessment task: ‘to assess the defined scenarios with respect to criteria which reflect the overall goal of transport and energy sustainability’

EU transport and energy policy documents agree that the main objective is that energy and transport contribute to sustainable development, making Europe both a homogenous area of **economic development** and an area where the **environment** in the broadest sense of the term is conserved. In other terms: the EU Common Transport Policy (CTP) has two basic goals: **efficient, accessible and competitive transport systems** - essential to growth and employment and to keep EU businesses competitive - and a **high level of safety and environmental protection**.

The design of the assessment criteria has been carried out with these policy objectives in mind. Despite the existing certain degree of heterogeneity among the different models used in STEPs, there are some important findings applicable to all of them. These findings are aimed being useful for policy makers in the field of transport and energy, and they constitute the basis for the work carried out in Chapter 12: Conclusions and Policy guidelines.

In this context, the list below summarizes some final remarks resulting from the assessment results:

- Energy and environmental criteria improve when fuel price increases (B' scenarios), business as usual ('0' scenarios), technology investment ('1' scenarios) and demand regulation (2' scenarios) measures are implemented, in all the models considered. The answer to the question of which of these four 'packages of measures' has a stronger effect will depend on the model under consideration.

- Demand regulation measures have shown to be more effective than technology investments in terms of energy consumption and environment criteria, i.e. the reduction in car use brought about by demand regulation measures surpasses the effect of more efficient technologies.

- The predicted effect in social criteria is not as straightforward. In general terms, safety indicators improve in all scenarios, whereas spatial equity indicators show both slight improvements and deteriorations, depending on the model considered. The predicted pattern of the spatial distribution of accessibility changes needs to be comprehensively analysed in order to draw significant conclusions on this topic.

- However, both fuel price increases and modelled policies result in higher transport costs, mobility constrains and reduced accessibility, which unavoidably lead to reduced GDP and employment growth rates, i.e. they result in a deterioration of competitiveness criteria.

- The trade-off between energy, environment and social criteria, on the one side, and competitiveness criteria, on the other, is a key factor in the design of any integrated Energy and Transport Policy. This conflict is present in the main recent EU policy documents (EC, 2000, 2001, 2003, 2004a, 2004b, 2004c): to what extent can economic growth be threatened in order to achieve environmental or social goals? The answer to this question lies out of the scope of the assessment carried out in STEPs. The objective of STEPs is to provide the decision-maker with consistent and reliable information on the predicted effect of different sets of policy measures. This information will help him/her to select the more appropriate strategy.

Part V: Conclusions

CHAPTER 12: Conclusions

The results of the STEPs analyses serve as a basis for the development of a view on future policy and research requirements in the area of transport and energy scenarios. The partial conclusions of each analysis were presented and discussed during clustering meetings and soundboard forums throughout the project. The synthesis of overall conclusions was presented at the final conference, and gave rise to a debate involving various views on future policy and research requirements.

This chapter presents a synthesis of the main findings on trends and policy scenarios, and the policy recommendations based on the STEPs results. Then some general reflections are presented, and we end with recommendations for further research.

12.1 Trends

- The long-term future of energy supply for transport appears difficult, and the situation has become significantly more critical even during the short project period of STEPs.

- Today a growing majority of experts believe that because of a combination of scarcity in cheap oil, increased global energy demand and greater supply disruptions provoked by Geo Political Dependence of Europe, fuel prices will continue to rise in the medium and long term. Indeed, mostly due to the emerging economies in Asia (in particular China and India), energy demand is rising significantly more than oil production and oil refining capacity, making disruptions in energy supply a major and increasing concern. The share of worldwide energy demand and energy market stress that these markets bring along with their expansion is overwhelming. The growth of mobility and transport systems in most Asian countries has progressed at a different speed – India and China had a slow start but have now surpassed Western regions in their economic growth rates, which is directly reflected in their transport demand, mobility growth, and increased energy demand.

- All trends in economic activity, goods transport and personal travel, point towards longer distances and, despite energy efficiency gains, to more energy consumption. This reflects a pattern shared by most industrialised countries which have developed their economy and lifestyles firmly rooted in the promise of cheap energy supply. We observe a trend towards an ever-increasing intensity of freight transportation. In the passenger transport sector we continue to observe a trend for increased mobility coupled with faster and more flexible realization of mobility needs and an increase in the use of private automobiles. This is noticeable in the increasing traffic flows, the modal split, high car dependency, etc. These trends are unsustainable vis-à-vis the trends of declining energy supply, increased supply disruption risks, higher energy costs and the growing risks of climate change.

- All efforts to decouple economic growth and energy consumption and to reduce greenhouse gas emissions have, with a few local exceptions, failed and are insufficient to meet the more demanding post-Kyoto targets.

12.2 Policies

- Demand management policies making road transport slower or more expensive (push measures) are more efficient in reducing transport fuel consumption than policies promoting more sustainable transport modes, such as walking/cycling or public transport (pull measures). Integrated strategies combining push and pull demand management policies, technology development policies and land use policies are more successful than isolated individual policies. The efficiency depends on the level of change of both push and pull measures, and availability of alternatives.

- Technology development policies making vehicles more energy-efficient or promoting alternative propulsion systems are successful in reducing fuel consumption per km, but tend to result in longer distances travelled by both passengers and freight unless the higher costs of new technologies are taken into account.

- All policies using dominant push measures resulting in lower fuel consumption for transport have negative effects on accessibility and hence economic activity. Public transport fare reductions (pull measures) would have good impacts on accessibility and lower fuel consumption.

12.3 Policy recommendations

- The widening gap between global energy demand and declining energy resources and the growing risks of climate change require immediate, strong and probably unpopular policy action, including transport, regional, agricultural and technology policy. The common transport policy of the European Union needs to be fundamentally reviewed in the light of the urgency of these risks.

- While it is irrelevant for the behaviour of users whether fuel price increases are caused by rising resource costs or fuel taxes, for decision-makers or governments it makes a difference. Fuel taxes contribute a lot to government revenues which may well be affected directly and indirectly through impacts on other taxes. A harmonised system of vehicle taxes, fuel taxes and road pricing for cars and lorries on all types of roads should be introduced in all EU member states to achieve the necessary energy savings and emission reduction targets, with special exemptions for disadvantaged and peripheral regions.

- Fuel taxes can be used to mitigate or reinforce the effects of increases in fuel resource costs. Consultation among governments could result in a unified fuel tax policy throughout Europe, aiming at increasing global competitiveness.

- Co-ordination between different government sectors and levels of government should be enhanced in order to design and implement integrated strategies combining policies from different policy fields, such as transport policy, regional policy, urban land use policy and environmental policy.

- The production and use of biofuels in Europe is seen as a promising short- to medium-term option to decrease European energy dependency regarding transport related energy consumption. Yet, despite the positive indications contained in the EU policy supporting the production of biofuels as an alternative to fossil fuels, there are little evidences that biofuels can effectively be seen as a full alternative to conventional sources, but rather as an interesting complement to satisfy a parcel of the energy demand in transportation.

- National, regional and local governments should be encouraged to support domestic economic linkages, regional and local production circuits, less car-dependent, more compact forms of settlements and pedestrian-friendly neighbourhoods.

- The EC should vigorously adopt a long-term goal to drastically reduce CO_2 emissions from transport by promoting, through stricter regulation and activation of public procurement, improvements of current vehicle technology, and tightening the standards for the introduction of near-zero emission passenger vehicles.

- One of the main instruments at EU level so far has been the voluntary agreements with the car industry. This approach is proving relatively weak in view of the challenges ahead and should become more ambitious if consumption of fossil fuels is to be reduced to a more sustainable level.

- European technology policy should increase funding of research and development for more energy-saving and alternative vehicles.

- The impact of energy scarcity and growing greenhouse gas emissions are a bigger threat together than either is alone. These concerns should be combined as issues and a comprehensive policy approach developed to deal with them as a package.

12.4 General reflections

- The future of energy supply to the transport system will be closely tied to the development and the options in stationary power plants. Hence, there will probably be no partial energy supply system dedicated to transport but rather a Global Energy Supply model shared by most applications including transport, which will adopt energy carriers rather than primary sources to fulfil mobility needs, necessarily bringing the discussion on this subject to a higher strategic level than is currently the case.

- The transport projects co-financed by the EU under the Structural and Cohesion Funds need to be re-assessed with more emphasis given to energy saving and sustainability targets.

- There is an urgent need to mobilise and combine fossil fuel-based energy supply concerns as a supporting driver for CO_2 reduction, since both challenges largely call for measures of a similar type. There seems to be no single policy solution to solve the energy supply issue to transport which brings us to the point that a multi-instrument approach is required if we want to reverse energy supply trends and associated problems.

- Particular attention should be paid to road transport, where most of the energy demand and CO_2 emissions in transportation have their origin. In particular regarding private transport performance, there will be a need to create a level playing field to market more energy-efficient power trains and climate neutral (bio-) fuels. It is also necessary to promote a more energy-efficient driving style (supported by in-car devices), traffic management to improve traffic flow, and innovations in logistics and freight demand management, where GALILEO applications will play a crucial role. European transport policy should therefore make maximum use of the potential of GALILEO as an instrument to implement energy saving oriented policies.

- The combined use of European models and regional models proved successful in examining effects of the scenarios at European and regional level. Linking the regional response to the more global modelling applied in environmental studies and climatic change analyses could add an additional dimension to the scenario assessment.

- The policies analysed in STEPs, are general strategies, rather than specific, operational policy measures. Policy measures will only be implemented if they have sufficient social and political support. Creating the basis for change is a process that can be stimulated through information, education, etc. STEPs clearly shows that change will be necessary. Anticipating this by starting the process of creating a social basis for change, will help smooth the transition, rather than waiting for shocks in the global energy markets to dictate sudden policy decisions with potential drastic effects.

12.5 Recommendations for further research

- Forecasting fuel price increases seems to be more difficult than forecasting the impacts of fuel price increases. Research should therefore address the issue of likely market responses to exogenous energy price shocks and the related policy responses.

- Future research should study more extreme energy price scenarios than were examined in STEPs in order to advise policy makers how to avoid or mitigate them through more energy-efficient technology, more sustainable transport and less car-dependent cities.

- Future research should study the impacts of energy price shocks not only on transport but also on land use, i.e. on urban form, the relationship between city and countryside and the related changes in lifestyles and work patterns.

- Further research is needed to explore the optimal tax policy under different oil price scenarios. A cost benefit approach could be used to find optimal prices/taxes. This perspective could also address the rural/urban issue: is fuel tax already too high in rural areas and too low in urban areas? We need to rethink the instrument for demand management.

- More advanced vertical (EU-regional/local) and horizontal (energy-land use-environment) integration between models, would provide a very powerful tool to assess regional impacts of European transport policies.

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APPENDICES

APPENDIX 1: List of Abbreviations

ACEA	European Automobile Manufacturers Associations
BAU	Business As Usual
CBA	Cost-benefit Analysis
CEC	Commission of the European Communities
CH_4	Methane
CNG	Compressed Natural Gas
CTP	Common Transport Policy
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DG	Directorate General
DM	Decision-Maker
DR	Demand Regulation
EC	European Commission
EEA	European Environment Agency
EU	European Union
Euro-CASE	European Council of Applied Sciences and Engineering
GDP	Gross Domestic Product
GHG	Green House Gases
GIS	Geographical Information Systems
HC	Hydrocarbons
HMA	Helsinki Metropolitan Area
ICE	Internal Combustion Engines
ICT	Information Communication Technologies
IEA	International Energy Agency
IPCC	Intergovernmental Pannel on Climate Change
JAMA	Japanese Automobile Manufacturers Associations
HC	Hydrocarbons
HMA	Helsinki Metropolitan Area
ICE	Internal Combustion Engines
ICT	Information Communication Technologies
IEA	International Energy Agency
IPCC	Intergovernmental Pannel on Climate Change
JAMA	Japanese Automobile Manufacturers Associations
JRC	Joint Research Centre
KAMA	Korean Automobile Manufacturers Associations
LDV	LDV: Light Duty Vehicles
LH_2	Liquefied Hydrogen
LPP	Lean Premixing Prevaporising
LPG	Liquid Petroleum Gas
LUTI	Land-Use and Transport Interaction
MARS	Metropolitan Activity Relocation Simulator
MCA	Multi-Criteria-Analysis
MCDM	Multi-Criteria Decision Making
MDO	Marine Diesel Oil
MGO	Marine Gas Oil
NG	Natural Gas
NGVs	Natural Gas Vehicles
NLEV	National Low Emission Vehicle

NMS	New Member States
NOx	Nitrogen Oxides
OECD	Organisation for Economic Co-operation and Development
PCU	Passenger Car Unit
PEST	Political Economical Social Technological
PM	Particle matter
PT	Public Transport
RBQQ	Rich Burn Quick Quench
RTD	Research and Technological Development
SCM	Supply Chain Management
SO_2	Sulphur Dioxide
SUV's	Sport Utility Vehicles
UIC	International Union of Railways
UNDP	United Nations Development Program
UPT	Public Transport Operators
US	United States
VAT	Value Added Tax
VOC	Vehicle Operation Cost
WBCSD	World Business Council for Sustainable Development
WEC	World Energy Council
ZEV	Zero Emission Vehicle

APPENDIX 2: List of Deliverables

D1 State-of-the-art.

D2 Overview of relevant trends and translation into parameters.

D3.1 Framework of the scenarios and description of the themes.

D3.3 A bee with a view – Essay.

D4.1 Modeling suite for scenarios simulations.

D4.2 Scenario impacts.

D5.1 Methodology for the assessment of transport and energy supply scenarios. - Database requirements.

D5.2 Assessment and comparison of scenarios.

D6 Final report.

D8.1 Report on the first Clustering Meeting, Budapest, 25th November 2004

D8.2 Report of the second Clustering Meeting, Krakow, 29th May 2005

D8.3 Report on the third Clustering Meeting, Gothenburg, 15th June 2006

D9.1 Dissemination plan.

D9.2 Dissemination materials

D9.3 Plan for using and disseminating knowledge

Reports in Bold are not available in the public domain

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