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Evaluating Economic Feasibility of Environmentally Sustainable Scenarios by a Backcasting Approach with ESCOT (Economic assessment of Sustainability poliCies Of Transport)

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Abstract

The aim of the System Dynamics Model ESCOT is to describe a path towards a sustainable transport system in Germany and to assess its economic impacts. ESCOT was developed within the **e**nvironmentally **s**ustainable **t**ransport (EST) project of the OECD that was designed to consider the ecological and technical aspects of a transition towards sustainable transportation. ESCOT comprises five models: the macroeconomic, the transport, the regional economic, the environmental and the policy model.

The economic assessment for environmentally sustainable scenarios show that the departure from car and road freight oriented transport policy is far from leading to an economic breakdown. With an expansion of the time period for the transition we derived even more encouraging results.

For the economic assessment it is important that ESCOT considers not only first round effects but also secondary effects. This ability makes ESCOT to a powerful instrument for the assessment of such large ecological changes.

1 Summary

The aim of ESCOT (Model for **e**conomic assessment of **s**ustainability poli**c**ies **o**f **t**ransport) is to describe a development path towards a sustainable transport system in Germany and to assess its economic impacts. In ESCOT the **System Dynamics Methodology** is applied for integrated modelling of transportation scenarios. The **Macroeconomic Model** of ESCOT forms the backbone of the economic assessment and enables to make complex policy studies.

The framework for the sustainable transport system is prescribed by severe environmental goals, which require sophisticated changes in the treatment of the environment. As major driving forces for these changes we have to consider e.g. the development of population, the way of living and housing, car ownership, consumption and other macroeconomic variables. In addition to the complex interrelationships between these driving forces the investigated scenarios cover a long period of time. Complexity of considered systems and long-term time horizon for the assessment suggest to use a **System Dynamics Model** (SDM) (chapter 2).

ESCOT is used to assess a development path towards sustainable transport in Germany in the project on **e**nvironmentally **s**ustainable **t**ransport (EST) of the OECD. Within the EST-project ESCOT contributes to the backcasting strategy of EST. The project is designed to consider the ecological and technical aspects of a transition towards sustainable transportation (chapter 3). The project first identified ecological goals and developed a business-as-usual (BAU) scenario considering the future development of different transport modes (road, rail, air, shipping) and their impacts on environmental indicators (air emission). As the BAU scenario leads to unsustainability it was necessary to design environmentally sustainable transport (EST) scenarios and policy strategies that should lead to sustainability. Two scenarios, the EST-80%, that leads to a reduction of 80% CO_2 in 2030, and the EST-50%, that expanded the time horizon till 2050 and leads in 2030 to a reduction of 50% CO_2, were developed using a backcasting approach. The EST scenario started with the identified environmental goals in 2030 and described a path towards this goals.

Besides environmental protection the economic feasibility forms a fundamental part of sustainability. The transition towards a sustainable transport system provides many economic impacts like changes in consumption of households, investment in infrastructure and technical progress. The objective of ESCOT is to describe these effects and especially their economic interactions entirely. ESCOT is divided in five models, the macroeconomic model, the transport model, the regional economic model, the environmental model and the policy model (chapter 4). Because this report emphasises the economic evaluation we focus on the macroeconomic model. As a key element an Input-Output-Table is integrated into the System Dynamics Model. At the present stage the implementation of an Input-Output-Table into a System Dynamics Model is an important step ahead for long-term economic assessment.

The results for EST-80% of the assessment of economic impacts clearly show that the departure from car and road freight oriented 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 that expanded the time period for change in order to decrease the speed of change and gave more room to compensating measures we derived more encouraging results (chapter 5).

ESCOT offers the opportunity to derive the macroeconomic development, considering first round effects that are in case of a path towards sustainability mostly governed by negative influences like higher prices and restrictions on the demand side. But it also considers structural changes including secondary effects that occur only in the long run. Secondary effects arise because transport is highly interrelated with other social systems such that a

policy measure e.g. charges for one mode causes a direct effect e.g. 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 the System Dynamics Model ESCOT to a powerful instrument for the assessment of such large ecological changes.

2 Basics of System Dynamics

Based on the finding that socio-economic systems as well as a lot of other real world systems often behave counterintuitively, 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. To model the feedback loops Forrester developed three types of structure elements: level variables (levels), flow variables (rates) and auxiliary variables. Levels represent the most important element of a system. They describe the state of a system and the system behaviour can be derived from their development. The values of levels change during a simulation according to their related rates. Rates can be inflows to a level in a way that the values of a rate are added to the values of the level within each time step. Or rates can be outflows from a level.

Three types of auxiliary variables are distinguished: Parameters, Exogenous factors and Intermediate variables. Parameters are constant during the simulation period. Exogenous factors represent variables that have an influence on the system but they are not influenced by the system. Intermediate variables are calculated by other variables of the system. The different elements are composed with a special scheme to sets of difference equations that describe the interrelationships within the system dynamics model.

Summarising, system dynamics has four theoretical foundations (Milling 1984):

- the mental problem solving process (e.g. evaluation of relevance of interrelation ships),
- 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 to another) and
- computer simulation.

The first step developing a system dynamics model is to define the system borders, the system variables and the relevance of their interrelationships. The second step is the most important one: the main feedback mechanisms have to be extracted and designed. The behaviour of a system is primary determined by this feedback mechanisms. 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 this computer simulation that calculate, based on interrelationships between variables, feedback mechanisms and decision rules, the system states step-by-step over the simulation period.

To evaluate policy packages that might lead to completely different transport systems than today it is necessary to asses long-term effects off these policy measures. For instance the construction and planning of transport infrastructure might take up to 10 years and the usage duration 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 into an environmentally friendly way or not. Car producers might 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. It is obvious that for a methodology relying strongly on data from the past like econometric or other modelling based mainly on statistical analysis results become less reliable the further into the future these models are applied (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.

3 The environmentally sustainable transport (EST) project

In 1994 the Pollution Prevention and Control Group of the OECD established a Task Force on Transport to look into ways and means to reduce the environmental impact of transportation significantly. 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 transport development in transport may look and a **environmentally sustainable transport (EST)** scenario which demonstrate 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 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.

3.1 Identification of Key criteria

Phase 1 of the EST project was dedicated to review government programmes in OECD member countries regarding evidence and thinking on transport and environment, and to identify the criteria for EST.

Table 1: Criteria for sustainable transport

Parameter	Criterion		Specification
CO_2	- 80 %	Emission reduction of the transport sector in 2030 compared to 1990	all areas
NO_x	- 90 %		
VOC	- 90 %		
PM	- 99 %		urban areas
Noise	<= 65 dB(A)		all areas
	<= 55 dB(A) daytime		residential areas
	<= 45 dB(A) night		
Land Use	criterion has to be developed		urban areas
	no extension of transport infrastructure		rural areas

The criteria identified to be the most important for a description of EST were carbon dioxide (CO_2), nitrogen oxides (NO_x), volatile organic compounds (VOC), particulate matter (PM) emissions, noise from transport and land use for transport infrastructure (OECD 1996).

3.2 BAU, EST-80% and EST-50% scenario

Research groups from the participating countries, Sweden, Norway, The Netherlands, Canada, France, Switzerland, Austria and Germany, described the future development of transportation. As a result the German group constructed a BAU and an EST scenario for Germany (OECD 1998).

The scenarios have scientific character and do 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 those structural changes and technical innovations are assumed that can be expected from today's point of view.

The EST-80% scenario describes a path towards sustainable transport that meets the identified criteria in 2030 (table 1). As CO_2 emissions are the most problematic air emission gas we assume that if we fulfil the criteria for CO_2 the other criteria for air emission gas are also fulfilled. The parameters noise and land use are considered separately. For a better understanding we call this EST scenario EST-80% scenario because its aim is to reduce CO_2 emissions by 80%.

The EST-80% scenario was developed using a backcasting approach. So the construction of the scenario started with the goal and then tried to find out which technical progresses and which transport reduction strategies are necessary to reach this goal.

Table 2: Assumptions of EST scenarios (Umweltbundesamt, Wuppertal Institute 1997)

Assumption	BAU	EST-80%
Population	Slightly growth until 2010 and than decrease	As in BAU
Economic growth	Moderate	As in BAU
Infrastructure	Federal Transport Master Plan	Increase of railway network, less roads
Fuel Price	Moderate growth	Growth driven by taxes
Automobile fleet	Increase of 85%	Equal as today
Car occupancy	Decreases	Increases
Yearly travelled km/car	Decrease	Decrease
Specific emissions from road vehicles	Significant reduction	High reduction
Specific energy consumption for transport modes	Decrease	High decrease (e.g. 2.5l fuel per 100 km for cars)
Noise emissions	Moderate reduction	High reduction
Car Ownership rate	820 per 1000 inhabitants	Similar as today
Share of diesel cars	From 15% (today) to 30%	0%
Share of electric cars	10%	0%
Energy	Similar as today	50% from renewable energy

Both scenarios are based on assumptions. Concerning the development of population and economic growth they are the same. Concerning the development of transport figures they differ strongly between the scenarios. Because of the fact that the BAU scenario assumes no significant policy changes and no surprising technical development 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 and a reduction of emissions.

To achieve an 80% reduction of CO_2 in the year 2030 biting restrictions and energy cost increases have to be introduced already decades ahead, which might cause economic risks. This required to modify the scenario and to construct an EST-50% scenario. The EST-50% scenario follows a reduction goal of 50% CO_2 emissions till the year 2030[1]. 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.

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

3.3 Packages of policy instruments to reach EST-80% and EST-50%

Both EST scenarios can only be reached by a new transport policy. The most important policy instruments for the EST-80% scenario are (Umweltbundesamt 1997):

- **CO_2 Emission Regulation:** this policy instrument means the lowering of gaseous emissions of vehicles. The implementation of this instrument for cars is stepwise. CO_2 emissions of cars starting in 1990 at 260g/km are reduced to CO_2 emissions of 58g/km in 2030. Altogether the effect results in a decrease of fuel consumption of an average car (e.g. 2,5 l/100km for gasoline cars) and CO_2-emissions by more than 75%.
- **Fuel Tax:** this policy instrument means an increase of the mineral oil tax for gasoline and diesel. It leads to lower fuel consumption for vehicles, shorter driving distances and to a reduction of urban sprawl. The fuel tax has to increase in a way that the fuel costs per vehicle km will double until 2030.
- **Road Pricing:** this policy instrument means the implementation of a charge for heavy duty vehicle (HDV) based on their driven km. The charge will be balanced by fuel tax refunds and will be introduced stepwise. A charge level of 0.50 DM/km will be introduced in 2003. It will rise up to 2.50 DM/km.
- **Road and Rail Infrastructure:** this policy instrument means the adjustment of the Federal Transport Network Plan in a way that the rail network will be extended and the extension of road network will be stopped after 2010.

Besides these main instruments it is necessary to implement measures for traffic calming strategies in towns, public transport services, railway services for freight transport, regional economic structures, local and regional tourist and recreational areas and low traffic land use patterns.

For the EST-50% scenario the same policy measures are applied. But the intensity of each policy measure is different to EST-80%. They are changed as follows:

- Increase of fuel tax less than 50% compared to EST-80%
- Increase of road pricing only 50% of EST-80% (e.g. charge level 0.25-1.25 DM/km)
- Improvements in emission regulation about 70% of EST-80%
- Expansion of railway infrastructure about 70% of EST-80%
- Inner city, railway service, regional economic and land use measures same as in EST-80%
- Energy policy measures same as in EST-80%.

3.4 Schedule of policy measures

Policy measures can not all be implemented once and for all at the same time. There are some restrictions for implementation that have to be considered with an incremental implementation schedule. E. g. the doubling of the rail network has to start with a large planning phase. After this phase the network itself can be expanded incrementally.

The pricing measures have to be implemented in several steps beginning with low fuel taxes and road pricing charges. This is important to gain the acceptance of the population for a new transport policy. Too restrictive policy measures in an early phase of the EST scenarios could cause strong resistance by population and companies.

Therefore a schedule for the implementation was worked out in the EST project (Umweltbundesamt 2000).

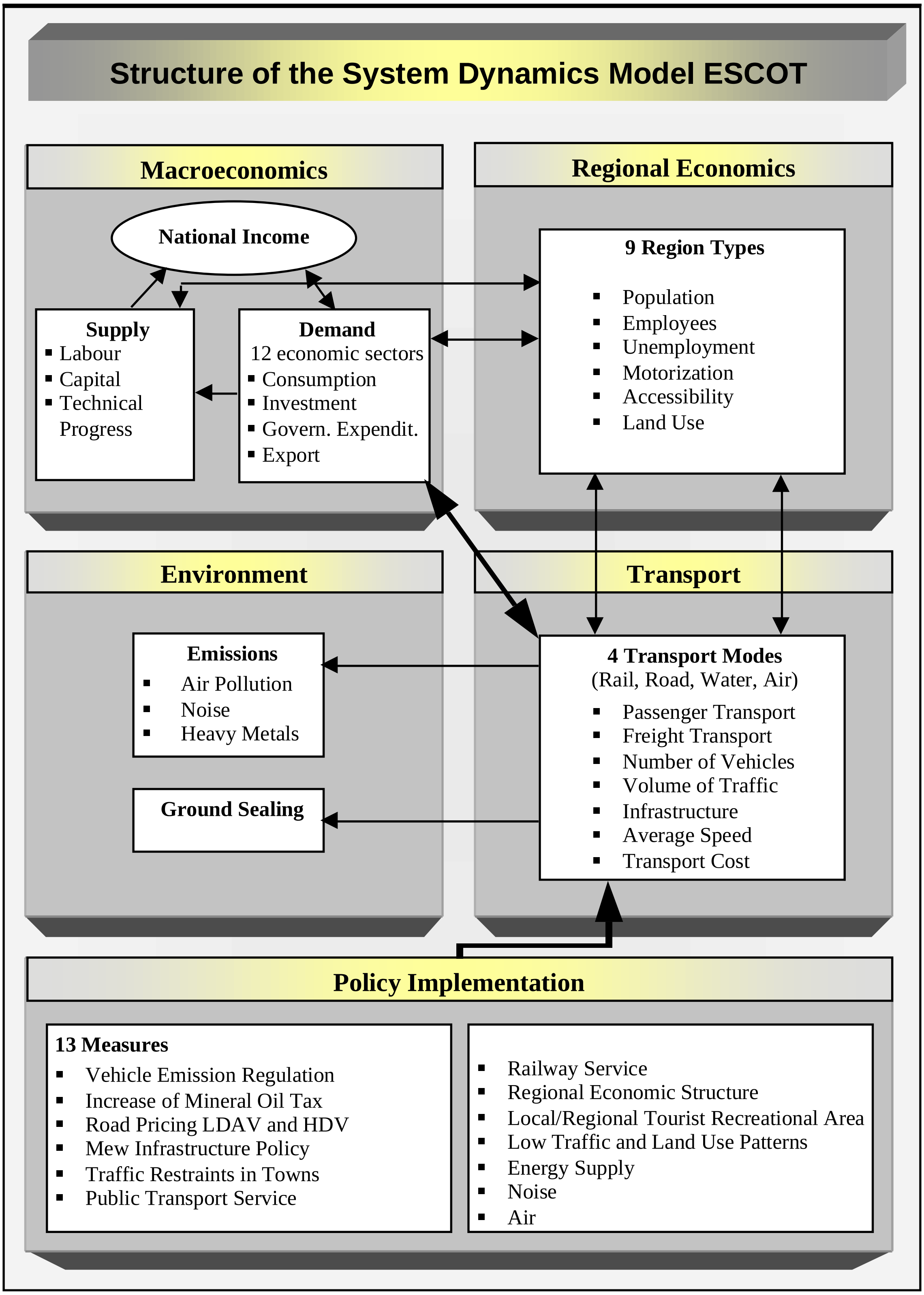
Table 3: Schedule of policy measures

	2000		2005		2010		2015		2020		2025		2030	
CO2 standards for vehicles	prep.	1. step		2. step		3. step		4. step		5. step		6. step		
Fuel Taxation	prep.	1. step		2. step		3. step		4. step		5. step		6. step		
Road Pricing for heavy duty vehicles	prep.	1. step			2. step				3. step				4. step	
Traffic Calming in Towns														
speed limit of 30 km/h inside towns		immidiate realisation, effects almost without delay												
parking management	prevent illegal p		start realisatio											
increase areas dedicated to pedest., cycl., PT		planning	start realisatio											
motor traffic bans		planning	start realisatio											
Public Transport														
priority for buses and street cars		immidiate realisation, effects almost without delay												
improving information systems	prep.	realisation												
increasing frequency, extending networks		planning		realisation 1. step					realisation 2. step					
service agencies for sustainable mobility	prep.	realisation												
Railway Service														
extension of rail infrastructure	planning			realisation 1. step				realisation 2. step						
improve rail-road intermodality		preparation		realisation 1. step			realisation 2. step							
internat. harmonisation of technol. and regul.		preparation		realisation 1. step			realisation 2. step							
introduce competition	prep.	start realisation												
improve service and logistics	prep.	realisation												
Regional Economics														
reform subsidy programmes		preparation		realisation										
support regional markets		preparation		realisation										
Regional Tourism														
provide support	start realisation													
improve nature conservation	prep.	start realisation												
Land Use														
charges on land use		prep.	start realisation											
planning for low traffic levels	realisation													
improve co-operation in regional planning institut.		prepar	realisation											
reform construction planning regulations	prep.	realisation												
tax parking opportunities		prep.	realisation											
reform housing subsidy programs		prep.	realisation											
promote town reconstruction and housing	realisation													
Energy Supply														
reform of energy legislation	prep.	realisation												
subsidize for energy saving technology	prep.	realisation												
CO2 / energy tax	1.step		2. step		3. step		4. step		5. step		6. step			
Noise Emission														
noise reception limits for traffic lanes	1. step		2. step											
noise regulations for rail vehicles	prep.	1. step		2. step										
noise regulations for road vehicles	prep.	1. step		2. step		3. step		4. step						
noise regulations for tires	prep.	2. step		2. step										
noise regulations for surfaces	prep.	realisation												
Aviation														
exhaust standards for NOx and CO2	prep.	1. step			2. step									
emission related charges	prep.	realisation												
taxation of kerosene	prep.	1. step		2. step		3. step		4. step		5. step		6. step		
optimise air transport management system	prep.	1. step		2. step				3. step			4. step			
tradable permits for CO2 emission							prep.		1. step		2. step			
			first effects of measure ...							effects fully realised				

4 Structure of ESCOT

The structure of ESCOT is based on five different models representing four most important subsystems describing the impact areas and the policy sphere.

Figure 1: Structure of the System Dynamics Model ESCOT with BAU/EST Policy Implementation



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 system. The most policy implementations intervene in the transport model such that this model usually is the steering area for simulating the impact mechanisms.

In figure 1 we see that the policy model contains only exogenous variables. Changes starting in this model (depicted by arrows) have their influence mostly on the transport model. In contrast the environmental model is driven by the transport model and has nearly no impact on other models. A high integration and many feedbacks we developed for the macroeconomic model, regional economic model and transport model that is stressed by two-directional arrows.

4.1 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, shipping (Umweltbundesamt 1994).

Figure 2: Structure of the transport model and its main linkages to other models

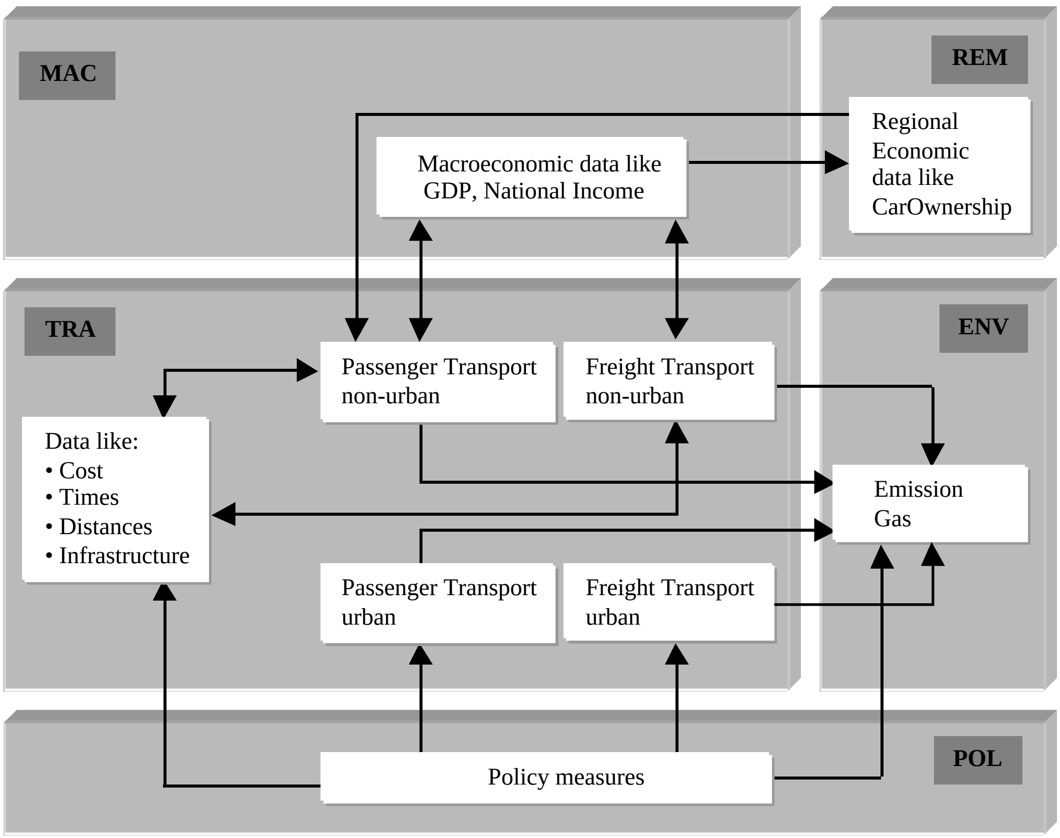
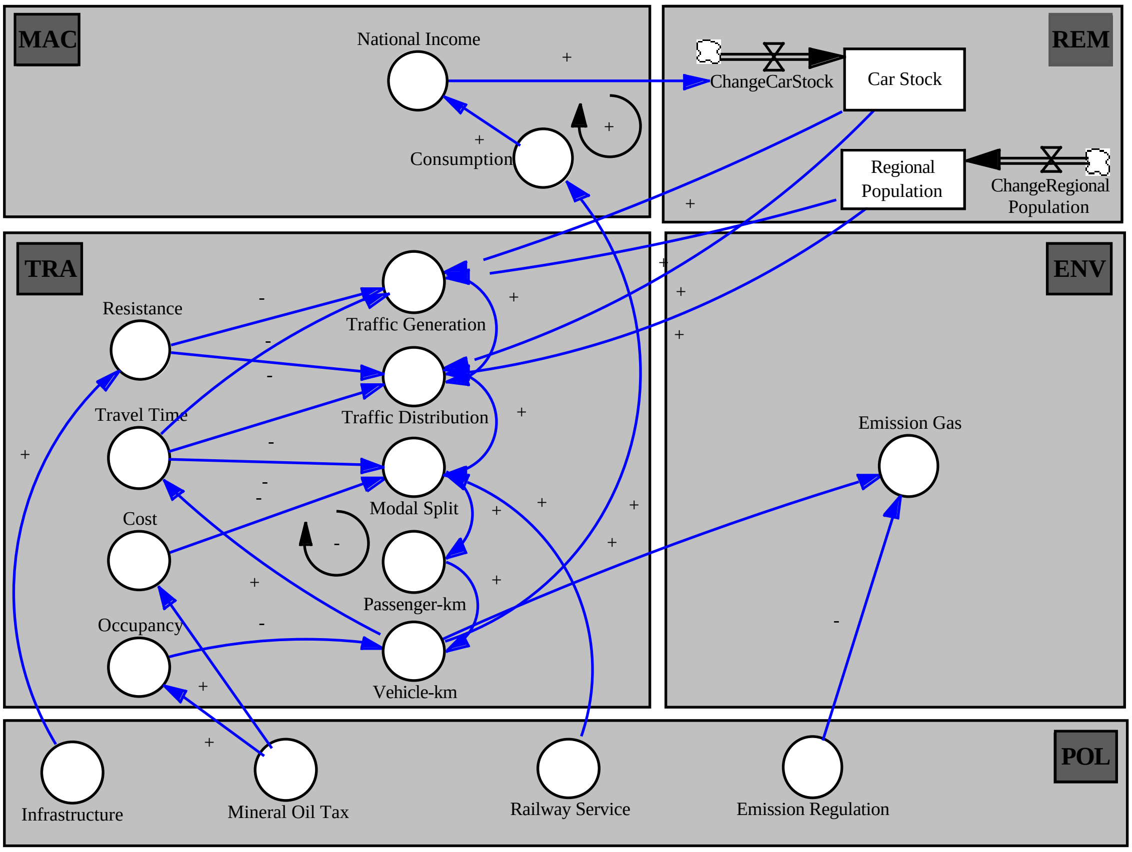


Figure 2 shows a more detailed view of non-urban passenger transport and its influences. We see that the policy sector is an exogenous sector with different policy measures (chapter 2). The policy measure Infrastructure has a direct influence on the resistance to travel between two regions. The resistance variable itself changes the traffic generation that has an influence on the traffic distribution. In the next step the modal split is calculated. This modal split is affected by e.g. transport cost and railway service that are affected by other policy measure.

In figure 3 we also see a feedback loop between the variables traffic generation - traffic distribution - modal split (Oum 1992, Wardman 1997b) - passenger-km per mode - vehicle-km per mode - transport time - traffic generation. This feedback loops means that a higher traffic generation lead in the end to higher vehicle-kilometre per mode. The increase of vehicle-km per mode leads to higher transport times and this effect dampers the 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 for 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 3: Passenger transport in ESCOT



4.2 The Environmental Model

The basic objective of the environmental model is to supply information that will lead to indicators (e.g. volume of emissions) which 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. Concerning 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 emission gas. With the yearly emitted amount of emission gas it can be verified whether the environmental goals are fulfilled.

There is no link from the environmental model back to the other models. Of course the policy sector reacts on environmental developments but the policy sector is considered exogenous. Reactions of the population need more time than 30 years to have a measurable effect on settlement or hospital charges. Therefore we calculate only pollution costs by multiplying the yearly amount of emission gas with specific pollution costs of emission gas.

4.3 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. The second level distinguishes in each of the areas between different types of cities and regions (NUTS-3-level). The following nine classes are resulting (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 is forming the motorised population and the population between 15 and 65 years correspondents to the work force).

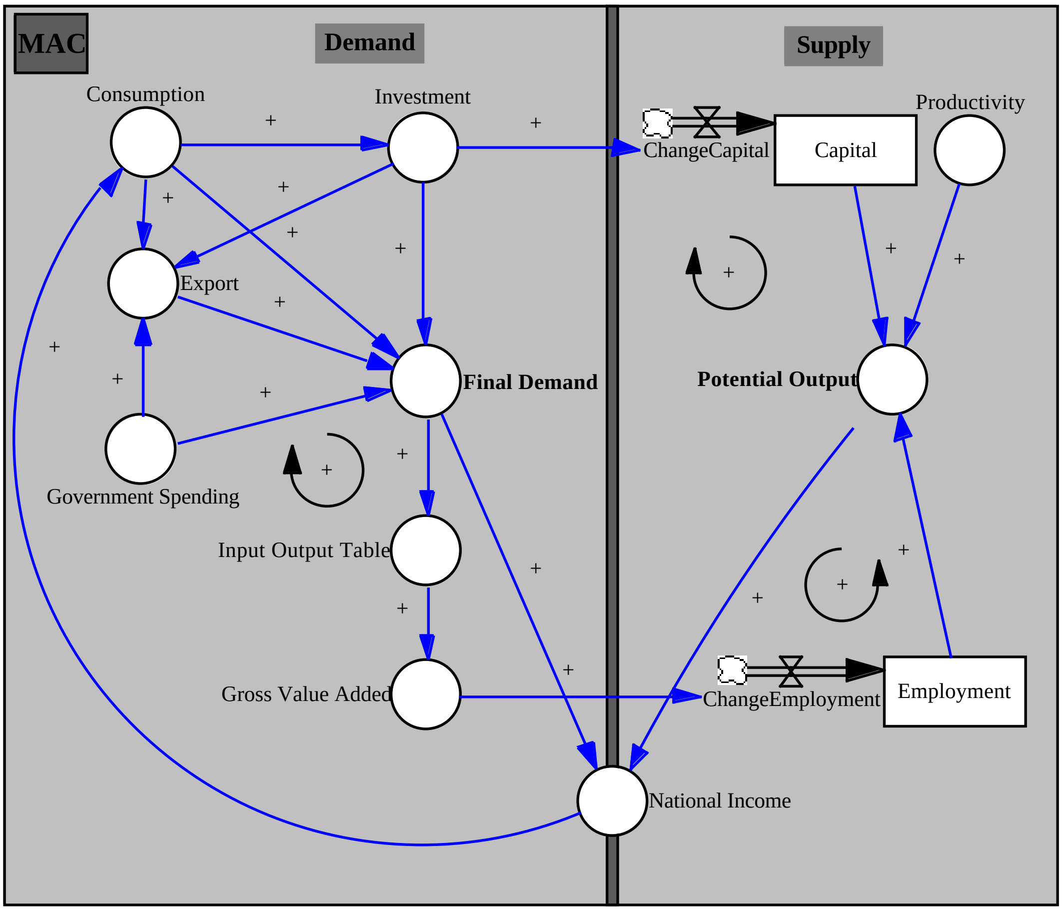
4.4 The Macroeconomic Model

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 (e.g. mineral oil industry).

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.

Figure 4: Demand and Supply Side in ESCOT



4.4.1 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:

- mineral oil industry: the consumption of fuel for car travel,
- vehicle demand purchases: consumption of cars and motorcycles, repair,
- 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 in a way that 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 because of complementarities between transport and other activities and incentive effects. For all calculations taxes and especially the mineral oil tax is taken into account.

The variable **investment** represents the investment of enterprises and 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 submodule. 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 investments made by the government in infrastructure for the road and rail mode is considered.

The variable **government** shows the expenditure of the government. We assume a yearly increase of 2%. In the system the variable **export** follows a similar development as consumption, investment and government for each sector. This means, that we add consumption, investment and government of one sector, derive the trend of this sum and link the export to this trend.

By adding consumption, investment, government and export of each sector we receive the **final demand** of each sector. Using the final demand concept we can calculate the following basic economic indicators:

- the national income,
- the gross value added and
- an input-output-table for intersectoral flows of products and resources.

4.4.2 Supply side

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

$$\text{Potential output}(t) = c * e^{(\text{productivity} * t)} * \text{labour}(t)^{\alpha} * \text{capital}(t)^{\beta} \qquad [1]$$

with c: constant

α, β: production elasticities

The variable **labour** stands for the yearly worked hours. It is based on the employment, which is derived by the gross value added and the specific employment per unit of gross value added for each sector. The sectors for transport vehicle production and transport services are separated into different modes. This enables us to consider the employment shift from one transport mode to another.

The variable **capital stock** depends on the private and public investment, and its depreciation. For the depreciation we assume a life cycle of 15 years. The increase of technical progress leads to a decrease of this life cycle. That reflects the fact that product cycles in recent years have always been shortened by the enormous technical development e.g. in the computer industry.

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-80% and EST-50% the fostering of higher emission standards of transportation for all modes lead to more investigations, innovations and new technologies. Therefore we derive in both EST scenarios an increase of this indicator and an increase of the rate of technical progress.

5 Evaluating Economic Feasibility of the Environmentally Sustainable Scenarios

5.1 Indicators

To evaluate scenarios we can consider key variables of each model or construct one or more aggregated indicator for all or a set of variables.

Normally in cost-benefit-analysis, scenarios are compared using one indicator. Different quantities like traffic volume or CO_2-emissions are multiplied with transport costs and costs per emitted tons of CO_2. Using this method we lose many interesting information of important variables. This is the reason why we focused on the following key indicators of each module:

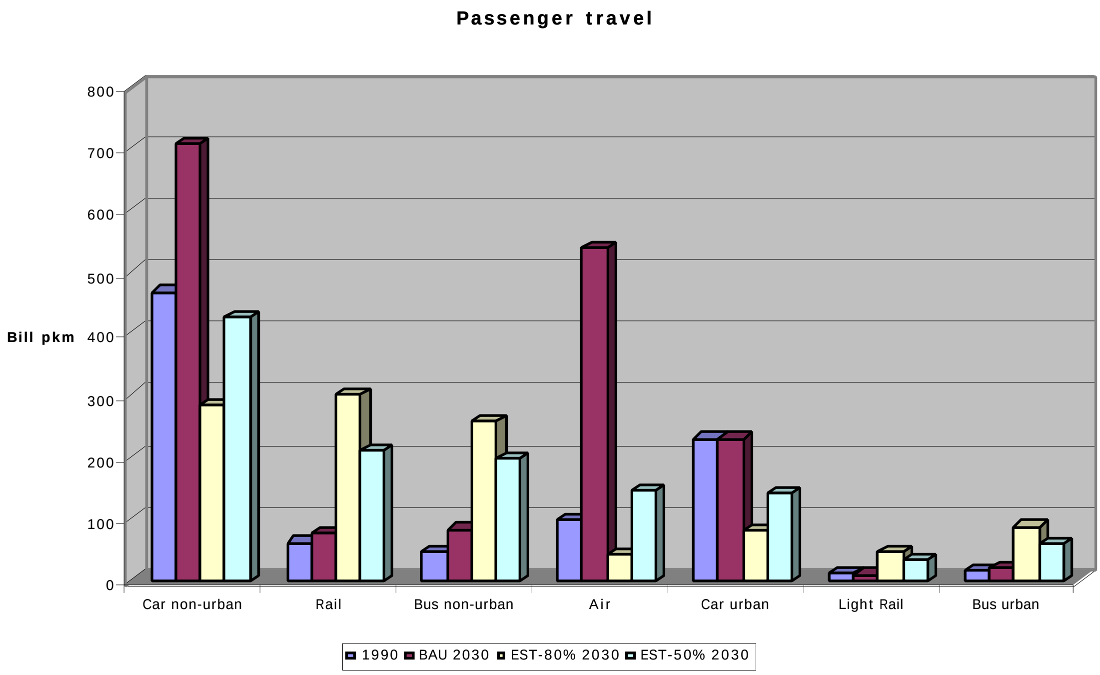
- Macroeconomic Model: consumption, investment, final demand, employment, potential output.
- Regional Economic Model: regional employment, regional population.
- Transport Model: traffic volumes for personal travel (urban and non-urban), traffic volumes for freight transport (urban and non-urban).
- Environment Model: CO_2, NOx, volatile organic compounds (VOC) and particulate matter (PM).

One major advantage of system dynamics compared to static cost-benefit-analysis is the ability to consider the development path of the indicators instead of only one certain point of time in a scenario. For some variables there may be no dramatic change at the end of different scenarios, but this does not mean that these variables cannot have large differences during the whole simulation period. Because of the different starting and ending points of the policy measures this problem will be strengthened. With ESCOT we can examine all variables during the whole simulation period and can extract variables that show undesirable developments. This makes it possible to vary the magnitude and the schedule of policy measures and enables us to improve the results of EST scenarios.

5.2 Results of the Transport Model

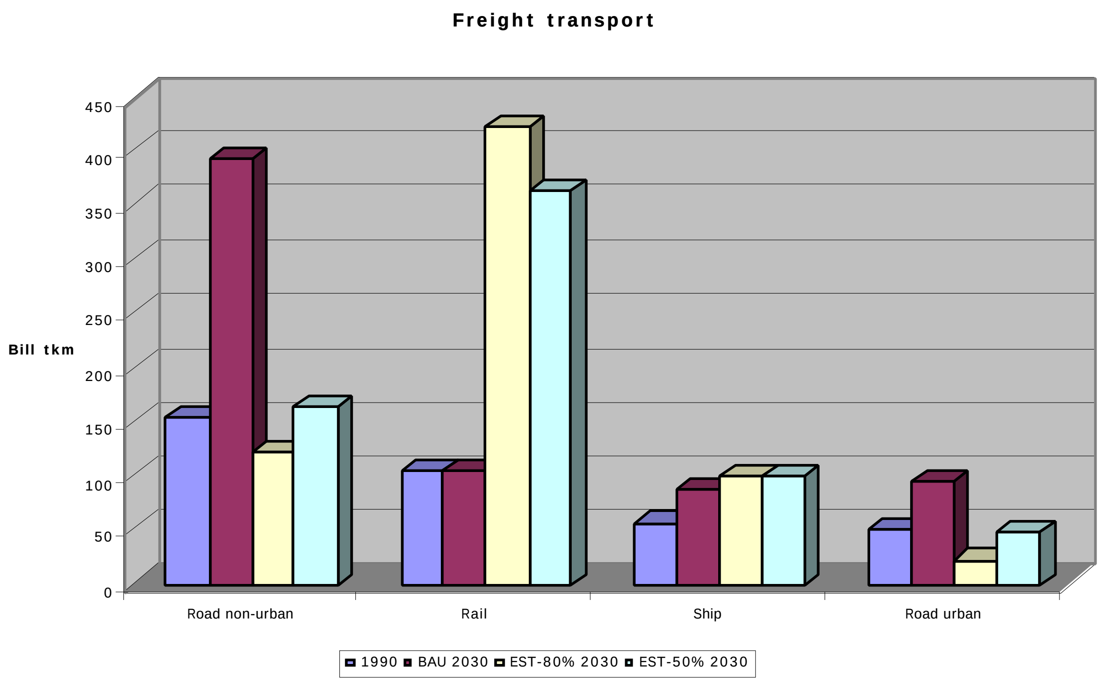
To get a clear understanding of the economic effects to be observed it is first required to look at the changes of transportation.

Figure 5: Comparison of passenger travel in 1990 and 2030 for BAU, EST-80% and EST-50%



To reach EST-80% drastic changes for car travel and air transport are necessary. For these two modes we derive a high decrease of passenger-km and a high increase for environmental more friendly modes. In EST-50% the amount of passenger-km for car travel and air transport can be held in 2030 on the same level as in the year 1990. The growth of passenger travel is absorbed by environmental friendly modes.

Figure 6: Comparison of freight transport for BAU, EST-80% and EST-50%



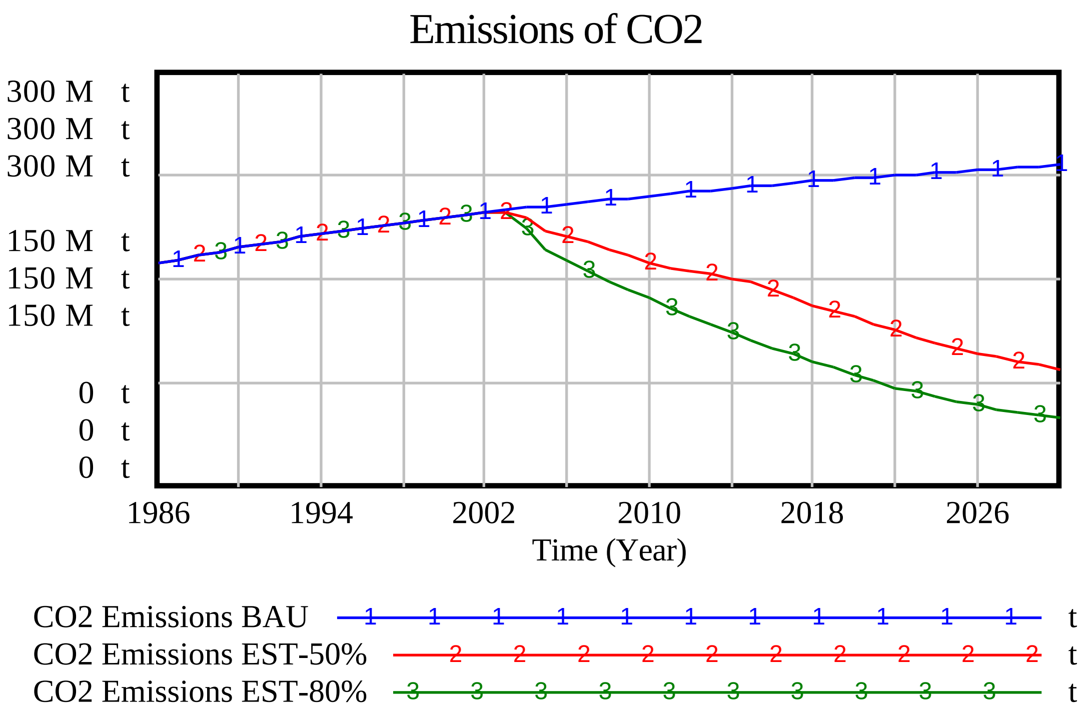
For freight transport we recognise the same characteristics. The amount of ton-km of road transport reaches for EST-50% in 2030 the same level as in 1990. The growth of freight transport is absorbed by rail and ship transport.

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.

5.3 Results of the Environmental Model

Looking at the totals of the EST-80% scenario the envisaged goal of a reduction of CO_2 emissions by 80% could not be reached completely because of the developments for freight transport. It was not possible to shift the desired amount of freight transport from road to rail. But with a reduction of CO_2 of more than 72% ESCOT is very close to this goal.

Figure 7: Yearly transport CO_2 emissions of the scenarios



For the EST-50% ESCOT meets the reduction of CO_2 emissions by 50%. A comparison of the development of yearly emissions shows that CO_2 emissions have the lowest decrease of the different emission gas. For NO_x, VOC and PM we see a high decrease even in the BAU scenario. This encourages the assumption that CO_2 emissions are the most problematic gaseous emission and if the EST scenarios would fulfil the criteria for CO_2 the other criteria are also fulfilled.

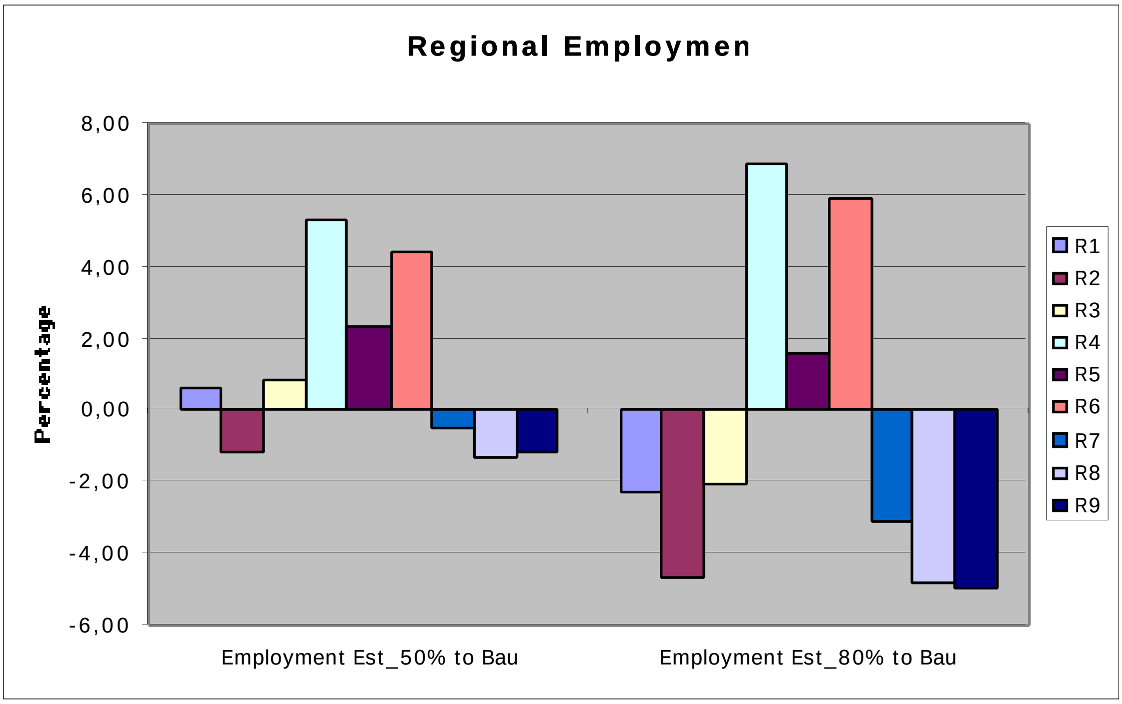
Table 4: CO_2, NO_x, VOC and PM emissions in percent

Gaseous emission [%, otherwise noted]	1990 in kt	1990	BAU	EST_80%	EST_50%
CO_2	173027	100.00	134.66	28.33	48.69
NOx	1378	100.00	44.20	6.64	15.62
VOC	1425	100.00	4.73	1.72	2.21
PM	43	100.00	20.86	3.43	8.07

5.4 Results of the Regional Economic Model

We derived small differences in the development of the regional employment. These differences depend on the share the sectors have on the regional economy. Especially important for a positive trend is a high share of agriculture and a high share of service sectors. A negative trend depends on the sectors energy and car production. For region 1 the negative trend of the car production sector will be balanced out by the increasing of the service sector in EST-50%. For the other regions the share of car production sector is lower so that in the most other regions negative developments can be overcompensated by agriculture and service sectors. For the regions 2, 8 and 9 this effect is too small because of the low share of the service sector. In EST-80% all these described effects are higher.

Figure 8: Regional employment of EST scenarios compared to BAU



For the development of population we can derive only very low differences between different scenarios. The highest change can be expected in the region 4 with an increase of 0.27% in the EST-50% scenario and an increase of 0.17% in the EST-80% scenario.

More interesting are the changes for car ownership. Here we observe high decrease for all regions. The highest decrease for the EST-50% scenario takes place in regions 2 and 7 with a minus of 23%. For the EST-80% scenario we derive in the same regions the highest decrease with a reduction of 40%. The different behaviour of the variable car ownership depends also on the results of the regional employment. While we observe very negative trends for region 2, 7, 8 and 9 we expect lower decreases especially for the regions 3, 4 and 5.

5.5 Results of the Macroeconomic Model

5.5.1 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 5. For EST-80% we notice in most of the sectors a small increase of **consumption**. The highest decrease is observed in sector 5 (includes vehicle production), a low decrease is in sector 3 (mineral oil). For **investment** overall changes are minor. The high decrease in sector 5 is offset by increase in sector 9, which is based on the investments in infrastructure for environmentally friendlier transportation. For **exports** we estimate a sharp decrease in sector 5. The influence of the vehicle production on the export sector is evident.

Table 5: Final Demand for BAU/EST scenario

Demand side in 2030 (Bill. DM)		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	21	23	23	1	1	1	0	8	8	8	30	32	32
2	Energy, Water	80	82	82	0	0	0	0	6	6	6	86	88	88
3	Chemistry and Mineral Oil	99	88	90	1	1	1	0	155	138	140	256	227	232
4	Iron, Steel	0	0	0	11	11	12	0	45	45	46	56	57	57
5	Mechanical and automotive products	106	58	81	219	194	203	0	305	234	265	629	486	549
6	Electronics	61	64	65	77	78	79	0	129	133	133	267	275	276
7	Wood, Paper	116	122	122	13	14	14	0	72	75	75	202	210	211
8	Food	295	309	310	0	0	0	0	46	48	48	341	357	358
9	Construction	3	3	3	321	352	337	0	2	2	2	326	358	343
10	Traffic Services, Commerrce	559	574	581	32	32	32	0	104	106	108	694	712	721
11	Private Services	793	832	834	25	25	25	0	37	39	39	855	896	898
12	Public Services	122	128	129	2	2	2	1212	2	2	2	1338	1344	1344
	Total	2256	2283	2320	701	710	705	1212	910	836	873	5080	5041	5109
	Difference betw. BAU and EST		1.1%	2.8%		1.3%	0.5%	0%		-8.1%	-4.1%		-0.8%	0.6%

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. So, final demand differs only by about 0.8% between both scenarios.

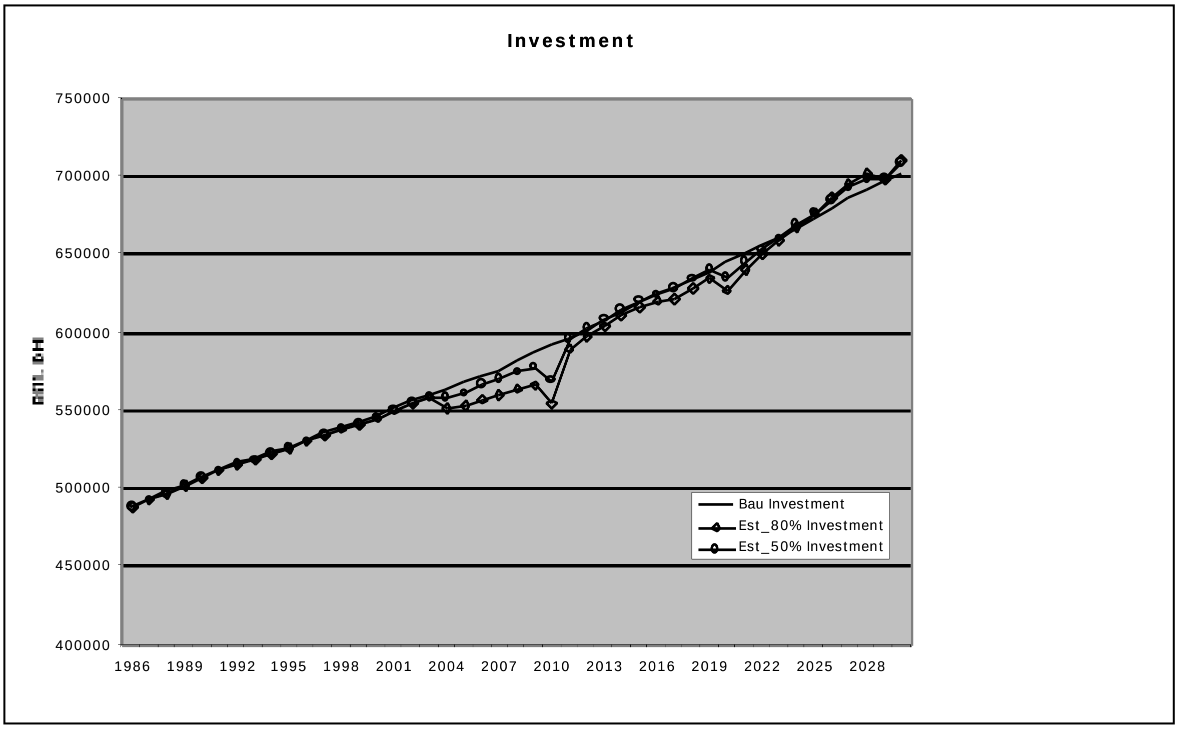
The structure of the changes between EST-50%/BAU on one hand and EST-80%/BAU on the other hand are similar. But significant differences in the magnitude of the changes occur. As for EST-80% we notice in most of the sectors a small increase of private **consumption**. Decreases of consumption are expected in sector 5 (includes vehicle production) and sector 3 (mineral oil). But these decreases are much smaller for EST-50%. With 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 can not be fully compensated by the increase of 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 us the entire effect on the different sectors. In total we notice that the negative effects in the export sector can 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%.

If we look at the graph for investment, we can give one reason for the positive development of consumption and investment. The first ten years the investment in EST is lower because of the negative effects of reduced consumption, investments into rail infrastructure still being in its planning phase. From the year 2010 the fostering of investments in rail infrastructure and the expansion of the rail network begin. This effect balances out the negative effects of the decrease of consumption.

Figure 9: Development of Investment



5.5.2 Supply side

In EST **employmen**t reaches a slightly lower level than BAU. The simulation shows a minus of 335000 jobs in the year 2030. **Capital stock** is also 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 6: Supply for BAU/EST scenario

Supply side	BAU-EST 1990	BAU 2030	EST-80% 2030	EST-50% 2030
Employment [Mill. Person]	34.921	32.206	31.871	32.541
Capital stock [Bill. DM]	10,709	13,246	13,085	13,106
Productivity [1/1000]	11.000	11.000	11.309	11.256
Potential output [Bill. DM]	2,844	5,379	5,382	5,441

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.

Table 7: Difference between EST-80%/EST-50% and BAU in absolute figures and as a percentage

Changes on the Supply side in percent	Difference between EST-80% to BAU		Difference between EST-50% to BAU	
	Abs.	Perc.	Abs.	Perc.
Employment [Mill. Person]	-0.335	-1.0%	+0.335	+1.0%
Capital stock [Bill. DM]	-161	-1.2%	-140	-1.1%
Productivity [1/1000]	+0.309	+2.8%	+0.256	+2.3%
Potential output [Bill. DM]	+3	+0.1%	+63	+1.2%

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% the employment reaches a higher level than in BAU at the end of the simulation period (of 335000 jobs at the year 2030). For capital stock there is a small decrease caused by the earlier depreciation by an increase of productivity. In total gross domestic goes up 1.2%.

In general these positive results on the supply side depend on two main effects. One 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 depends itself on the higher emission regulation that enforces research and development in the vehicle and the energy industries.

The other effect belongs to the influence of the demand side with its positive effects on consumption, investment and final demand.

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. To develop such environmental policies we have to take into consideration the weight between technical policy measures and pricing policy measures and of course the positive economic effects caused by higher productivity.

6 Conclusions

For EST-80% the results of the System Dynamics Model ESCOT 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 that expanded the time period for change in order to decrease the speed of change and to give more room to compensating measures we observed more encouraging results. Although 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 potential output is accelerated as well, and there are positive effects on employment to be expected. 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. To develop such environmental policies we have to take into account 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.

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 as ESCOT are constructed to describe complex social and economic systems. They are not only sticking with the first round effects that are in case of a path towards sustainability mostly governed by negative influences like higher prices and restrictions on the demand side. ESCOT offers the opportunity to derive 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 such that a policy measure e.g. charges for one mode causes a direct effect e.g. 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 to a powerful instrument for the assessment of such large ecological and economic changes.

7 References

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, Wiesbaden.

INFRAS/IWW (1995): External Effects of Transport. Study for the UIC. Prepared by S. Mauch, W. Rothengatter et al. Zürich, Karlsruhe.

INFRAS (1998): Fixed and variable charges for road transport, System analysis and basic evaluation, Zürich.

Meyer-Krahmer (1989): Arbeitsmarktwirkungen moderner Technologien (2): Sektorale und gesamtwirtschaftliche Beschäftigungswirkungen moderner Technologien, Walter de Gruyter, Berlin.

Milling, Peter (1984): System Dynamics: Konzeption und Anwendung einer Systemtheorie paper in economical sciences at the University of Osnabrück, Osnabrück.

Kuchenbecker, K. (1998): Strategische Prognose und Bewertung von Verkehrsentwicklungen mit System Dynamics, Universität Karlsruhe, Karlsruhe.

Norsworthy et al. (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), Paris.

OECD (1998): Scenarios for Environmentally Sustainable Transport: Report on Phase 2 of the Project on Environmentally Sustainable Transport (EST), 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.

Roeger, W.; in't Velt, J. (1997): QUEST II A MULTI Country Business Cycle and Growth Model, II/505/907, DGII, European Commission, Brussels.

Rothengatter, W. (1998): Economic Assessment of EST scenarios. Methods and Approach, University of Karlsruhe, Karlsruhe.

Schade, B.; Rothengatter, W. und Schade, W. (2002): Strategien und Maßnahmen für eine dauerhaft umweltgerechte Verkehrsentwicklung. Bewertung der Strategien und Maßnahmen für eine dauerhaft umweltgerechte Verkehrsentwicklung mit dem System Dynamic Modell ESCOT (Economic assessment of Sustainability poliCies Of Transport). F + E Vorhaben im Auftrag des Umweltbundesamtes FKZ 298 96 108. Umweltbundesamt, Berlin.

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

Schnabl (1997): Innovation und Arbeit, Tübingen.

Sommer (1981): System Dynamics und Makroökonometrie, Bern.

Stobbe (1975): Gesamtwirtschaftliche Theorie, Heidelberg.

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

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

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

Wardman (1997a): Disaggregate Urban Mode Choice, Institute for Transport Studies, Leeds.

Wardman (1997b): Disaggregate Inter-Urban Mode Choice, Institute for Transport Studies, Leeds.