The Economic Impact of Environmentally Sustainable Transport in Germany

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The economic assessment of the Environmentally Sustainable Transportation (EST) scenarios developed throughout this paper are part of Phase 3 of the overall project, which is on social and economic assessment and on devising packages of instruments that - if implemented - would result in attaining EST.
Two methods were chosen for the assessment of the scenarios: a qualitative evaluation based on a simplified cybernetic model (SCM) and a system dynamics model (SDM).
In the assessment with the simplified cybernetic model, a conservative baseline has been chosen in order to start with a scenario that incorporates some pessimistic views of the industry. The aim is to show that, even in this case, an economic disaster will not occur.
The System Dynamics Model ESCOT was designed to consider the ecological and technical aspects of a transition towards sustainable transportation. It is important that ESCOT considers not only first round effects but also secondary effects, which makes it a powerful instrument for the assessment of such large ecological changes.
The economic assessment of environmentally sustainable scenarios shows that the departure from car and road freight oriented transport policy is far from leading to an economic collapse. The effects concerning economic indices are rather low, even though the measures proposed in the EST-80% scenario designate distinct changes compared to today's transport policy. The impacts on some economic indicators, however, are clearly negative. With an expansion of the time period for the transition in the EST-50% scenario we derived even more encouraging results than for EST-80%.

1. Introduction

The objective of this paper is to describe a development path towards sustainable transport in Germany and to assess its economic impacts. This economic assessment is part of the Environmentally Sustainable Transport (EST) project of the OECD. The results of the economic assessment may be used as an example for the evaluation of sustainable transport scenarios in other countries.

In 1994, the Pollution Prevention and Control Group of the OECD established a Task Force on Transport to look into ways and means to significantly reduce the environmental impact of transportation. Starting from December 1994, an Expert Group met several times to prepare a proposal and to start work on a project on environmentally sustainable transport comprising four phases:

- To **identify key criteria** for what might be sustainable transport.
- To **construct a business-as-usual (BAU)** scenario revealing how further unsustainable development in transport may look and an **environmentally sustainable transport (EST)** scenario which demonstrates a path towards achievement of the key criteria, taking 1990 as the reference year and 2030 as the year for which attainment of the EST criteria is supposed to be achieved.
- To **identify packages of policy instruments** which enable attainment of the criteria in the EST scenario with a backcasting approach.
- To **assess the BAU/EST scenario** with respect to its technical, economic and political feasibility.

Research groups from the participating countries, Sweden, Norway, the Netherlands, Canada, France, Switzerland, Austria and Germany, identified a number of criteria, defining the goals of sustainability (OECD 1996, 1999a und 1999b). The main focus is to achieve a considerable reduction of carbon dioxide (CO_2) emissions. As CO_2 emissions are the most problematic air emission gas, we assume that if we fulfil the criteria for CO_2, then the other criteria are also met.

1.1 BAU, EST-80% and EST-50% scenarios

In the next phase the German group constructed a BAU and an EST scenario for Germany[1]. The scenarios have scientific character, and as such they neither describe envisaged policies, nor environmental targets established by governments. The BAU scenario assumes that no significant policy changes and no major technical changes will take place in the transport sector. Only the structural changes and technical innovations which can be expected to take place from today's point of view are included. So the development of the BAU scenario started with data from today and extrapolated them till the year 2030. In table 1 the main assumptions of the BAU scenario are depicted.

In contrast to the BAU scenario, the EST scenario is goal-oriented. It describes a transport scenario that meets the identified criteria in 2030. The goal-oriented character of the EST scenario suggests applying a backcasting approach. The first step in such an approach is to construct the end state. The next step is to develop the path to this end state (Gausemeier 1995). So the construction of the EST scenario started with the goal and then tried to find out

[1] see for a more elaborate description of the German case study Verron and Friedrich, elsewhere in this volume

which technical progresses and which transport reduction strategies are necessary to reach this goal.
The goal of the EST scenario is to reach sustainability by the end of the time horizon. For greater clarity, we call this EST scenario EST-80% because its aim is to reduce CO_2 emissions by 80%.

Table 1. Assumptions of BAU and EST-80% (Umweltbundesamt, Wuppertal Institute 1997)

Assumption	BAU	EST-80%
Population	Slight growth until 2010 (84.9 m persons) and then decrease (81.1 m persons)	As in BAU
Economic growth	Moderate (2 % growth of GDP per year)	As in BAU
Infrastructure	Federal Transport Master Plan (about 1% growth of road network per year)	Railway network almost doubled till 2030, no extension of road network after 2010
Fuel Price	Moderate growth (1% per year)	Growth driven by taxes (about a doubling of the cost per driven km)
Automobile fleet	Increase (68 m cars in 2030)	Similar as in 1990 (43 m cars in 2030)
Car occupancy	Decrease (urban areas: 1.49 in 1990 to 1.3 in 2030)	Increase (1.9 in 2030)
Yearly travelled km/car	Decrease (from 13 700 km/car in 1990 to 12 000 km/car in 2030)	Decrease (6 700 km/car in 2030)
Specific emissions from road vehicles	Significant reduction (e.g. reduction of CO_2 emission equals reduction of energy consumption)	High reduction
Specific energy consumption for transport modes	Decrease (e.g. for gasoline 8.9l per 100 km for cars in 1990; 5.8l per 100 km in 2030)	High decrease (e.g. for gasoline 2.5l per 100 km for cars)
Noise emissions	Moderate reduction	High reduction (e.g. decrease of standards for noise from 71 dB(A) to 62 dB(A))
Car ownership rate	820 cars per 1 000 inhabitants	Similar as in 2000 (530 cars per 1 000 inhabitants)
Share of diesel cars	From 15% (today) to 30% in 2030	0%
Share of electric cars	10% in 2030	0%
Energy	Similar as today (6% from renewable energy in 2000)	50% from renewable energy

Both scenarios are based on a number of certain assumptions. The same assumptions are taken for all scenarios concerning the development of population and economic growth, while they differ strongly regarding the development of transport figures. Because the BAU scenario assumes no significant policy changes and no surprising technical developments, the future trends can be extrapolated by the trend of the last decade. The assumptions for EST-80% are completely different. Because of a new transport policy, this scenario expects e.g. higher road transport prices. The rise of transport prices lower the yearly travelled km per car and this leads to a high decrease of specific energy consumption. To avoid arbitrage it is assumed that other countries are also following the EST path.
In order to achieve an 80% reduction of CO_2 in the year 2030 drastic restrictions and energy cost increases have to be introduced already decades ahead, which might cause economic risks. For this reason the scenario required modification and an EST-50% scenario was

constructed. The EST-50% scenario follows a reduction goal of 50% CO_2 emissions till the year 2030[2]. With EST-50% we can observe the economic impacts if we apply the same time horizon, weaken the ecological goals and decrease the intensity of policy measures that change the transport behaviour of population or firms.

The paper is organised as follows: Section 2 presents the conventional instruments of economic assessment, for instance, cost-benefit analysis and compares it with alternative approaches which are based on the system dynamics concept. As it will not be possible to apply a complex system dynamic assessment model to all studies of the expert groups, a simplified method has been developed which is called IPA (Impact Path Assessment) and is applied in the German case study in section 3. In section 4 the system dynamics model ESCOT is also applied to the German case study and in section 5 the results of both methods are compared. Section 6 gives conclusions on the assessment of the EST scenarios.

2. Assessment Methods

In general, conventional assessment methods, such as cost-benefit analysis (CBA), multi-criteria analysis (MCA) or cost-efficiency (CEA), are based on "point forecasts" for the year of projection and are applied to marginal changes of the state of the world. As they are usually applied to a time horizon between 10 and 20 years, they only consider a one-directional impact mechanism (policy measure -> traffic behaviour -> physical impacts -> values of impacts) and do not include feedback mechanisms between transport, the socio-economic system and the ecological system (Rothengatter 1998)

Specific economic assessment methods, like input-output analysis (IOA) and computable general equilibrium (CGE), are most useful for analysing marginal changes in economic systems over the short term. As they do not consider any time dimensions they are applied only for point-to-point forecasting.

It is obvious that methodologies relying strongly on data from the past, like IOA or econometric modelling, are based mainly on statistical analysis. Their results become less reliable the further into the future these models are applied.

The time horizon of BAU and EST scenarios, however, is about 35 years and could easily be extended to 50 years. The hypotheses with respect to technology or behaviour are speculative in the sense that they reflect major instead of marginal changes of presently existing patterns. The policy actions that are necessary to achieve EST cannot be regarded to be once-and-for-all measures. On the contrary, they spread over time and will have different intensities, most probably low intensities at the beginning and high intensities at the end of the process.

In view of these properties of the evaluation problem (dynamics, feedbacks, uncertainties), it does not seem appropriate to apply one of the conventional assessment methods or one of the specific economic assessment methods which have been developed assuming a world which is static, with one-directional and certain effects. Alternative approaches have to be investigated which take into account complex problems with uncertainties and a long-term time horizon.

[2] Note that IPCC has proposed to achieve this goal in 2050, not in 2030

2.1 System dynamics modelling (SDM)

The **system dynamics approach** is used to simulate the dynamic behaviour of complex biological, bio-physical, social, i.e. generally speaking, bio-cybernetic systems (Forrester 1962; 1972; Bockstael, Costanza et al. 1995). Based on the finding that socio-economic systems as well as many other real world systems often behave counter-intuitively, which means that measures that have a positive influence in the short run have a negative outcome in the long run, Forrester (1972) concluded that such systems are composed of several interacting feedback loops. The system dynamics approach has been applied for the long-term forecasts of the Club of Rome (Meadows) as well as the bio-cybernetic experiments of F. Vester (1995) concerning the social impacts of industrial or transport development. There is growing international research into applying this instrument to problems of integrated assessment of policy strategies (Kuchenbecker 1998; ASTRA 2000; Schade 2002)
Summarising, the basics of system dynamics are

- the mental problem-solving process (e.g. evaluation of relevance of interrelationships),
- the information-feedback theory (e.g. constructing a model of several feedback loops),
- the decision theory (e.g. defining decision rules to move along the time path from one system state into another) and
- computer simulation.

When developing a system dynamics model it is important to define the system borders, the system variables and the relevance of their interrelationships. A system dynamics model consists of state variables (levels, reservoirs; e.g. population), flow variables (rates, changes; e.g. population growth) and auxiliary variables to establish dynamic relationships (e.g. birth rates). The dynamic relationships are represented in form of feedback loops that can be positive or negative, i.e. self-enforcing or dampening. For instance, the relationships between transport infrastructure, traffic growth and change of spatial patterns can be modelled in form of positive feedback loops. The behaviour of a system is primarily determined by its feedback mechanism (Forrester 1972; Bossel 1994). Because of the impossibility to prove an equilibrium solution, in most cases it is necessary to solve the problem by computer simulation. Results are produced within the computer simulation that calculates the system states step-by-step over the simulation period, based on interrelationships between variables, feedback mechanisms and decision rules.

In order to evaluate policy packages that might lead to completely different transport systems from today, it is necessary to assess long-term effects of these policy measures. For instance, the construction and planning of transport infrastructure may take up to 10 years and the duration of use is often longer than 40 years. But this construction has impacts on e.g. development of population, the way of living and housing, car ownership, investment and other macroeconomic variables.

The long-term time horizon of the assessment causes the problem of uncertainty. There might be changes on the behavioural or on the technical side, e.g., the population might change their habits to an environmentally favourable way or not. Car producers may construct cars with less carbon dioxide emissions and less fuel consumption. Or, maybe, cars with small fuel consumption will represent only a small portion of the total car production.

Since forecasting has to cope with long-term effects and their uncertainties, it is wise to apply a modelling technology that diminishes uncertainties (Schade et al. 1999). Finally, it has to be emphasised that system dynamics models are not used for point-to-point forecasts and

assessments, but for forecasting the development of the model variables over time, such that the time path development of the variables can be used for assessment. The SDM offers the opportunity to construct a feedback mechanism for the transport sector and for the macroeconomic development, which includes also structural changes induced by second round effects, which only occur in the long run.
There are several software packages on the market to solve system dynamics problems efficiently, such as STELLA, ITHINK, VENSIM or POWERSIM. It is possible to decompose models such that different types of aggregation can be studied. The software provides tools for graphical presentation of the results. Trajectories for dynamic adjustments can be plotted for long-term time ranges. By this it is possible to control the dynamic development of critical variables with respect to sustainability benchmarks.

2.2 Simplified cybernetic modelling (SCM)

SDM is based on a mathematical system of dynamic equations. Missing information on the shape of functions can be substituted by the modeller through more vague data input, for instance, in the form of curves which represent observations of the past or in the form of subjective value judgements. However, if many inputs have to be generated in this way then the quantitative form of SDM loses its justification, as data are produced which cannot be interpreted in a quantitative manner.

Therefore it can be considered to apply more simple tools in this case. The first part of the SDM analysis can be simplified by increasing the level of aggregation so that the complexity of the system is reduced. Instead of introducing functional forms for the relationships, the second part can consist of a qualitative analysis that can be called the ”manual computer”. The strength of each relationship is valuated by a ranking scale, for instance consisting of numbers 0, 1, 2, ..., n, zero denoting that there is no influence, n indicating that there is a very strong influence. If this is performed for the forward and backward directions of the influences, then a matrix of impact indicators is arrived at. This matrix can be analysed to find out the most relevant factors and relationships.

In a system describing transport/economy/ecology, Vester (1995) constructed about 100 feedback loops. After the described simple manual incidence analysis he showed that human behaviour is the key variable, because it is an element of many ”positive” (reinforcing) feedback loops. Influencing behaviour consequently is the most important policy to find the right trajectory towards sustainability of the transport system. Relying on the change through technological progress is not enough; on the contrary, without a change of values, technical progress might reinforce the activities depleting the natural resources.

3. Application with simplified cybernetic modelling

As a result of the discussions in the OECD EST group meetings it was concluded that traditional cost-benefit analysis and other conventional methods were not preferred on one hand, while on the other hand preparing the data and functional inputs for an SDM would require considerable additional work and bring about problems with handling the complex structure of a dynamic system. Therefore most expert teams identified a **simplified**

cybernetic model (SCM) as the preferred solution. Only the German Umweltbundesamt launched a project to develop a sophisticated SDM for evaluating the German case study; this exercise can be used as a prototype for SDM modelling (Schade 2002).

3.1 Basic Idea of Impact Path Analysis

Looking at the partially detailed and quantitative scenarios of the case study teams applying the most simple version of SCM (using the values (-, 0,+) which are often applied in management seminars) would abstract from all cardinal information which has been generated by the teams. Therefore, a variant of an SCM, which gives the case study teams the opportunity to exploit all information elaborated as deeply as possible and which can be extended to an SDM for selected case studies, is presented in the following section. We will call this method the **impact path approach (IPA)** because it is based on the idea that the assessors follow the chain of impacts level by level through the economic system to result finally in aggregate economic indicators, and assess the order of magnitude of their changes.

The flow stream of the basic part of the IPA method is exhibited in Figure 1. The bold lines in the Figure represent the mainstream of the analysis. The country teams were asked to perform a one-directional walk through the micro, meso- and macro-levels of the impact areas, starting from concrete specifications of the policy actions and the doses in which these should be applied. Dotted lines indicate additional relationships between the level blocks that might be relevant but have to be neglected in the IPA analysis in order to reduce complexity.

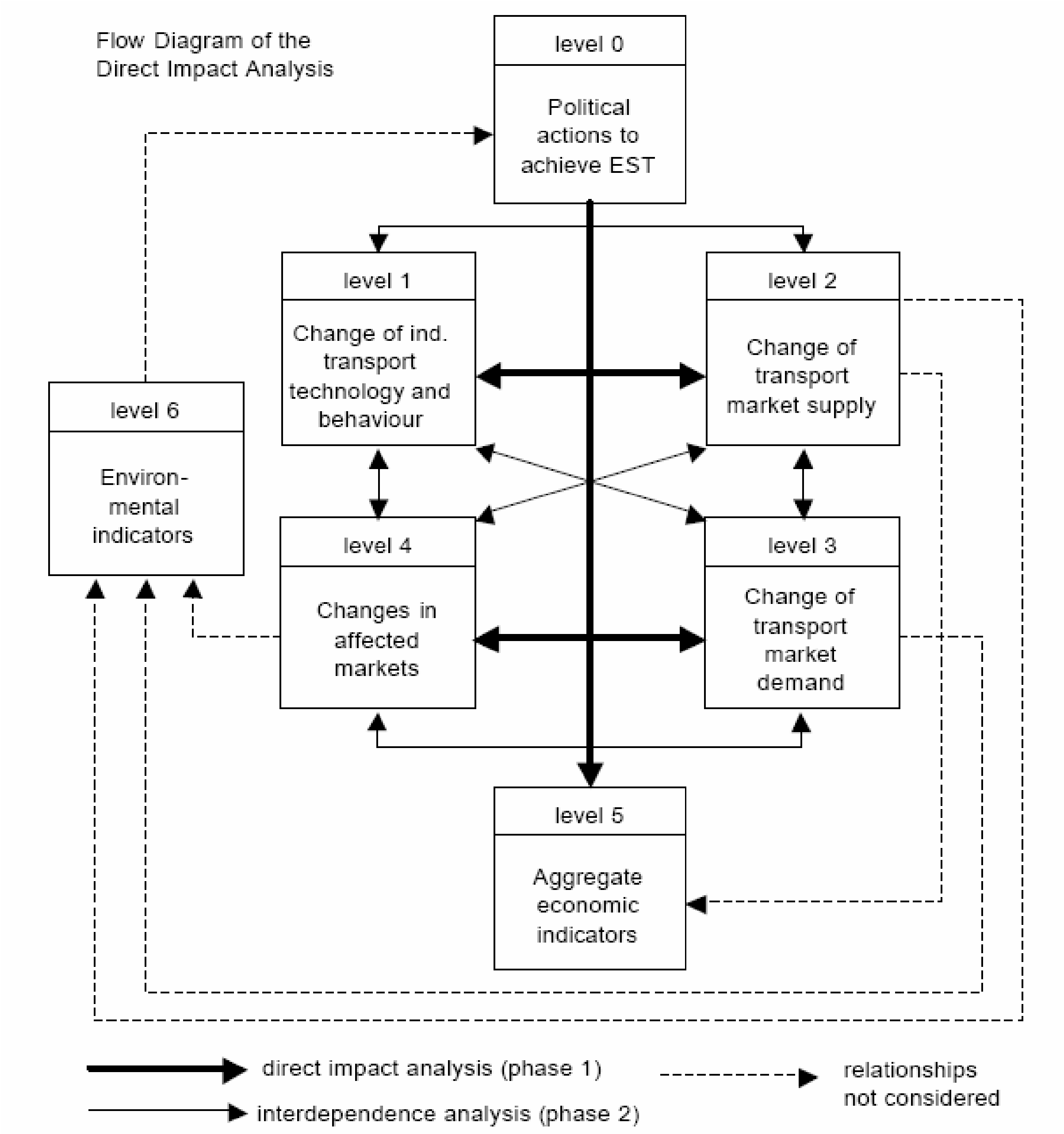

Figure 1. Flow Diagram of the Direct Impact Analysis

3.2 Assessment of the EST scenarios with SCM

The IPA method has been applied tentatively to the German case study to construct a first example for the procedure.

EST-80% for the year 2030

A paper of the Umweltbundesamt and the Wuppertal Institute presented the assumptions of the German case study (Umweltbundesamt, Wuppertal Institute 1997). A quick glance

through the evaluation sheets for all levels of the IPA assessment brought the following results. There are many policy measures which have an influence on transport markets, so instead of evaluating each policy measure separately, it is easier to bundle similar policy measures into categories. For the IPA the following categories were defined: pricing variable, pricing fixed, standards fuel, standards exhausts, standards noise, standards behaviour, management efficiency gain, land use, education and energy production.
The outcome of level 1 is that changes of technical aspects of the EST-80% scenario contribute only about 27%, while behavioural changes contribute about 73% to the total CO_2 reduction. On the technological side, the scenario puts much emphasis on technology for road vehicles as well as for trains and aircraft. The most important policy instruments for this aspect are standards exhaust.
In level 2, the change of generalised costs indicates the intensity of public measures necessary to achieve the changes of technology and behaviour of level 1:

- The real generalised costs of car travel have to increase by at least 100% compared with BAU.
- In the case of trucking, an even higher increase of generalised costs, in the magnitude of 175%, would be a precondition for the drastic changes to be achieved.
- To stop the fast growth of air travel and to achieve a drastic reduction compared to BAU, the generalised costs of air traffic would have to be increased by at least 600%.

In the next level the traffic volume of EST-80% has to be derived. The impacts of pricing policies are estimated by elasticities and the change of generalised cost. Further, the impacts of regulatory policy measures are assumed. This leads in level 3 to the following changes of traffic volumes compared with BAU:

Table 2. Traffic Indicators of EST3

Traffic volume [bn pkm or tkm]	1990	BAU 2030	EST 2030	Change of traffic volume of EST-80% compared to BAU
Non-motorised transport	53.2	44.9	79.8	+ 78 %
Light rail/bus transport	82.6	87.0	263.8	+ 203 %
Heavy rail, passengers	61.5	81.0	281.8	+ 248 %
Cars, motor bikes	721.9	1057.5	340.4	- 68 %
Rail freight	104.4	104.4	468.0	+ 348 %
Inland waterways	56.0	84.6	105.0	+ 24 %
Trucking	202.2	487.4	63.5	- 87 %
Air traffic	100.3	529.7	37.3	- 93 %

Economic indicators are considered in level 4. The economic sectors that are influenced in the first instance by the assumed measures are the road vehicle manufacturing industry, the related secondary business (energy, repair etc.), the railway industry, the airline industry, tourism and the retail business. Losses of demand in the first two sectors can be partly offset by gains in other sectors, depending on the substitution behaviour of customers. The overall effects can be estimated by input-output analysis using changes of traffic volumes as main indicator. The results are:

- As the road vehicle industry plays an important role in the German economy, there is considerable influence on the gross value added (GVA) in the first round of impacts. Road vehicle manufacturing loses about 45% and secondary businesses 60% of their original GVA.
- The airline industry is expected to lose even 90% of their production compared with BAU.
- These losses can be partly offset by increases in the more environmentally friendly transport industries. For instance, the railway industry gains 120%.
- The second and third round effects of the economic adjustment process include the effects of demand diversions to other sectors. The national tourist industry and also retail businesses could profit by about 10% each.

In level 5, the sectoral effects investigated in level 4 are analysed with respect to the overall multiplier effects, considering the interdependence effects exchanged between all sectors. This results in the estimation of overall production and employment effects. The above analysis is based on input-output figures. It can be assumed, however, that during the phase of transition to EST production technology will adjust and technological progress will be accelerated, strengthening an economy that in the long term will be exposed to rising energy prices. Such a process of technological adjustment has been simulated on the base of a production function approach. The productivity in the production function rises every five years. In 2030 the productivity is 3% higher than in 1990.

- Summing up, a loss of national production value remains in material terms. It is associated with a reduction of final demand that is estimated at about 5% of the BAU value. The reduction of private consumption that indicates material well-being of consumers is slightly higher at about 6 %.
- Based on the projected development of labour productivity, one can estimate the change of employment, which is an important indicator in countries with high unemployment. The result is an expected loss of employment of about 3%. This figure is significantly lower than the percent reduction of gross production value that indicates that production has shifted from sectors with higher to sectors with lower labour productivity.
- The feedback between the change in transport technology and the acceleration of technical progress has been implemented. Under modest assumptions on the effects of technological change, the above figures of production and employment losses come out about 50% smaller, i.e. technological change can partly offset the negative demand side effects.

As the German EST scenario includes drastic restrictions on economic behaviour it has to be expected that economic disadvantages in term of production and employment losses occur, which can be halved by accelerating technical progress through stimuli in the transport sector. Finally, the expected production losses might come out at 2.5, losses of material consumption at 3% and the employment losses at 1.5 %.

4. Application with system dynamics modelling

4.1 Structure of BAU/EST - ESCOT

Figure 2 shows the structure of the SDM. It is based on five different models representing four of the most important subsystems describing the impact areas and the policy sphere (Schade 2002).

The macroeconomic model supplies information on the aggregate economic level (e.g. national income). The regional economic model is disaggregated into 12 different economic sectors. Furthermore, 9 functional types of regions are defined (e.g. rural regions or highly agglomerated areas). This classification is also applied for the **transport model**. In addition, this model distinguishes between different transport modes (road, rail, water, air) and different types of infrastructure links (e.g. high-speed links between agglomerations). The **environmental model** calculates data on emissions of transport activities and estimates their first round effects. The **policy model** drives the scenarios that influence the other model systems. Most of the policy implementations simulated intervene in the transport model, so that this model usually is used as the steering area for simulating the impact mechanisms.

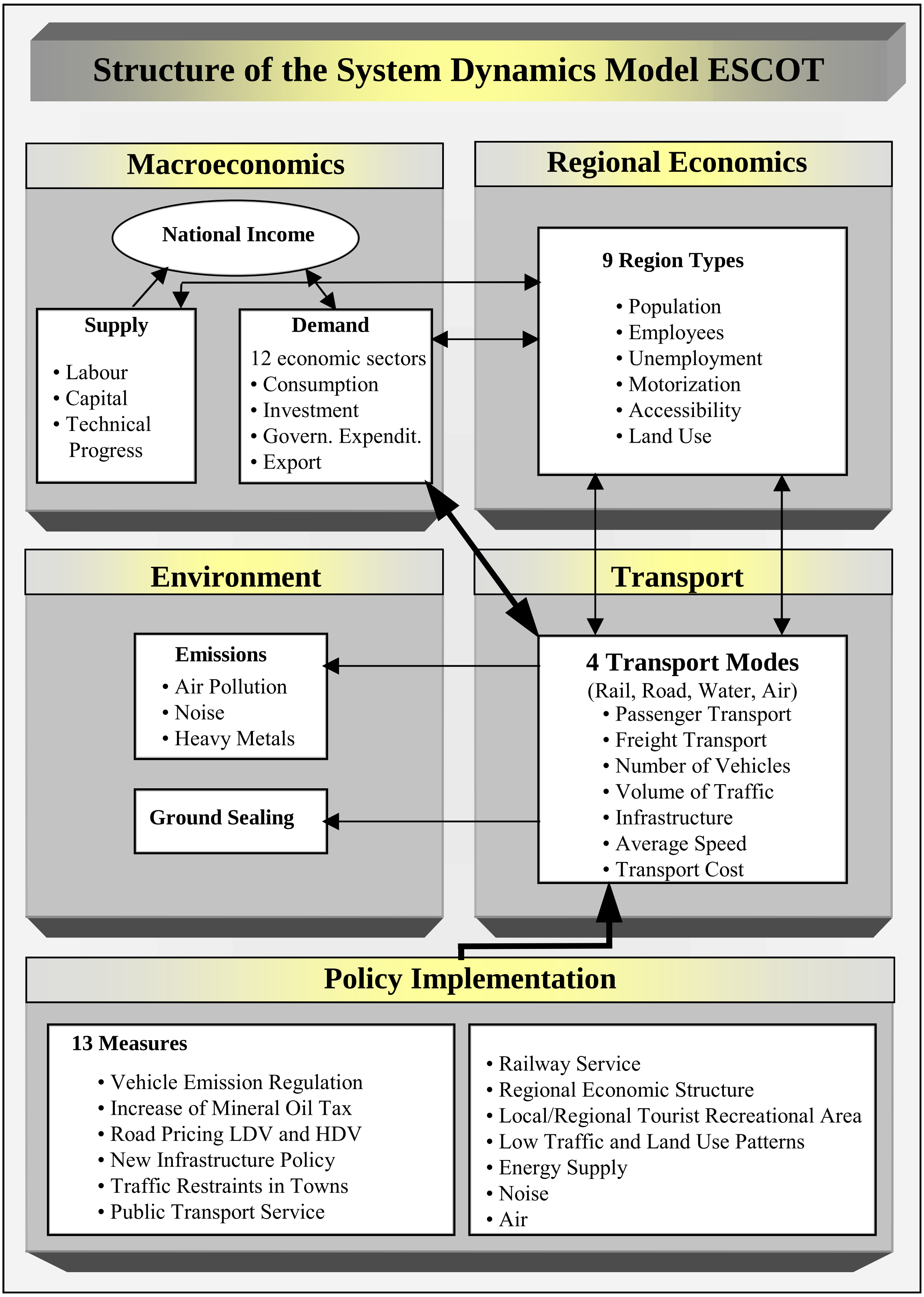

Figure 2. Structure of System Dynamics Model ESCOT with BAU/EST Policy Implementation

4.2 The Macroeconomic Model

Constructed with elements of a Keynesian and Neoclassic model, the macroeconomic model is divided into two main parts: the demand and the supply side.
Demand is split into four main demand sectors: consumption, investment, government expenditure and export. Each of the four demand sectors is disaggregated into 12 economic sectors (agriculture, energy, chemistry and mineral oil industry, steel, mechanical and automotive productions, electronics, wood, food, construction, commerce and traffic services, private services, public services).

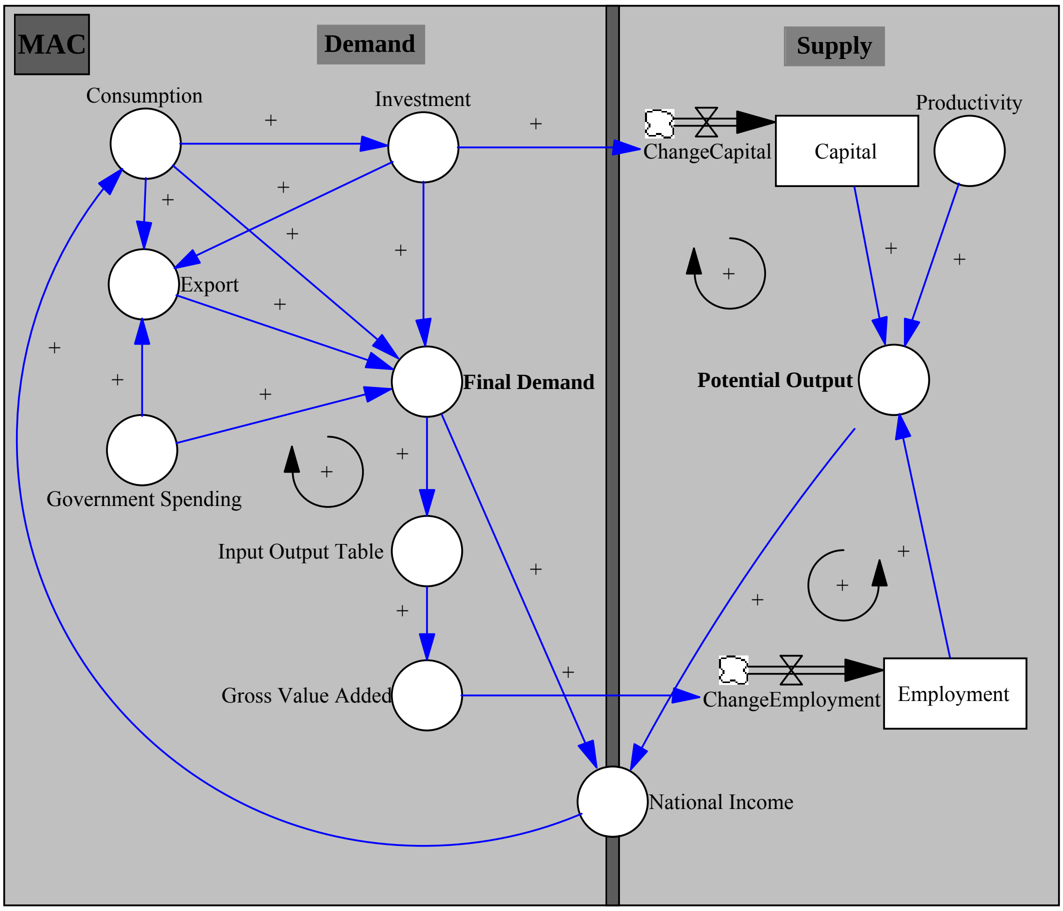

Figure 3. Demand and Supply Side in ESCOT

The supply side is split into the production factors labour and capital. In addition, technological progress is considered on the supply side to integrate the technical development within the economy.

Demand side
The main objective of the demand side is to calculate the final demand. The final demand is determined by the development of consumption, investment, government spending and export.

The variable **consumption** represents the consumption of the private households. For its calculation, we use the national income as one input. Additional inputs are the consumption spent in the transport sector like:

3. mineral oil industry: the consumption of fuel for car travel,
4. vehicle demand purchases: consumption of cars and motorcycles, repair,
5. transport service: rail, bus and air travel.

The reason for this approach is that private households change their consumption patterns if transport prices increase. We consider that consumption in transport sectors causes impacts on consumption in non-transport sectors, e.g. a decrease of consumption in transport sectors leads to a non-negligible increase of consumption in non-transport sectors. This does not mean that there will be a complete compensation of expenditure types because of complementarities between transport and other activities. In addition to net expenditures, in all simulation runs taxes and especially the mineral oil tax are taken into account.
The variable **investment** represents the investment of enterprises and the government. The development of investment in one sector depends on the development of consumption in the same sector. Another influence on investments depends on the freight transport sub-module. The transport models provide information about the traffic volume of road, rail and ship freight transport. These inputs are used as an indicator for investment in vehicles and buildings. Finally, the investment in road and rail infrastructure made by the government is considered. The main part of infrastructure investment is needed for the expansion of the railway network. In the EST-80% scenario a doubling of the length of the railway network is assumed to be necessary to handle the increased traffic volumes.
The variable **government** shows the expenditure of the government. We assume an annual increase of 2%. In the system the variable **export** follows a similar development as consumption, investment and government for each sector.
By adding consumption, investment, government and export of each sector we receive the **final demand** of each sector.

Supply side
The main objective of the supply side is to calculate the **potential output,** which can also be interpreted as the potential output of the economy in terms of the calculation method. To calculate the potential output, an extended Cobb-Douglas function is used including labour, capital and productivity as inputs:

$$Potential\_output = c * e^{(productivity*t)} * labour(t)^{\alpha} * capital(t)^{\beta} \quad (1)$$

The variable **labour** stands for the yearly worked hours. It is based on employment, which is derived by the gross value added and the specific employment per unit of gross value added for each sector. The variable **capital stock** depends on the private and public investment, and its depreciation. We assume a life cycle of 15 years for the depreciation. We treat the variable **productivity** by assuming an autonomous development of technical progress. This autonomous increase of productivity is the same for both scenarios. Besides this autonomous development of technical progress, we have to take into consideration that the vehicle production sector in Germany is an important factor for the productivity. Therefore we implemented an indicator for the development of productivity caused by car, low-duty vehicle, heavy-duty vehicle and plane production. In EST the fostering of higher emission standards of transportation for all modes leads to more investigations, innovations and new technologies. Therefore, we assume in EST an increase of this indicator and an increase of the rate of technical progress.

4.3 The Transport Model

The transport model is divided into passenger and freight transport, and into non-urban and urban traffic. Non-urban traffic has higher dependencies with macroeconomic, cost, time and infrastructure data. Passenger transport is divided into the different traffic modes road, rail, air and freight transport into road, rail and shipping (Umweltbundesamt 1994).

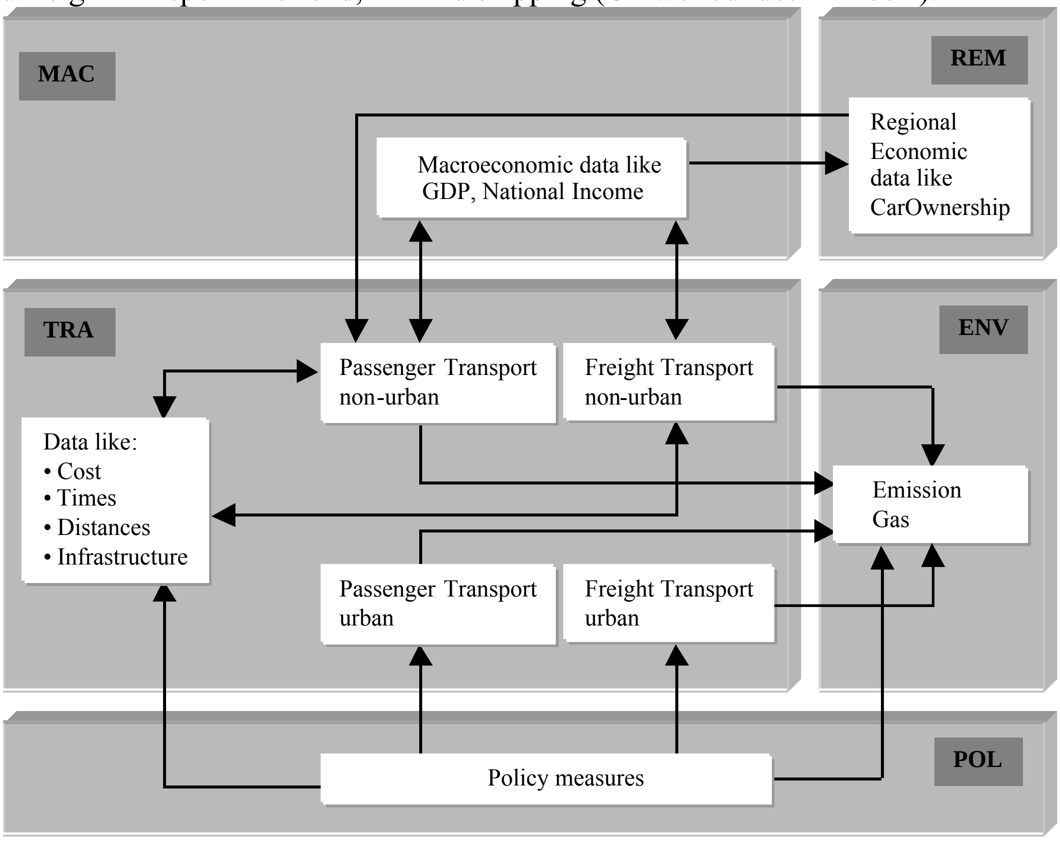

Figure 4. Structure of the Transport Model and its Main Linkages to Other Models

Figure 4 shows a more detailed view of non-urban passenger transport and its driving factors. We see that the policy sector is an exogenous sector with different policy measures (chapter 2). The policy measure infrastructure has a direct influence on the resistance to travel between two regions. The resistance variable itself changes the traffic generation that has an influence on the traffic distribution. The modal split is calculated in the next step. Among other influencing variables, the modal split is affected by transport cost and by railway services, which again are affected by other policy measures.

In figure 5 we also see a feedback loop between the variables traffic generation - traffic distribution - modal split (Oum 1992, Wardman 1997) - passenger-km per mode - vehicle-km per mode - transport time - traffic generation. This feedback loop implies that a higher traffic generation leads in the end to higher vehicle-kilometre per mode. The increase of vehicle-km per mode leads to higher transport times, and this effect puts a damper on traffic generation.

Another interesting feedback loop is traffic generation - traffic distribution - modal split - passenger-km per mode - vehicle-km per mode - consumption - national income - car ownership - traffic generation - traffic distribution. It means that a growth of traffic leads to higher values for consumption and national income. The more money people earn, the more they spend on owning a car. This effect leads in the end to a higher growth of traffic. This loop shows a positive feedback between the macroeconomic model, regional economic model and transport model.

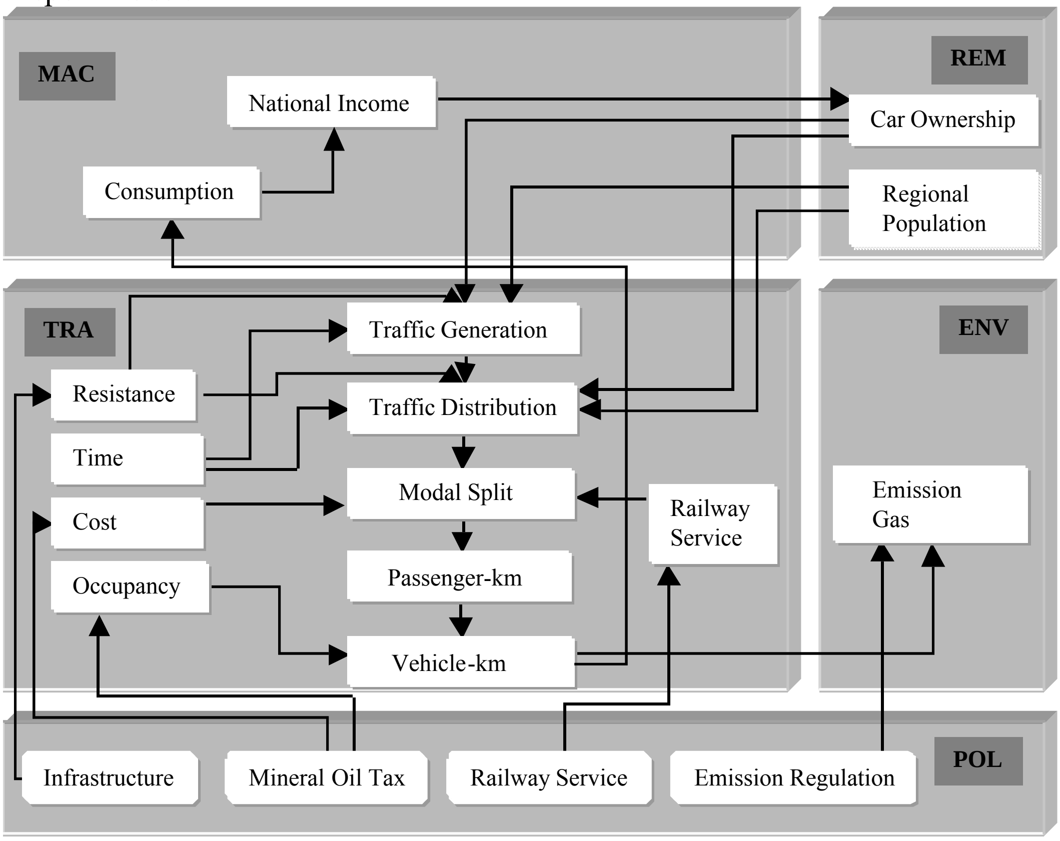

Figure 5. Passenger Transport in ESCOT

4.4 The Environmental Model

The basic objective of the environmental model is to supply information that will lead to indicators (e.g. volume of emissions) that can be used as a control for the different scenarios. The main link between other models is the link to passenger-, freight- and vehicle-km of the transport model and one link from the policy measure that is called emission regulation to the emission factors of different vehicle types. The emission factors themselves depend on the technical standards of the vehicles. For air emissions, we have a classification into four types of emissions: CO_2, VOC, NO_x and particulate matter. The transport volume is combined with these emission factors to derive the yearly emitted amount of gas.

4.5 The Regional Economics Model

The spatial classification has two levels. The first level distinguishes between three types of areas (NUTS regions): highly aggregated areas, modestly aggregated areas and areas with rural character. In each of these areas, the second level distinguishes between different types of cities and regions (NUTS-3 level). The following nine classes result (Kuchenbecker 1998):

- central cities in highly agglomerated areas (R1)
- highly agglomerated regions in highly agglomerated areas (R2)
- agglomerated regions in highly agglomerated areas (R3)
- rural regions in highly agglomerated areas (R4)
- central cities in modestly agglomerated areas (R5)
- agglomerated regions in modestly agglomerated areas (R6)
- rural regions in modestly agglomerated areas (R7)
- agglomerated regions in areas with rural character (R8)
- rural regions in areas with rural character (R9)

The modelling of the population consists of four different age groups (0 to 14, 15 to 40, 41 to 65, over 65 years old). With the regional classification, the population development is represented for each group and cohort differentiated for every region type. The age classes of the cohort-model refer to other model elements (e.g. population over 15 years forms the motorised population and the population between 15 and 65 years corresponds to the work force).

5. Results for the BAU/EST Scenarios

The time period from 1986 to 2000 is used to calibrate the SDM. The numbers based on the assumptions stated in table 1 were implemented to derive the BAU scenario[3]. ESCOT figures out the assumed trends and the numbers for the year 2030 quite exactly.
The simulation of the EST scenario is based on a variety of policy instruments[4]. Technical and pricing policy measures had to be implemented to meet the drastic reduction targets of the EST scenarios.
As a first result, we check whether the policy instruments are stringent enough to achieve EST. Looking at the results, the EST-50% scenario reaches the target of a reduction of CO_2 emissions by 50%. The EST-80% scenario could not attain the envisaged goal of a reduction of CO_2 emissions by 80%. But with a reduction of more than 72%, ESCOT is very close to this goal.

5.1 Results of the Transport Model

To get a clear understanding of the economic effects to be expected, it is first necessary to look at the changes of transportation. We can see the difference between reference year 1990 and the year 2030 for the different scenarios BAU, EST-80% and EST-50%. Drastic changes

[3] The number for population and related variables were changed for all scenarios based on a study from the Statistisches Bundesamt (Statistisches Bundesamt 1996)

[4] see for a more elaborate description of policy instruments of the German case study Verron and Friedrich, elsewhere in this volume

for car travel and air transport are necessary to reach EST-80%. For these two modes we derive a high decrease of passenger-km and a high increase for more environmentally friendly modes. In EST-50%, the amount of passenger-km for car travel and air transport can be held in 2030 at same level as in the year 1990. Only the growth of passenger travel is absorbed by environmentally friendlier modes.

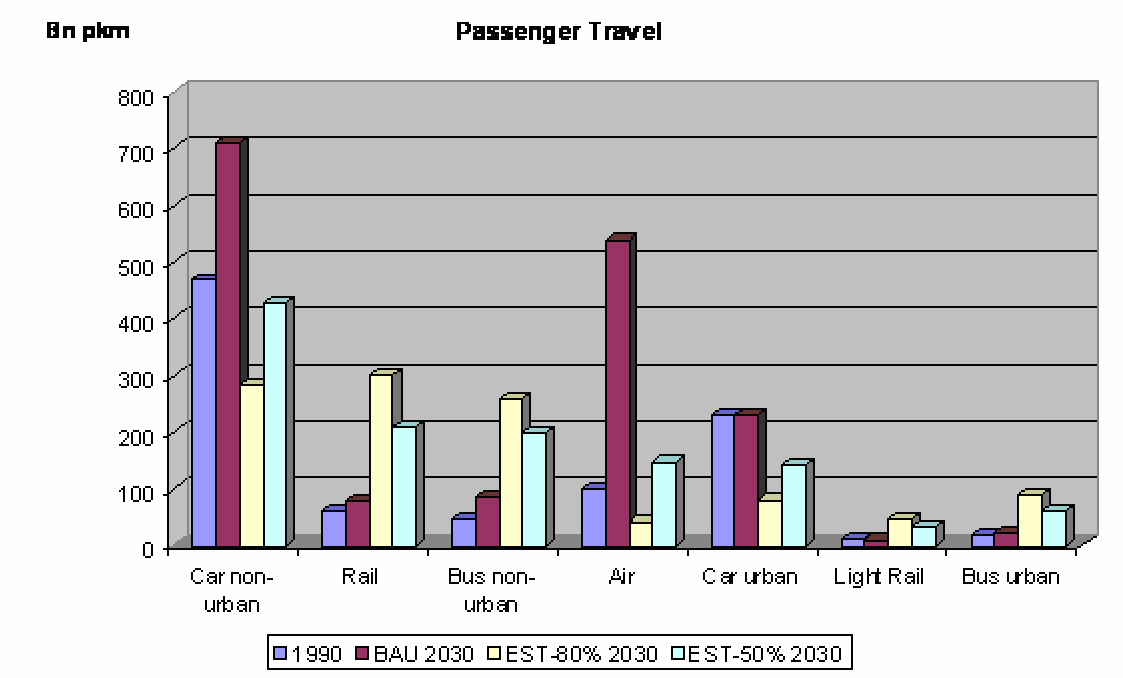

Figure 6. Comparison of Passenger Travel in 1990 and in 2030 for BAU, EST-80% and EST-50%

We recognise the same characteristics for freight transport. For EST-50% in 2030, the amount of ton-km of road transport remains at the same level as in 1990. The growth of freight transport is absorbed by rail and ship transport.

The changes for passenger travel and freight transport are much lower in EST-50% than in EST-80%. This goes further with mode shift effect towards environmentally friendlier modes as in EST-80%. But it is important that the environmentally friendlier modes have to be attractive enough to absorb the growth of transport activity.

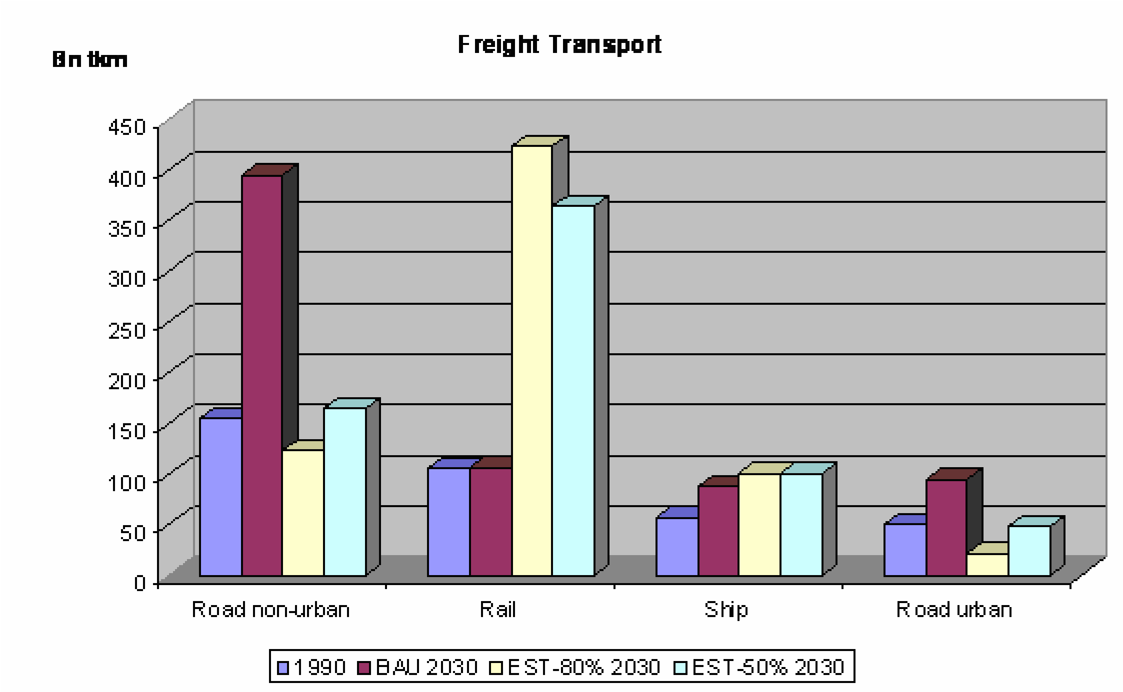

Figure 7. Comparison of Freight Transport in 1990 and in 2030 for BAU, EST-80% and EST-50%

5.2 The EST-80% and EST-50% scenario in 2030

Demand side

The results of the simulation for the year 2030 with respect to consumption, investment, export and final demand in the different scenarios are listed in table 3. For EST-80% in most of the sectors, we notice a small increase of **consumption**. The highest decrease is observed in sector 5 (includes vehicle production), while a comparably low decrease is observed in sector 3 (mineral oil). Overall changes are minor for **investment**. The high decrease in sector 5 is offset by the increase in sector 9, which is based on the investments in infrastructure for environmentally friendlier transportation. We estimate a sharp decrease in sector 5 for **exports** . The influence of the vehicle production on the export sector is evident.

The **final demand** side shows the entire effect on the different sectors. In total, we notice that the negative effects on export are mostly offset by the development of consumption and investment. Thus, final demand differs only by about 0.8% between both scenarios.

The structure of the changes between EST-50%/BAU on one hand and EST-80%/BAU on the other hand are similar. But significant differences in the magnitude of the changes occur. As for EST-80% we notice in most of the sectors a small increase of private **consumption**. Decreases of consumption are expected in sector 5 (includes vehicle production) and sector 3 (mineral oil). But these decreases are much smaller for EST-50%. At 2.8%, the overall increase for consumption is much higher than the 1.1% increase for EST-80%. This effect depends on the similar technical policy measures and the moderate pricing policy measures compared to EST-80%.

Also for **investment** and **exports** changes in EST-50% are minor (e.g. the decrease in sector 5 and the increase in sector 9). By this effect the increase of investment is smaller (0.5%) than the increase of 1.3% for EST-80%. The negative effects for exports of automotive products cannot be fully compensated by the increase in other sectors. We derive a total negative effect for exports of 4.1% compared to 8.1% for EST-80%.

The **final demand** side shows the entire effect on the different sectors. In total we notice that the negative effects in the export sector may be overcompensated by the development of consumption and investment. So, final demand increases by about 0.6% above the level of BAU compared to a decrease of 0.8% for EST-80%.

Table 3. Results of the Demand Side for EST-80% in 2030

Demand side in 2030 (bn Euro)	**Consumption**			**Investments**			**Gov.**	**Export**			**Final Demand**		
Sector	BAU	EST-80%	EST-50%	BAU	EST-80%	EST-50%	BAU/EST	BAU	EST-80%	EST-50%	BAU	EST-80%	EST-50%
1 Agriculture	11	12	12	1	1	1	0	4	4	4	15	16	16
2 Energy, Water	41	42	42	0	0	0	0	3	3	3	44	45	45
3 Chemistry and Mineral Oil	51	45	46	1	1	1	0	79	71	72	131	116	119
4 Iron, Steel	0	0	0	6	6	6	0	23	23	24	29	29	29
5 Mechan. and automot. prod.	54	30	41	112	99	104	0	156	120	135	322	248	281
6 Electronics	31	33	33	39	40	40	0	66	68	68	137	141	141
7 Wood, Paper	59	62	62	7	7	7	0	37	38	38	103	107	108
8 Food	151	158	159	0	0	0	0	24	25	25	174	183	183
9 Construction	2	2	2	164	180	172	0	1	1	1	167	183	175
10 Traffic Services, Commerce	286	293	297	16	16	16	0	53	54	55	355	364	369
11 Private Services	405	425	426	13	13	13	0	19	20	20	437	458	459
12 Public Services	62	65	66	1	1	1	620	1	1	1	684	687	687
Total	1153	1167	1186	358	363	360	620	465	427	446	2597	2577	2612
Difference betw. BAU and EST		1.1%	2.8%		1.3%	0.5%	0%		-8.1%	-4.1%		-0.8%	0.6%

Supply side
EST **employmen**t reaches a slightly lower level than BAU. The simulation shows a minus of 335 000 jobs in the year 2030. Higher employment levels in other sectors cannot compensate the negative development in the automotive sector and the mineral oil sector. **Capital stock** is nearly the same as in BAU. For capital stock the higher amount of investment balances out the abridged depreciation of capital in the vehicle production sectors.

Table 4. Supply for BAU/EST Scenario

Supply side	BAU-EST 1990	BAU 2030	EST-80% 2030	EST-50% 2030	EST-80% 2030	EST-50% 2030
Employment [m person]	34.921	32.206	31.871	32.541	-1.0%	+1.0%
Capital stock [bn Euro]	5 475	6 773	6 690	6 701	-1.2%	-1.1%
Productivity [1/1 000]	11.000	11.000	11.309	11.256	+2.8%	+2.3%
Potential output [bn Euro]	1 454	2 750	2 752	2 782	+0.1%	+1.2%

For **productivity** we estimate an increase of about 2.8%. This is caused by an increase of the rate of technical progress from 0.011 (estimation of the technical progress from production function under BAU conditions) to 0.0113 (according to the growing share of high transport technology of the total capital stock). This productivity is a major influence on the growth of potential output.
In the graph for **potential output** we realise that potential output of EST is lower at the beginning of the policy measures. Due to the increase of investments (public and private), potential output of EST approaches the BAU value at the end of the simulation.
In EST-50% employment reaches a higher level than in BAU at the end of the simulation period (of 335 000 jobs in the year 2030). For capital stock there is a small decrease caused by the earlier depreciation offset by an increase of productivity. The gross domestic product goes up by 1.2% in total.
In general, these positive results on the supply side depend on two main effects. One of these is the increase of **productivity**. The productivity increases in the EST-50% scenario by 2.3% (2.8% for EST-80%). This increase of productivity itself depends on the higher emission regulation that encourages research and development in the vehicle and the energy industries.
The other effect stems from the demand side with its positive effects on consumption, investment and final demand.
Accordingly, the EST-50% scenario shows that environmental policy can have positive impacts on the economy if it actively makes use of flexible market adjustments without overstressing them. In order to develop such environmental policies, the weight between technical policy measures and pricing policy measures and of course the positive economic effects caused by higher productivity must be taken into consideration.

5.3 Comparison between ESCOT and IPA

The IPA method found negative effects for all indicators of the demand side that increased over time. The macroeconomic results we derived with IPA for consumption, final demand and employment are rather high by comparison (see table 5).
In ESCOT the negative effects on consumption and investment were balanced out and the impacts on final demand were lower than calculated with IPA. This compensation is based on structural changes and dynamic developments that are not considered in the IPA. At level 4

of IPA, all data are calculated without taking into account that higher productivity may arise and change potential output as well as the economic indicators on the demand side.

Table 5. Comparison of Final Demand for IPA and ESCOT

Demand and supply side [%]	IPA 2030 EST-80% in 2030	ESCOT EST-80% in 2030
Consumption	-6.0	+1.1
Final Demand	-5.0	-0.8
Employment	-3.0	-1.0

This means that IPA more or less sticks to the first round effects that are governed by negative influences of higher prices and restrictions on the demand side. For this reason IPA may be the right method to assess scenarios with minor changes. The IPA model give results with the right sign but overestimates the economic impacts. The method could be still useful in scenario evaluation with low emission reduction targets.

For scenarios assuming more far-reaching changes, ESCOT is the appropriate method. ESCOT includes second round effects and the major feedback mechanisms that become effective in the long run. It assumes that the market forces can be positively stimulated by environmental policy, leading to an increase of productivity on the supply side. In the long run, the productivity gain and the associated stimulation of production may more than offset the initial reductions of demand.

6. Conclusions

In the IPA assessment, a conservative baseline was chosen to start with a scenario that incorporates some pessimistic views of the industry. The aim is to show that even in this case an economic disaster will not occur. The results of the System Dynamics Model ESCOT for EST-80% clearly show that the departure from car and road freight orientated transport policy is far from leading to an economic breakdown. The effects concerning economic indices are rather low, even though the measures proposed in the EST-80% scenario designate distinct changes compared to today’s transport policy. The impact on employment, however, is clearly negative because of lower developments in economic sectors.

For the EST-50% scenario, which expanded the considered time period in order to decrease the speed of change and to give more room for compensating measures, we observed more encouraging results. Although the export level is still lower than expected in BAU, this effect is fully compensated by consumption, and the total of final demand is slightly positive. The growth of the potential output is accelerated as well, and there are positive effects to be expected on employment. So the EST-50% scenario shows that environmental policy can have positive impacts on the economy if it actively makes use of flexible market adjustments without overstressing them. In order to develop such environmental policies, the trade-off between technical policy measures and pricing policy measures and of course the positive economic effects caused by higher productivity of production activities must be taken into account. The model results indicate that technical policy measures have more positive impacts on the economy than pricing policy measures. As technical policy measures are not sufficient to reach EST alone, pricing policies are also necessary (Umweltbundesamt, Wuppertal Institute 1997). However, a shift towards more technical policy measures while still reaching the CO_2 targets would have even better economic results.

Results could be also more positive if other economic sectors make similar efforts to reduce their emissions of CO_2. This may foster technical progress in their sectors and it may encourage changes in the transport system in a more sustainable direction. But the impacts from activities to reach sustainability in other sectors could also strengthen negative effects, for instance, it could worsen the results for export.

Compared to other studies of environmental research institutes the results of the economic assessment might look too negative. The Öko-Institut/VCD (1998) study, for instance, comes to the conclusion that an overall increase of employment would be the probable outcome of a strict environmental transport policy. Similar conclusions are drawn by the DIW (1994) forecasts of positive prospects of green policies. However, the assumptions of the studies look different and show more optimism with respect to the responses of demand and supply to environmental stimuli. The main reasons for the positive results of these studies are (i) less challenging criteria for EST (e.g. only 30 % CO_2 reduction), (ii) hypothesis that final demand is restructured towards more environmentally friendly activities, but not reduced, (iii) hypothesis that foreign exchange is reduced, resulting in lower imports without changing exports.

For the assessment of such large ecological improvements we have to consider the development of population, the way of living and housing, consumption and other macroeconomic data. In addition, the period of time for the scenarios covers 40 years. This long period of time and the complexity of the scenarios cause many difficulties for the assessment. System Dynamics models like ESCOT are constructed to describe such complex social and economic systems as, in case of a path towards sustainability, they do not only stick to the first round effects that are mostly governed by negative influences like higher prices and restrictions on the demand side. ESCOT offers the opportunity to postulate the macroeconomic development, considering also structural changes, including secondary effects that occur only in the long run. Secondary effects arise because transport is highly interrelated with other social systems, so that a policy measure like charges for one mode causes a direct effect, that is a decrease in demand for this mode, but also secondary effects e.g. technological changes for other modes because of increased demand for these modes, changes in state revenues or private consumption. This ability makes ESCOT a powerful instrument for the assessment of such large ecological and economic changes.

References

ASTRA (2000): *Assessment of Transport Strategies. Project of the EU Commission on Strategic Assessment of Transport Policy Actions*. Institute for Policy Research, University of Karlsruhe, Karlsruhe.

Bockstael, N.; Costanza, R.; Strand, I.; Boynton, W.; Bell, K.; Wainger, L. (1995): Ecological Economic Modeling and Valuation of Ecosystems. *Ecological Economics*. 14. 143-159.

Bossel, Hartmut (1994): *Modellbildung und Simulation*. Vieweg, Braunschweig/Wiesbaden.

DIW (1994): *Ökosteuer – Sackgasse oder Königsweg? Study for Greenpeace*. Prepared by S. Bach, M. Kohlhaas et al. Berlin.

Forrester, J. W. (1968): *Principles of Systems*. Cambridge, Massachusetts.

Forrester, J. W. (1972): *Grundzüge der Systemtheorie*. Gabler, Wiesbaden.

Gausemeier, J. (1995): *Szenario-Management: Planen und Führen mit Szenarien*. Hanser, München.

Kuchenbecker, K. (1998): *Strategische Prognose und Bewertung von Verkehrsentwicklungen mit System Dynamics*. Institute for Policy Research, University of Karlsruhe, Karlsruhe.

Norsworthy, J. R.; Jang, S. L. (1992): *Empirical Measurement and Analysis of Productivity and Technological Change*. North-Holland, Amsterdam.

OECD (1996): *Environmental Criteria for Sustainable Transport: Report on Phase 1 of the Project on Environmentally Sustainable Transport (EST)*. OECD, Paris.

OECD (1999a): *Scenarios for Environmentally Sustainable Transport: Report on Phase 2 of the Project on Environmentally Sustainable Transport (EST)*. OECD, Paris.

OECD (1999b): *Environmentally Sustainable Transport: Individual Project Case Studies for Phase II*. Annex Volume to the Report on Phase II of the OECD EST Project on Environmentally Sustainable Transport, OECD, Paris

Öko-Institut/VCD (1998): *Hauptgewinn Zukunft – Neue Arbeitsplätze durch umweltverträglichen Verkehr*. Freiburg.

Oum, T.H.; Waters, W.G.; Young, J-S. (1992): Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates. *Journal of Transport Economics and Policy*, pp. 139-154.

Rothengatter, W. (1998): *Economic Assessment of EST scenarios. Methods and Approach*. Institute for Policy Research, University of Karlsruhe, Karlsruhe.

Schade, B.; Rothengatter, W.; Schade, W. (2002): *Strategien, Maßnahmen und ökonomische Bewertung einer dauerhaft umweltgerechten Verkehrsentwicklung. Bewertung der dauerhaft umweltgerechten Verkehrsentwicklung mit dem systemdynamischen Modell ESCOT (Economic assessment of Sustainability poliCies Of Transport)*. Federal Environmental Agency, Berlin.

Schade, W.; Rothengatter, W. (1999): *Long-term Assessment of Transport Policies to Achieve Sustainability*. 4th European System Science Conference in Valencia, Proceedings, Valencia.

Statistisches Bundesamt (1996): *Modellrechnungen zur Bevölkerungsentwicklung bis zum Jahre 2040*. Metzler-Poeschel, Stuttgart.

Umweltbundesamt (1994): *Verminderung der Luft- und Lärmbelastungen im Güterfernverkehr 2010*. Federal Environmental Agency, Berlin.

Umweltbundesamt, Wuppertal Institute (1997): *OECD Project on Environmentally Sustainable Transport (EST) Phase 2, German Case-Study*. Federal Environmental Agency, Berlin.

Umweltbundesamt, IWW (2000): *OECD Project on Environmentally Sustainable Transport (EST) Phase 3, German Case-Study*. Federal Environmental Agency, Berlin.

Umweltbundesamt, Wuppertal Institut, IWW (2001): *Dauerhaft umweltgerechter Verkehr. Deutsche Fallstudie zum OECD Projekt Environmental Sustainable Transport (EST)*. Federal Environmental Agency, Berlin.

Vester, F. (1995): *Crashtest Mobilität*. Heyne, München.

Wardman, M. (1997): *Disaggregate Inter-Urban Mode Choice*. Institute for Transport Studies, The University of Leeds, Leeds.