Possible Future Transport and Land Use Strategies for Sustainable Urban Development in European Cities

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Abstract

The concept of sustainable development has led to a paradigm shift in urban planning in European cities. In recent years air pollution, traffic noise and loss of open space and more recently energy scarcity and climate change have become leading issues of urban planning. This paper looks into the achievements and challenges of transport and land use planning in European cities today. It starts with an overview on current policies at the European level to promote a better integration of transport and land use planning in European cities, summarises the results of studies on integrated transport and land-use strategies and presents examples of successful best practice in this field in European cities. To demonstrate the magnitude of the challenge, it presents results of the EU project STEPs (Scenarios for the Transport System and Energy Supply and their Potential Effects), which examined the impact of different scenarios of fuel price increases, resulting market responses and different combinations of transport and land use policies on regional economic development, travel patterns and the environment in metropolitan areas using several European and urban/regional simulation models.

1. Introduction

The concept of sustainable development has led to a paradigm shift in urban planning in European cities. While in the post-war period urban expansion and the accommodation of increasing traffic dominated urban planning, in recent years sustainability has become the major goal of planning in most cities. In addition, the objectives behind the concept of sustainability have changed since the identification of the environmental, economic and social dimension of sustainability at the Rio Conference in 1992. While initially air pollution, traffic noise and loss of open space were the leading issues of sustainable planning, today energy scarcity and climate change have become the most urgent topics on the sustainability agenda.

European cities have responded in a variety of ways to the growing public awareness of sustainability. Major industrial sources of air pollution have been replaced by cleaner technologies, more energy-efficient buildings are now standard, and great progress has been made towards cleaner, energy-saving cars and lorries and the promotion of environment-friendly modes of travel, such as public transport, cycling and walking. And it has been recognised that isolated sectoral policies are not effective but that only integrated strategies combining measures from different fields of policy making achieve the desired results.

One important field of public policy is the integration between urban transport and land use planning. Making travel and goods transport more energy-efficient and less polluting is not sufficient if at the same time continuing suburbanisation and urban sprawl result in ever longer trips to places of work, shopping, education and leisure.

This paper looks into the achievements and challenges of transport and land use planning in European cities today. It starts with an overview on current policies at the European level to promote a better integration of transport and land use planning in European cities. It summarises the results of studies funded by the European Union which clearly show that integrated transport and land-use strategies are more successful than isolated sectoral approaches in achieving progress towards urban sustainability and presents examples of successful best practice of integrated transport and land use planning in cities in Europe.

However, it also shows that these advances are by no means sufficient to cope with the new challenges of energy scarcity and climate change cities are facing today. It argues that technological advances in energy efficiency of buildings and vehicles and alternative fuels will not achieve the reductions in energy consumption and greenhouse gas emissions necessary to cope with future energy scarcity and to combat climate change, but that substantial changes in life styles and mobility patterns will be needed to meet government greenhouse gas reduction targets – and that the most affluent countries, the largest consumers of energy and producers of green house gases, must take the lead.

To demonstrate the magnitude of the necessary changes, the paper presents selected results of the EU 6th Research and Technology Development Framework project STEPs (Scenarios for the Transport System and Energy Supply and their Potential Effects). The project examined the impact of different scenarios of fuel price increases, resulting market responses and different combinations of policy interventions in the fields of infrastructure and technology, travel demand regulation and land use control on regional economic development and travel patterns and on the environment, accessibility and land use in metropolitan areas using several European and urban/regional simulation models. Here the results for the metropolitan region of Dortmund in Germany are presented.

The model simulations show that only scenarios in which car driving becomes significantly more expensive, be it through fuel price increases or government taxation, will achieve the necessary reductions in transport energy consumption and greenhouse gas emissions. These constraints on mobility will have significant consequences for life styles and mobility patterns in cities and in many cases imply a loss of quality of life. The policy challenge will be to make these constraints socially and politically acceptable by providing attractive alternatives of mixed-use, higher-density housing with nearby opportunities for education, shopping and leisure and promoting more environment-friendly mobility by public transport, cycling and walking. For this cities need integrated and long-term transport and land use strategies that include a combination of pricing policies directed at car users with moderate public transport fares, public transport infrastructure investments to improve public transport speed and service and a regional spatial development plan supporting living near central areas, in satellite cities or along public transport corridors.

Moreover, integrated transport and land use strategies for whole metropolitan areas require a high degree of co-operation between the core cities and suburban municipalities. They require a strong regional planning system and efficient mechanisms of horizontal and vertical co-ordination between government departments and levels, a broad public debate between researchers, policy makers, stakeholders and citizens and strong efforts to raise public awareness of the importance of preparing regions and cities for a sustainable future by promoting more sustainable modes of transport, regional economic circuits and less car-dependent settlement structures.

2. Land-use transport interaction

The modern city is based on mobility. The railway, and later the automobile, made the vast expansion of cities into metropolitan areas possible. Because transport was fast, efficient and cheap, households could afford to leave the medieval city and enjoy life in the suburbs or countryside and still travel to work in the city. Only much later did retail, services and manufacturing follow their customers or employees to the suburbs creating the fragmented urban-rural landscape surrounding most of our cities today. The price for the suburban arcadia is high: declining city centres, loss of open space, long travel times and growing emissions of greenhouse gases, air pollutants and traffic noise. Moreover, it ignores the imperative to reduce greenhouse gas emissions in order to avoid or at least slow down climate change, and it ignores the fact that cheap mobility will not be here forever.

That urban land use and transport are closely inter-linked is common wisdom among planners and the public. That the spatial separation of human activities creates the need for travel and goods transport is the underlying principle of transport analysis and forecasting. Following this principle, it is easily understood that the suburbanisation of cities is connected with increasing spatial division of labour, and hence with ever increasing mobility.

However, the reverse impact from transport to land use is less well known. There is some vague understanding that the evolution from the dense urban fabric of medieval cities, where almost all daily mobility was on foot, to the vast expansion of modern metropolitan areas with their massive volumes of intraregional traffic would not have been possible without the development of first the railway and later the private automobile, which has made every corner of the metropolitan area almost equally suitable as a place to live or work. However, exactly how the development of the transport system influences the location decisions of landlords, investors, firms and households is not clearly understood even by many urban planners.

The recognition that trip and location decisions co-determine each other and that therefore transport and land use planning need to be co-ordinated led to the notion of the 'land-use transport feedback cycle'. The set of relationships implied by this term can be briefly summarised as follows (see Figure 1):

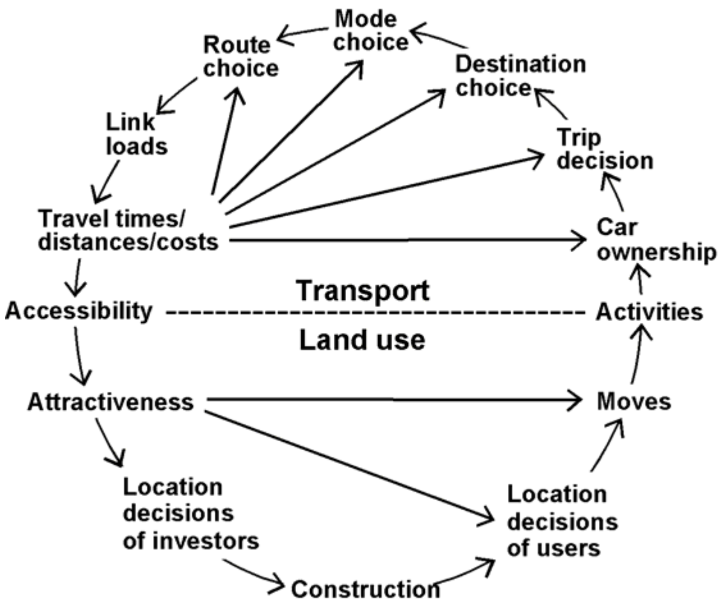


Figure 1. The 'land-use transport feedback cycle'

- The distribution of *land uses*, such as residential, industrial or commercial, over space determines the locations of human *activities* such as living, working, shopping, education or leisure.
- The distribution of human *activities* in space requires spatial interactions or trips in the *transport system* to overcome the distance between the locations of activities.
- The distribution of infrastructure in the *transport system* creates opportunities for spatial interactions and can be measured as *accessibility*.
- The distribution of *accessibility* in space co-determines location decisions and so results in changes of the *land use* system.

The recognition of the two-way interaction between urban transport and land use has strongly influenced the direction of urban and regional planning in Europe and has led to a variety of policy initiatives at the European level and in individual EU member states, a broad range of research projects and a great diversity of good practice examples in European cities.

2.1 Current policies

In 2006 the European Commission adopted the *Thematic Strategy on the Urban Environment* (European Commission, 2006) with the objective of "contributing to a better quality of life through an integrated approach concentrating on urban areas" and to a "high level of quality of life and social well-being for citizens by providing and environment where the level of pollution does not give rise to harmful effects on human health and the environment and by encouraging sustainable urban development". The Strategy calls for appropriate land use planning to reduce urban sprawl and the loss of natural habitats and the preparation of Sustainable Urban Transport Plans (SUTP) co-ordinated with land use planning at the appropriate administrative levels (European Commission 2007a).

In 2007, after broad public consultation, the Commission published the Green Paper *Towards a New Culture for Urban Mobility* (European Commission, 2007b) addressing five themes: congestion, emissions, intelligent transport systems, accessibility and safety and security. The Green Paper calls for a "balanced co-ordination of land use and integrated approach to urban mobility" in order to contain suburbanisation and urban sprawl and dispersal of home, work and leisure facilities resulting in increased transport demand and making it difficult to offer collective transport solutions of a sufficient quality to attract substantial amounts of users.

These two policy documents are representative for a large number of similar commitments for sustainable urban development by national governments and individual cities all over the European Union.

2.2 Research

There is a long and rich tradition of EU-funded applied research on the interaction between transport and land use in the EU Research and Technology Development (RTD) Framework Programmes. A summary of this research is given in Marshall and Banister (2007).

The empirical and modelling studies clearly confirm the importance of land use patterns for sustainable urban transport. There is broad agreement between the projects that the decentralised low-density forms of settlement of most European cities made possible by the automobile are now a serious impediment to a return to more sustainable forms of urban transport.

One important finding of many projects is that integrated transport and land use strategies are more successful than isolated individual policies in either field:

- Transport and land use policies are only successful in reducing travel distances, travel time and the share of car travel if they make car travel less attractive (i.e., more expensive or slower) and provide attractive land use alternatives to suburban living.
- Land use policies to increase urban density or mixed land use without accompanying measures to make car travel more expensive or slower have little effect as people will continue to make long trips to maximise opportunities within their travel cost and travel time budgets. However, these policies are important in the long run as they provide the preconditions for less car-dependent lifestyles in the future.
- Transport policies making car travel less attractive (more expensive or slower) are very effective in achieving the goal of reducing travel distances and the share of car travel. However, they depend on a spatial organisation that is not too dispersed. In addition, highly diversified labour markets and different work places of workers in multiple-worker households set limits to a optimum co-ordination of work places and residences.
- Large retail and leisure facilities that are not spatially integrated increase the distances travelled by car and the share of car travel. Land use policies to prevent the development of such facilities ('push') are more effective than land use policies aimed to promote high-density, mixed-use development ('pull').
- Transport policies to improve the attractiveness of public transport in general do not lead to a major reduction of car travel, attract only limited development at public transport stations, but contribute to further suburbanisation of population.

In summary, where there are integrated strategies in which transport and land use policies are combined, transport and land use policies reinforce each other so that positive synergies can occur. In such integrated strategies, the impacts of 'pull' measures, e.g. of land use development incentives or of improvements in public transport, are much weaker than the impacts of 'push' measures, such as land use restrictions or increases in travel time or travel cost or other constraints on mobility. If transport and land use policies are compared, transport policies are far more direct and efficient in achieving sustainable urban transport than land use policies. However, accompanying and supporting land use policies are essential for creating less car-dependent cities in the long run.

2.3 Good practice

There is a broad range of local initiatives by cities and regions towards better integration of transport and land use planning for reducing car travel and promoting environment-friendly modes of travel, such as public transport, cycling or walking.

The POLIS network (http://www.polis-online.org) currently includes 63 major and medium-sized cities working together to improve transport at the local level in relation to the environment, mobility demand and the economic and social dimensions of transport and safety. Another group are the more than 140 cities in the CIVITAS (CIty-VITAlity-Sustainability) network, which since 2002 has conducted EU-funded demonstration projects on integrated sustainable urban transport strategies in 17 model cities (http://www.civitas-initiative.org). In October 2008, the 133 larger cities of the EUROCITIES network (http://www.eurocities.eu) pledged their commitment to fight climate change in a common declaration.

In 2010, the European Green Capital Award will be presented for the first time to the City of Stockholm. In May 2009, the award was linked up with the earlier Japanese Eco Model Cities Award (http://ec.europa.eu/environment/europeangreencapital).

The Annex to the *Thematic Strategy on the Urban Environment* (European Commission, 2007a) lists examples of good practice of integrated land-use and transport planning in European cities including improving public transport, new public transport oriented settlements, mixed-use development, redevelopment of inner city brownfield sites, walking/cycling strategies, information, pedestrian and cyclist friendly urban design, car-free new developments and inner cities, parking regulations road user charges and reallocation of existing public and road space. Examples are:

- *Vienna*. The city of Vienna aims at a polycentric development by the development of existing areas and new developments on former industrial sites near public transport stations. The Eastern Donaustadt development combines the extension of a metro line, the increase of capacity of a commuter rail line and the extension of a tramway line with high density mixed-use development near the public transport nodes.

- *Aalborg*. The city of Aalborg follows the principles of sustainable environment laid down by the Danish Government. The main goal of its master plan is to obtain a balance of functions, services and housing in each area of the city to reduce the need for trips and increase the accessibility by sustainable modes by improving the cycling network.

- *Tübingen*. The Südstadt in the south of Tübingen is a redeveloped brownfield site 5 km from the city centre formerly used by the military. The redevelopment plan implements mixed use with a balanced ratio of working, living and leisure and enabling short distances, priority to pedestrians and restrictions on car use.

- *Amsterdam*. In the centre of Amsterdam a car-free housing area with 600 housing units was built with parking only at the fringe of the area, which greatly supported the use of bicycles for short trips within and outside the area.

Other noteworthy examples are the successful implementation of cordon pricing schemes in London and Stockholm. The London congestion charge, only recently expanded to a wider area and increased to £8 per day has significantly reduced car traffic with only little loss of retail sales in central London. The similar scheme in Stockholm, though with much lower charges, was introduced as permanent in 2007 after a successful trial period.

3. New challenges

These best practice examples are encouraging. However, they are by no means sufficient to cope with the new challenges of energy scarcity and climate change cities are facing today. Technological advances in energy efficiency of buildings and vehicles and alternative fuels will not be enough to meet the reductions in energy consumption and greenhouse gas emissions necessary to combat climate change (Banister and Hickman, 2007). Substantial changes in life styles and mobility patterns will be needed to meet the greenhouse gas reduction targets of the European Union and its member states.

Twenty percent of mankind command eighty percent of the world's wealth and are responsible for eighty percent of greenhouse gas emissions. This inequality is growing. Since the 1970s, the per-capita income of the industrialised countries has grown by a factor of ten, whereas that of the developing countries has only tripled. Yet, this traditional division of the world into rich and poor countries is collapsing. In particular, four so-called developing countries, Brazil, China, India and Russia, have two-digit growth rates of their economies and in a few years will produce more than North America and Europe taken together. The globalisation of markets for goods and services will destroy millions of jobs in today's industrial countries and lead to hitherto unknown distribution conflicts.

Climate researchers agree that anthropogenic greenhouse gas emissions contribute significantly to climate change and that to avoid the worst implications of global warming a reduction of greenhouse gas emissions by 50 percent world-wide is necessary. The question is how this reduction is to be achieved., Figure 1 shows CO_2 emissions per capita per year in 1990 and 2006 compared to the CO_2 emissions per capita considered as climate-neutral (2 t per year). It is apparent that countries like the United States or Canada need to reduce their CO_2 emissions by 90 percent, most European countries by 80 percent and China by 50 percent in order to allow developing countries like India, Bangladesh or Rwanda to catch up in economic development.

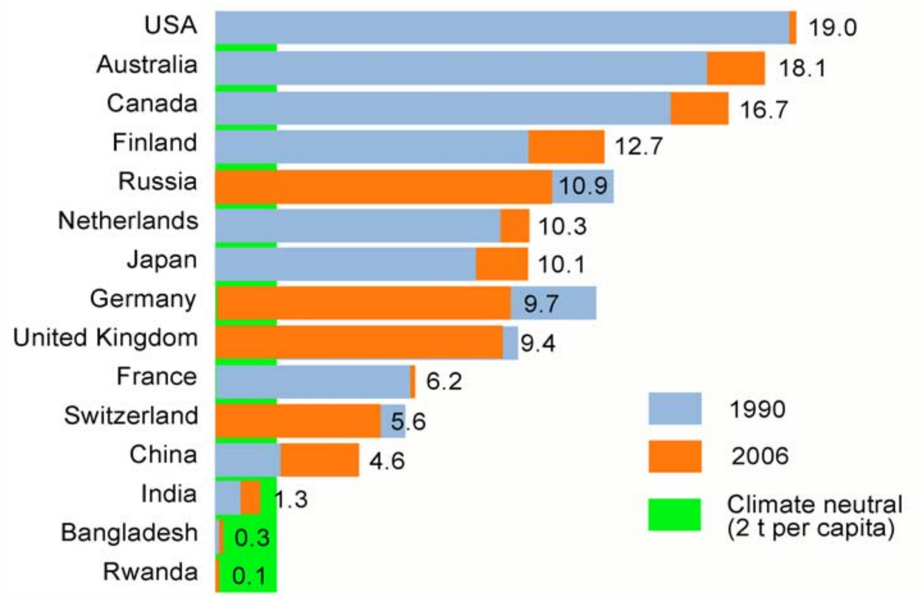


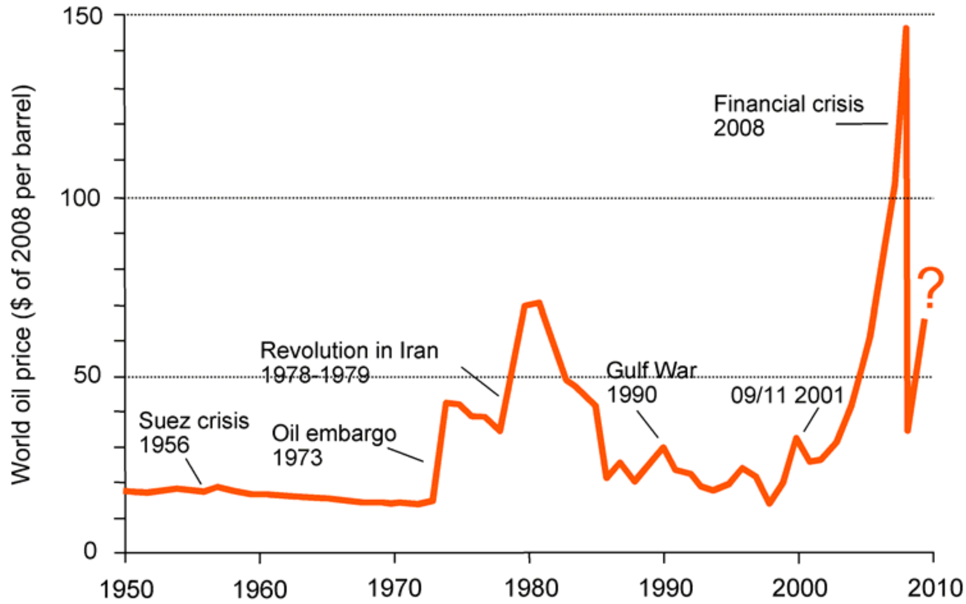
Figure 1. CO_2 emissions per capita per year (t) 1990-2006 (CDIAC, 2009)

The Kyoto Protocol of the United Nations Framework Convention on Climate Change, adopted in 1992, sets mandatory targets for the reduction of greenhouse gas emissions by 2012 in comparison to 1990: 5.2 percent world-wide, 8.0 percent for Europe, 6.0 percent for Japan and no reductions for developing countries, including China and India. The Kyoto Protocol has been in force since 2005; to date, it has been signed by 170 countries. In 2007 the EU heads of state signed a resolution to achieve 20 percent less energy, 20 percent renewable energy and 20 less carbon dioxide (CO_2) emissions by 2020. In 2007, the political leaders of the G-8 summit committed their countries to aim for a reduction of greenhouse gas emissions by 50 percent by 2050.

But, according to the latest report of the United Nations Intergovernmental Panel on Climate Change (IPCC, 2007), this is not enough. In order to reach the world-wide fifty-percent target, today's industrialised countries will have to cut down their greenhouse gas emissions by 80 percent in order to allow the developing countries to expand their economies. The responsibility of the rich countries to go ahead in reducing greenhouse gas emissions was also behind the compromise resolution of the Bali Climate Change Conference in December 2007 and will be a major topic of the Climate Change Conference in Copenhagen in December 2009.

Closely related to this are the challenges of energy scarcity. Another multiplication of production, consumption and resource use of the rich countries by a factor of ten as in the last thirty years would exceed the resources of the planet. Today, it is already foreseeable that if the energy consumption of the world continues to grow only as it has in the past, the known deposits of fossil fuels will be exhausted before the end of this century. If one adds the growing energy demands of Brazil, China, India and Russia, they will already be depleted in a few decades.

In July of 2008 the price of crude oil rose to almost 150 US $ per barrel. During the recent worldwide financial and economic crisis it temporarily went back to below 40 US $ per barrel (Figure 2). Most experts believe that, because of the final depletion of oil resources, of political instability in the Middle East and of rising demand of fast growing developing countries, oil will continue to become more expensive. This will have significant impacts on fuel production, fuel types, fuel efficiency, location choice and mobility.



. Figure 2. World oil price 1950-2009 (WTRG Economics 2008, updated)

It is hard to say which of the two will hit faster, energy scarcity or the requirements of climate protection. But they will both work in the same direction: energy for transport will become more expensive, either through political conflicts or simply because oil is running out, or through government-imposed taxes on fossil fuel or vehicles or through user fees, such as emission permits or road pricing.

4. The STEPs project

To demonstrate the magnitude of the necessary changes, selected results of the EU 6th Research and Technology Development Framework project STEPs (Scenarios for the Transport System and Energy Supply and their Potential Effects) will be presented. The STEPs project examined the impact of different scenarios of fuel price increases, resulting market responses and different combinations of policy interventions in the fields of infrastructure and technology, travel demand regulation and land use control on regional economic development and travel patterns and on the environment, accessibility and land use in metropolitan areas using several European and urban/regional simulation models (Fiorello et al., 2006).

4.1 The models

Here the results for the metropolitan region of Dortmund in Germany are presented. For this, the SASI simulation model of regional economic development and the IRPUD simulation model of urban land use and mobility were used.

The SASI model is a recursive simulation model of socio-economic development of regions in Europe subject to exogenous assumptions about the economic and demographic development of the European Union as a whole and transport infrastructure investments and transport system improvements, in particular of the trans-European transport networks (Wegener, Bökemann 1998; Bröcker et al. 2004; Wegener, 2008). The SASI model differs from other approaches to model the impacts of transport on regional development by modelling not only production (the demand side of regional labour markets) but also population (the supply side of regional labour markets). The spatial dimension of the model is established by the subdivision of the European Union, Norway and Switzerland and the Western Balkan countries in 1,330 regions and by connecting these by road, rail and air networks.

The SASI model has six forecasting submodels: European Developments, Regional Accessibility, Regional GDP, Regional Employment, Regional Population and Regional Labour Force. A seventh submodel calculates Socio-Economic Indicators with respect to efficiency and equity (cohesion). Figure 3 shows the main interactions between the seven submodels.

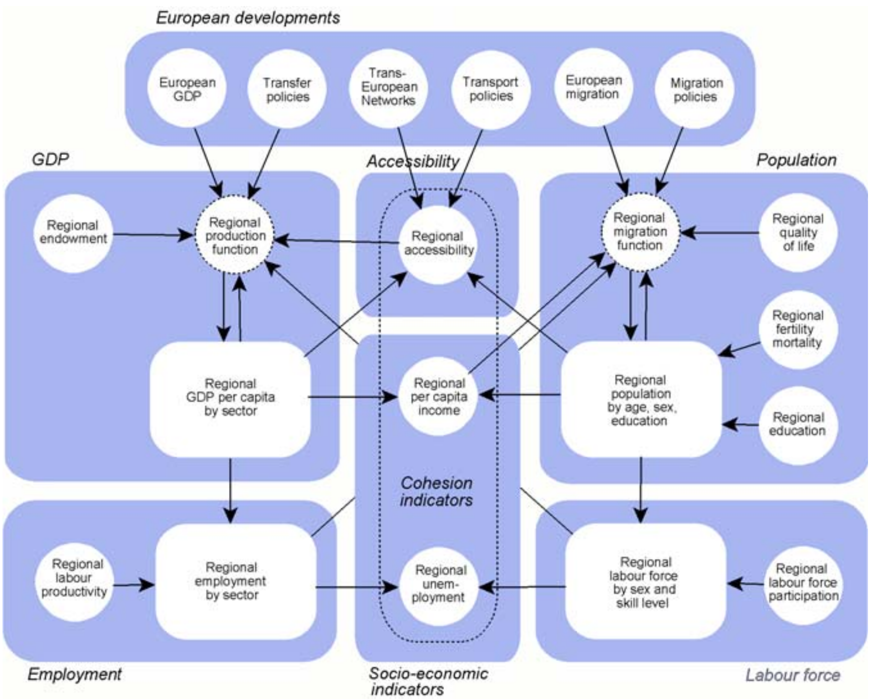


Figure 3. The SASI model.

The IRPUD model is a simulation model of intraregional location and mobility decisions in a metropolitan area (Wegener 1998; Lautso et al. 2004). It receives its spatial dimension by the subdivision of the study area into zones connected with each other by transport networks containing the most important links of the public transport and road networks coded as an integrated, multimodal network including all past and future network changes. It receives its temporal dimension by the subdivision of time into periods of one or more years duration.

The IRPUD model has a modular structure and consists of six inter-linked submodels operating in a recursive fashion on a common spatio-temporal database:

- The *Transport* submodel calculates work, shopping, service, and education trips for four socio-economic groups, and three modes: walking/cycling, public transport and car.
- The *Ageing* submodel computes all changes of the stock variables of the model (employment, population and households/housing) which result from biological, technological or long-term socio-economic trends.
- The *Public Programmes* submodel processes public programmes specified by the model user in the fields of employment, housing, health, welfare, education, recreation and transport.
- The *Private Construction* submodel considers investment and location decisions of private developers, i.e. of enterprises erecting new industrial or commercial buildings, and of residential developers who build flats or houses for sale or rent or for their own use.
- The *Labour Market* submodel models intraregional labour mobility as decisions of workers to change their job location in the regional labour market.
- The *Housing Market* submodel simulates intraregional migration decisions of households as search processes in the regional housing market in a stochastic microsimulation framework.

Figure 4 shows how the submodels work together. The top corners of the diagram show the main actors of the model, employment (firms) and population (households). The bottom corners show the corresponding residential and non-residential buildings. Between the four boxes there are regional markets: the labour market, the housing market, the market for non-residential buildings and the land market. They are linked by the transport market in the centre.

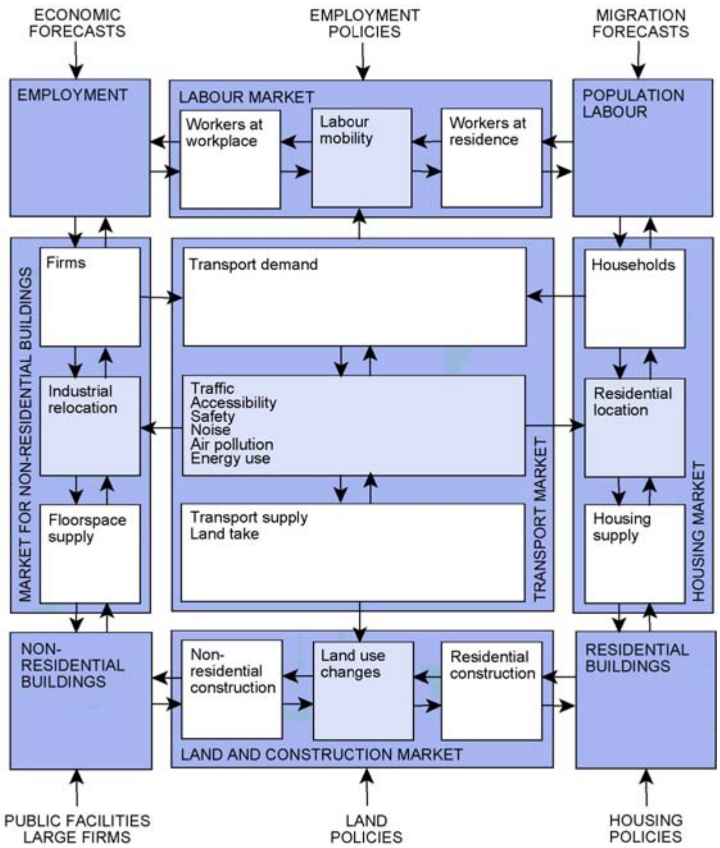


Figure 4. The IRPUD model

4.2 Scenarios

The STEPs project developed a set of scenarios combining different rates of consumer fuel price increases with three sets of policies (Table 1):

Table 1: STEPs scenarios

Policy	Fuel price increase		
	+1% p.a.	+4% p.a.	+7% p.a.
Do-nothing	**A-1***	B-1	C-1
Business as usual	A0	B0	C0
Infrastructure & technology	A1	B1	C1
Demand regulation	A2	B2	C2
All policies	A3	B3	C3

* Reference Scenario

The A scenarios assume consumer fuel price increases by one percent per annum in real terms (or about one third between the base year 2005 and the target year 2030). The Reference Scenario A-1 is a do-nothing scenario: i.e., it assumes that no government policies to respond to the changes in energy prices are implemented, however, it assumes that technical innovation and market response lead to moderate reductions in energy use of cars, lorries and trains. The business-as-usual Scenario A0 assumes that already planned road and rail projects are implemented, that progress in energy efficiency, emission control and alternative fuels is made as in the past and that there is no change in land use policies. The infrastructure and technology Scenario A1 assumes that large-scale road and rail projects are implemented and significant efforts to promote energy efficiency, emission control and alternative fuels are made. The demand regulation Scenario A2 assumes strong disincentives to car travel and goods transport on roads through speed limits, road pricing and higher petrol taxes, supported by incentives for public transport use and land use development at rail stations or substitution of work trips by telework. The combination Scenario A3 combines the policies of Scenarios A1 and A2.

The B scenarios assume real consumer fuel price increases of four percent per annum (or +167 percent until the target year 2030). Except for the assumed higher fuel prices, the B scenarios are the exact counterpart of the corresponding A scenarios, including the assumptions about the diffusion of energy-saving and alternative vehicles.

The C scenarios are based on the assumption that consumer fuel prices grow dramatically by seven percent per year, or almost five-fold, until 2030. Again, Scenario C-1 is a do-nothing scenario in which no policy response is assumed. However, the remaining C scenarios assume a stronger policy response than the corresponding A and B scenarios. Scenario C0 assumes that governments attempt to compensate their economies for the high costs of transport through tax rebates and even subsidies (as in the case of aircraft kerosene), even at the expense of less investment in high-speed rail. Scenario C1 invests more in transport technology to promote energy-saving cars and trains and more alternative vehicles. Scenario C2 uses heavy fuel taxes and road user charges to save fuel by reducing travel by all modes. In addition, Scenario C2 applies strict anti-sprawl land use policies allowing development only on brownfield sites in the inner urban areas of the three largest cities in the metropolitan area. Scenario C3, which applies the policies of Scenarios C1 and C2 together, is the strongest imaginable policy response.

4.3 Results

In this section, the results of the two simulation models for the 15 scenarios are presented. Each diagram shows the development of one indicator. The heavy black line represents Reference Scenario A-1. As the scenario policies are introduced only after 2006, all scenarios have the same historical path as the Reference Scenario until 2006. After that, each scenario is represented by a different line identified by its scenario code.

European regions

Figure 5 shows the impact of 15 scenarios on *accessibility* in Europe. In the past, regional accessibility has grown continuously because of the infrastructure development and the removal of political, social or cultural barriers through European integration. Even in Reference Scenario A-1, which assumes no network development or acceleration of modes in the future, accessibility grows slightly because of the underlying assumptions on further European integration

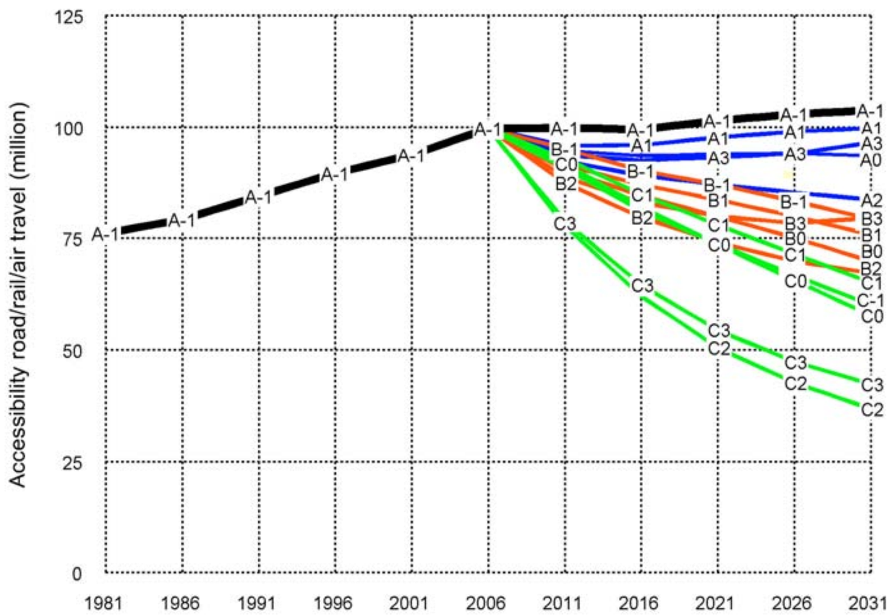


Figure 5. SASI model results: accessibility road/rail/air travel 1981-2031

All scenarios have a significant impact on accessibility. The effects vary with the scenario assumptions on fuel price increases and the different forms of policy intervention. In all scenarios, accessibility is below that of the Reference Scenario. This is to be expected for the do-nothing Scenarios B-1 and C-1 as their fuel cost increases are higher than in Scenario A-1. But, none of the policy scenarios is able to compensate the effects of the fuel price increases. This is so because, in all policy scenarios, road transport is made even more expensive by road pricing. This is also true for policy scenarios in which rail is favoured either by assumptions on network development and an increase in speed (as in the infrastructure and technology scenarios A1, B1 and C1) or through a reduction of rail fares per km (as in the demand regulation scenarios A2, B2 and C2). Even the combination of both (in Scenarios A3, B3 and C3) does not compensate for the loss in accessibility because of the massive policies against car and lorry use in these scenarios. The magnitude of the negative impact depends primarily on the assumptions about fuel cost. The *economic* impact of the fuel-price and policy scenarios predicted by the SASI model are presented in Figure 6.

In all scenarios, the economic growth of the past continues in the future – the model runs were conducted before the recent world economic crisis. No scenario leads to additional growth; all policy interventions slow down economic growth. Whereas in the Reference Scenario A-1 the average GDP per capita in 2031 is about 38,000 Euro, the combination of high fuel price increases and strong policy response, as in Scenarios C2 and C3, leads to an average GDP per capita of only about 34,000 Euro, more than ten percent less than in the Reference Scenario.

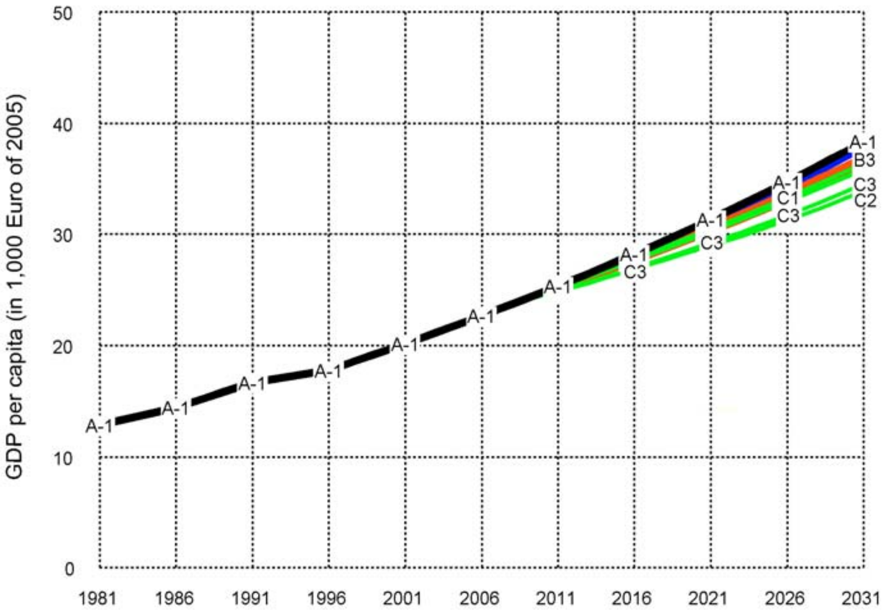


Figure 6. SASI model results: GDP per capita 1981-2031

Metropolitan region

The study area of the IRPUD model is the metropolitan area of Dortmund with a population of 2.6 million. Exogenous inputs are forecasts of total regional employment and net migration of the metropolitan area and global policies, such as taxation or regulation, and local policies, such as transport and land use policies. In the application for STEPs, the forecasts of total employment in the study region were adjusted to the forecasts of the SASI model by adjusting the regional employment control totals of the IRPUD model to the GDP forecasts of the SASI model for the ten NUTS-3 regions of the Dortmund metropolitan area (Table 2).

Table 1: Dortmund metropolitan area: GDP effects

Policy	Fuel price increase					
	+1% p.a.		+4% p.a.		+7% p.a.	
Do-nothing	**A-1***	0.0%	B-1	-2.5%	C-1	-5.2%
Business as usual	A0	-1.5%	B0	-4.1%	C0	-5.7%
Infrastructure & technology	A1	-1.0%	B1	-3.5%	C1	-4.6%
Demand regulation	A2	-2.8%	B2	-5.1%	C2	-10.6%
All policies	A3	-1.7%	B3	-3.9%	C3	-9.3%

* Reference Scenario % values indicate differences to Reference Scenario in 2031

All fuel price and policy scenarios result in lower regional GDP per capita than in Reference Scenario A-1: the SASI model predicts GDP per capita in the Dortmund metropolitan area between 1.0 percent (Scenario A1) and 10.6 percent (Scenario C2) lower than in the Reference Scenario in 2031. These reductions in economic activity affect employment, non-residential construction, household incomes and work trips and transport emissions in the metropolitan area.

The scenarios were run from 1970 to 2030. All scenarios are identical until 2005, with the first policies becoming effective in 2006. In Figures 7 and 8, as in Figures 5 and 6, the heavy black line represents the Reference Scenario; each thinner line represents one policy scenario identified by its scenario code.

All assumed 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 for the fuel price effect.

Figures 7 shows that fuel price increases have a major impact on travel behaviour. In all scenarios, the share of car trips goes down compared with Reference Scenario A-1. If the policies are combined with land use policies, as in Scenarios A2 and A3, B2 and B3 and C2 and C3, people again make more trips by bicycle or foot, and public transport use returns to levels common in the 1950s and car travel to what it was in the 1970s.

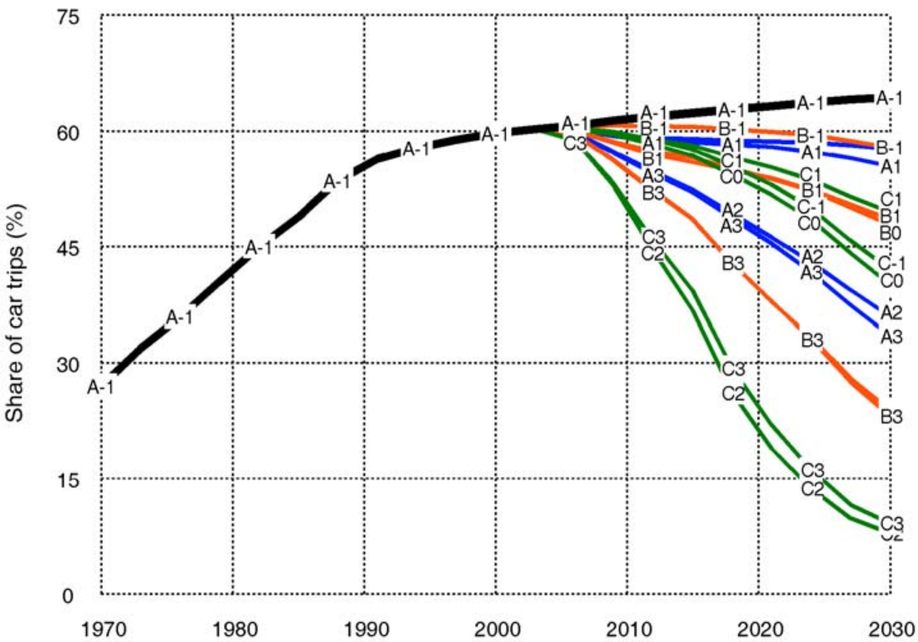


Figure 8. IRPUD model results: share of car trips 1970-2030

In Scenarios C2 and C3, car use is reduced to less than ten percent of all trips. That may appear a rather extreme response of the model. However, in these two scenarios in 2030 a litre of petrol costs 22 € at the petrol stations in today's money and almost 40 € including inflation. At the same time, household incomes in the Dortmund metropolitan area grow by about ten percent less than in Reference Scenario A-1 according to the SASI model. This makes it impossible for households to increase their travel budgets in order to maintain their present level of mobility. In particular, long-distance car commuters will have only two choices: to travel to work by public transport or to move closer to their place of work.

The distance-reducing effects of fuel price increases can also be seen in Figure 8 showing average trip distances. If one looks at the fuel-price only Scenarios A-1, B-1 and C-1, the results are consistent with expectations. 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. Average trip lengths have grown by 40 percent since 1970: travel distances per capita per day have more than doubled and person-km by car have quadrupled. In scenarios A3, B3 and C3, average trip distances start to rise again after 2020 because faster trains and buses offer travel alternatives not available in Scenarios A2, B2 and C2.

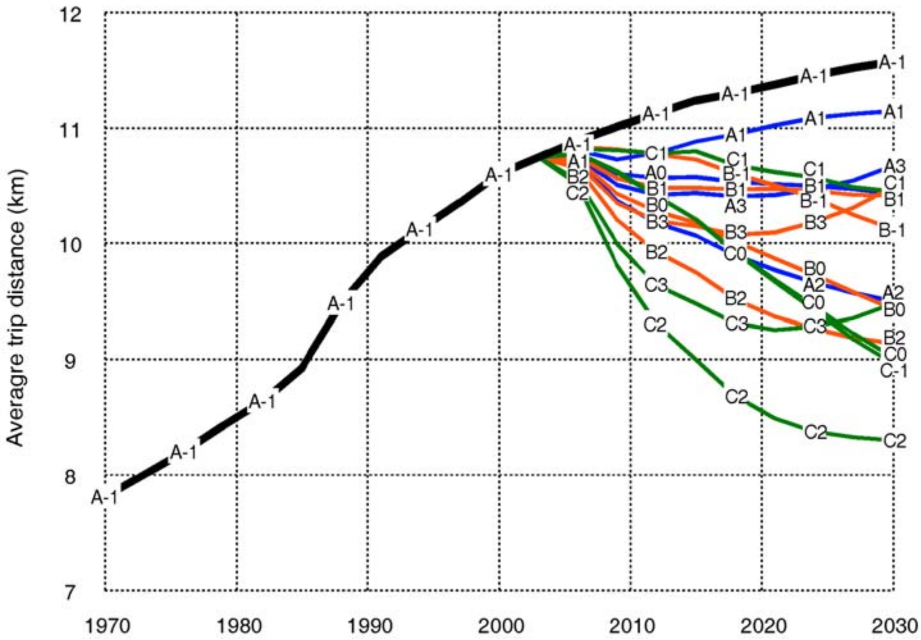


Figure 8. IRPUD model results: average trip distance 1970-2030

With the assumed reductions in fuel consumption per car-km, car fuel consumption and *emissions* can be calculated. Transport emissions are calculated using speed-related emission functions and information about the changing composition of the vehicle fleet.

Figure 9 shows the results of the calculation of emissions of greenhouse gases from transport per capita per day based on the traffic flows by vehicle type and speed predicted by the IRPUD model.

CO_2 emissions from transport have grown continuously in the past because of the combined effect of growing transport volumes and the trend to larger, more fuel-consuming cars which has more than offset the effect of decreasing fuel consumption per vehicle. CO_2 emissions will continue to grow, though at a slower rate, in the Reference Scenario A-1. All fuel price and policy scenarios have a significant impact on future CO_2 emissions, i.e., they lead to strong reductions. 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 infrastructure and technology scenarios (A1, B1, C1). The combination of infrastructure and technology with demand regulation policies and rigorous anti-sprawl land use policies (A3, B3, C3) leads to the largest reduction, which is in line with earlier model results (Lautso et al. 2004). All scenarios result in CO_2 emission levels per capita below those of 1990 by 2030. Only combinations of policies that restrict car travel with infrastructure, technology, demand regulation and land use policies meet the EU greenhouse gas reduction target of 20 percent less CO_2 emissions by 2012 compared with 1990.

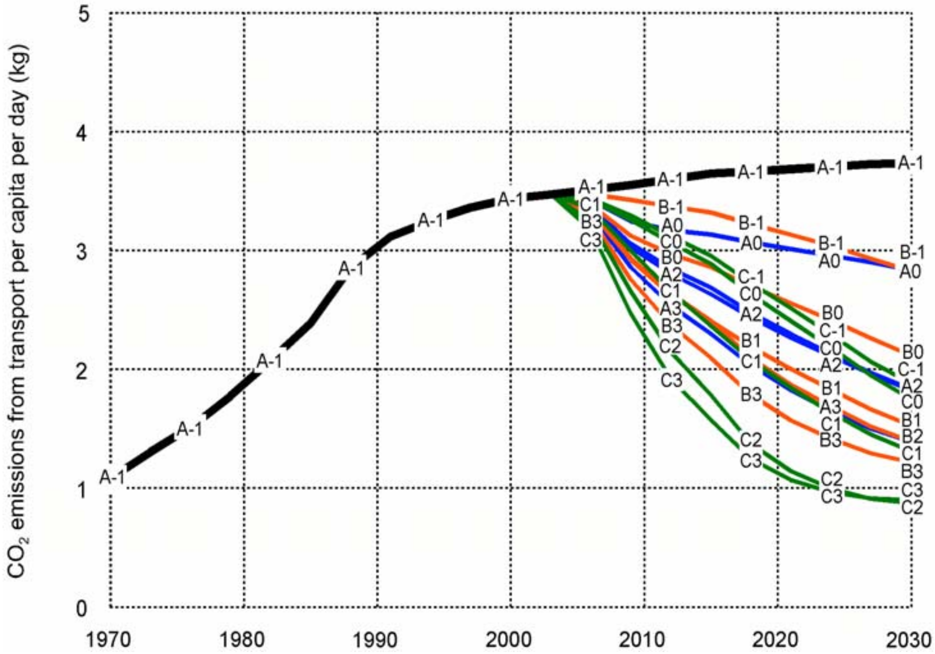


Figure 9. IRPUD model results: CO_2 emissions from transport per capita per day 1970-2030

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

The simulations with the IRPUD 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. Only in extreme cases of long-distance commuting from rural areas in which there are neither acceptable public transport connections nor job alternatives, will a move be the only choice. The effects of the fuel price increase and associated policy scenarios on the distribution of population and employment in the urban area are therefore negligible except in the scenarios in which land use policies are applied (A2, A3, B2, B3, C2, C3). However, Figures 7 and 8 show that the scenarios with strong anti-sprawl land use planning perform better in terms of environmental quality and sustainability and are better prepared to cope with fuel shortages and high fuel prices.

Conclusions

The combined scenario simulations with the SASI and IRPUD models show that the assumed fuel price increases and policy responses have a strong negative impact on the economy and daily mobility in the metropolitan area. The transport-related policies do not improve the situation. Most of the policies, in particular, those aiming at demand regulation, contain so many additional costs for car travellers that average accessibility in the policy scenarios is lower than in the corresponding fuel-cost only scenarios. The improvements in public transport are not strong enough to compensate for the cost increases in car travel. This results in levels of accessibility not only lower than in the Reference Scenario, but even lower than today.

These constraints in mobility lead to significant changes in daily travel behaviour. In all scenarios, the long-term trend towards more and longer trips and more trips by car is stopped or even reversed. Average travel distances per capita return to the level of the 1990s, average travel distances by car to the level of the 1980s and before. There is a renaissance of cycling and trips, and the number of trips by public transport more than doubles or even triples. The share of car trips declines to levels last experienced in the 1970s.

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

However, European cities contain a huge potential for internal reorganisation through better co-ordination of activities. When mobility becomes more expensive, accessibility becomes again an important location factor. Households move closer to their work places and firms closer to their customers, suppliers and workers. Farther-away destinations are replaced by nearer ones that can be reached by bicycle or foot. Neighbourhood relations become important again. High-density, mixed-use urban structures facilitate these adjustments.

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

To mitigate the hardships and maximise the benefits of higher fuel prices, regions and cities need integrated and long-term transport and land use strategies that include a combination of pricing policies directed at car users with moderate public transport fares, public transport infrastructure investments to improve public transport speed and service and a regional spatial development plan supporting living near central areas, in satellite cities or along public transport corridors.

In summary, the model simulations show that only scenarios in which car driving becomes significantly more expensive, be it through fuel price increases or government taxation, will achieve the reductions in energy consumption and greenhouse gas emissions necessary to meet the EU targets of 20 percent less energy and 20 percent less CO_2 emissions by 2020 compared with 1990. These constraints on mobility will have significant consequences for life styles and mobility patterns in cities and in many cases a loss of quality of life. The policy challenge will be to make these constraints socially and politically acceptable by providing attractive alternatives of mixed-use, higher-density housing with nearby opportunities for education, shopping and leisure and more environment-friendly mobility by public transport, cycling and walking. For this cities need integrated and long-term transport and land use strategies that include a combination of pricing policies directed at car users with moderate public transport fares, public transport infrastructure investments to improve public transport speed and service and a regional spatial development plan supporting living near central areas, in satellite cities or along public transport corridors.

Moreover, integrated transport and land use strategies for whole metropolitan areas require a high degree of co-operation between the core cities and suburban municipalities. They require a strong regional planning system and efficient mechanisms of horizontal and vertical co-ordination between government departments and levels, a broad public debate between researchers, policy makers, stakeholders and citizens and strong efforts to raise public awareness of the importance of preparing regions and cities for a sustainable future by promoting more sustainable modes of transport, regional economic circuits and less car-dependent settlement structures.

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