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Improving Assessment of Transport Policies by Dynamic Cost–Benefit Analysis

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In the history of cost–benefit analysis (CBA), macroeconomic and microeconomic foundations have been developed. The latter has dominated in transport CBA during the last decades. The most widely used CBA approach can be characterized as comparative static and based on separate partial modeling. However, when it comes to significant indirect effects in the economic, social, and environmental systems connected with the transport system, alternative approaches to the microeconomic approach become inevitable. A system dynamics platform was developed that allows for a dynamic CBA integrating the most important indirect effect of transport policies. The approach was tested with large infrastructure programs and transport policy packages. Results of the dynamic approach reveal that the choice of the most favorable policy can change over time and depend on the time horizon defined for the analysis. In particular the dynamic approach allows for a clear allocation of costs and benefits to periods of time, which might be valuable information for policy acceptance and implementation. This research is integrated within a stream of European Commission projects on integrated and dynamic assessment, starting with the Assessment of Transport Strategies project (ASTRA) and extended by the projects Transport Infrastructure and Policy: A Macroeconomic Analysis for the European Union (TIPMAC) and Integrated Appraisal of Spatial Economic and Network Effects of Transport Investments and Policies (IASON). IASON focuses on analysis of indirect, second-round, or induced benefits and costs that occur through feedback effects between the transport sector and other economic sectors.

As the rigid microeconomic framework of impact analyses has dominated the cost–benefit methodology in the transport sector for some decades, the comparative static approach is most frequently used as a standard evaluation scheme. This approach is based on a comparison of a situation with and without the considered transport initiative (transport investment project or general transport policy) for a defined year of the future. For the transport sector, this approach has a clear computational advantage. The forecasting algorithm—which usually includes socioeconomic development, change of traffic behavior, change of industrial location and logistics, traffic generation, distribution, modal split, and assignment on a network scale—has to be performed for only 1 year of the past (for calibration purposes) and 1 year of the future (for forecasting and impact analyses). Also, the assessment and the appraisal analyses can be done by applying standard static welfare concepts, so that the complex dynamics stemming from the feedback mechanisms within the transport sector and between it and other economic sectors as well as the difficult construction of a dynamic, intergenerational welfare concept are not necessary. If dynamics are introduced, then in most cases they are based on very simple assumptions to avoid the complexity mentioned above. For instance, in the German standard scheme for the evaluation of investments in the federal transport system, it is assumed that the yearly benefits, which have been calculated for the year of forecasting, remain constant over the lifetime of the investment projects.

While the estimation failures stemming from this static procedure might be small for small, independent projects, which produce only marginal changes of the initial situation, large errors are possible for large-scale projects or interdependent project bundles, which heavily influence the transport sector and other sectors of the economy. Therefore, the intention is to develop a dynamic cost–benefit analysis (CBA), which is appropriate for evaluating actions with a heavy impact on the transport sector that can lead to repercussions and evolutionary feedback mechanisms. In principle this approach will be based on a system dynamics platform that has been developed in a European research project on Assessment of Transport Strategies (ASTRA) (*1, 2*). The main extension of the ASTRA framework, which is proposed here, is to introduce a cost–benefit module that summarizes the welfare impacts that arise from the change of variables that are simulated by the dynamic simulation algorithm. One of the big advantages of the system dynamics platform is that one can combine microeconomic, mesoeconomic, and macroeconomic approaches to derive reliable impact figures, which can be tested on each level, and also build in consistency checks to include long-term effects on the one hand and avoid double counting of effects on the other hand.

TYPOLOGY OF APPROACHES

Macroeconomic Approaches

Macroeconomic approaches are usually either Keynesian or neoclassic. Keynesian approaches presuppose that price mechanism does not work efficiently so that important markets are permanently constrained. If this holds, for instance, for the supply sides of the goods market and the labor market, then a permanent situation of unemployment accompanied by an underutilization of the labor and capital resources of the economy follows. Public investments, including investments in networks, then can produce a multiplier effect, which relaxes the constraining situation on the markets and moves the economy to a higher equilibrium position.

Neoclassical approaches start from the assumption that the supply side is governing the economic development. Consequently the production function is the focus of analyses. To analyze the influence of infrastructure on economic development, it is possible to specify a production function in a way that the transport infrastructure represents one of the endogenous factors of economic roads.

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Econometric estimation of the production function eventually disaggregated by sectors and inserting the "with and without" figures of transport infrastructure capital into the function give an aggregate estimate for the influence of the transport infrastructure capital on the economy.

In both cases, the Keynesian and the neoclassic, figures of national accounting such as gross domestic product (GDP), domestic consumption, or domestic employment are used as measures of welfare. In the following section, it will be shown that this does not conform to the microeconomic concept of welfare.

Microeconomic Approaches

The microeconomic approaches are in general based on the Kaldor–Hicks criterion, which states that a public measure brings a net benefit to society if the advantaged parties are able to compensate the disadvantaged parties and still enjoy a net advantage after compensation. Starting from this general criterion one can work out the theoretical foundation either on the base of utility or on the base of demand theory.

The welfare concepts based on demand theory date back to Marshall (*3*), Hicks (*4*), and Henderson (*5*). Marshall introduced the concept of consumers' and producers' surplus into the welfare discussion. Separating the considered market from the interrelationships with other markets, he depicted the situation in this market by introducing demand and supply functions and their equilibrium position. The equilibrium position is characterized by a price, which does not exhaust the total willingness of the consumers to pay. The sum of all willingness-to-pay measures of the consumers, which exceed the equilibrium price, is denoted as the consumers' surplus. On the suppliers' side, the equilibrium position can be characterized by the surplus of revenues over costs. The change of the welfare position, then, can be measured by the sum of the variations of the consumers' and the producers' surplus [see the reformulation of surplus theory by Hicks (*4*) and Henderson (*5*)].

As the quantification of the demand and supply curves is a nontrivial exercise, most of the standard evaluation schemes assume that prices are constant over the interval considered. In this case, one can separate the cost–benefit analysis in two parts: the quantification of impacts (forecasting) and the appraisal of impacts using constant willingness-to-pay measures (appraisal). Usually, these willingness-to-pay measures are taken from surveys (i.e., they are inserted as constant values into the appraisal part). This approach allows for a very differentiated benefit measurement, beginning with the generalized costs (operating and time costs) and including accident costs, environmental costs, and eventually spatial effects. Although computation of costs and benefits is—applying these simplifying rules—comparatively easy and transparent, it incorporates a number of caveats, including the following:

- Willingness-to-pay measures abstract from income distribution, which means that people with a higher income usually express the higher willingness to pay for a good.
- The Kaldor–Hicks test is not actually performed but only implicitly done through calculating the surplus of benefits over costs. Therefore, it can happen that, in a sequence of state actions, the same social groups are always losers in the public policy game.
- The rigid assumptions of microeconomic analysis hold, which means that dynamic interactions are not considered.
- If the spatial competition is incomplete, then the partial surplus measures give wrong indications on welfare changes.

Spatial Price Equilibrium or Computable General Equilibrium Models

Computable equilibrium models for transport have become popular through the work of Krugman (*6*), Venables (*7*), and Venables and Gasiorek (*8*). The main difference from the standard microeconomic approach is that spatial price equilibrium (SPE) and computable general equilibrium (CGE) models start from the assumption that demand and supply are distributed over space and that spatial competition exists, which is distorted by market imperfections (monopolistic competition in at least one sector or regional barriers to trade). Public activities, which remove restrictions to interregional trade, then can be assessed by applying constraint equilibrium modeling and comparative static analysis. Obviously this spatial approach has big advantages over the microeconomic approach based on the simple partial market analysis of Marshall. However, again this method suffers from the very rigid assumption of equilibrium theory and the computational problems that arise in the real economy. The analyses of Krugman (*6*) and Venables (*7*) have shown that, to simulate realistic reaction mechanisms in the regional economic system, imperfect markets have to be assumed. However, a quantitative analysis of interdependent regions with incomplete markets in a sectorally disaggregated economic system is very tedious and has not been successful up to now. Therefore the Standing Advisory Committee on Trunk Road Assessment (SACTRA) of the U.K. department of transport has decided—after detailed discussion of the approach of Venables and Gasiorek (*8*)—to restrict to a purely qualitative interpretation of the outcomes of this type of model. These outcomes are clearly dependent on the constraints, which are assumed for interregional trade, the flexibility of prices, the spatial organization of the industry, and the regional equipment with private and public production sectors. SACTRA concludes that investments in roads can have positive economic effects beyond the effects measured by the standard microeconomic approach. However, these effects can be positive or negative. This means that there cannot be a general rule for the deviation of the actual benefits and costs in the regions from the results that have been computed on the basis of traditional microeconomics. Dealing with the same question as SACTRA, Lakshmanan and Anderson (*9*) suggest, though raising some fundamental doubts about CGE, further developing CGE for the assessment of indirect effects of transport policies.

Evolutionary Approaches with System Dynamics Models

Since the work of Schumpeter (*10*), evolutionary theory as a branch of economic dynamic theory has developed on the basis of parallels to biological evolution, which is governed by processes of selection and mutation of species. The agents do not decide on the basis of maximization calculus, but rather by learning schemes. They behave according to routines, which they change only if failures force them to rethink their attitudes. Satisfying behavior replaces optimal behavior, because in an uncertain world the agents never know what the exact parameters for an optimality calculus are (*11*).

When it comes to the measurement of impacts for CBA, the main building blocks of evolutionary theory can be used by employing system dynamics modeling (SDM). The use of system dynamics for giving decision support to transport policy makers has been presented in Schade and Rothengatter (*12*). SDM is a tool able to handle a high complexity of interactive subsystems so that it is appropriate for analyzing long-term impact mechanisms within the transport sector and between the transport sector and other sectors of the economy.

With system dynamics, it is also possible to include the regional dimension. In the European project on Scenarios for the Trans-European Network (SCENARIOS), the regional analysis with quasi-production functions (*13*) that consider agglomeration, space for industrial settlement, transport infrastructure, natural resources, and infrastructure for education, has been successfully combined with a system dynamics model to analyze the long-term effect of transport investments on European NUTS III (nomenclature of territorial units for statistics) regions of different type (*14*). Depending on the bottleneck situation of the quasi-production factor "transport infrastructure," this instrument diagnoses strong or weak affinities of regions to transport infrastructure. Therefore, in some cases transport infrastructure investments can even lead to negative results for the regional economy ("backwash effects"). In other cases, such investments are the *conditio sine qua non* for regional development.

It is possible to integrate a number of welfare criteria into the framework of a system dynamics model. This can include microeconomic (individuals), mesoeconomic (groups, sectors), and macroeconomic indicators. In particular it is feasible to define a standard CBA indicator that measures the change of aggregate willingness to pay. The difference then, compared with the microeconomic approach, is that the interactions between regions and sectors as well as the evolution of variables over time are considered in a consistent way. Compared with SPE or CGE approaches, the system dynamics model has the advantage that it is not bound to the equilibrium concept. The development can be completely evolutionary, that is, it has a history but it does not repeat. In the transport sector, there is some evidence that this type of dynamics is more appropriate to transportation development, which we can observe, than the equilibrium theory. To summarize, system dynamics is a most flexible instrument to cope with complex systems in an evolutionary environment and therefore provides an excellent platform for a dynamic assessment of political actions, including CBA.

FROM STATIC CBA TO DYNAMIC CBA: EXAMPLE WITH SYSTEM DYNAMICS MODEL ASTRA

The previous sections elaborated on the major economic theories that can be applied to build the foundations of a cost–benefit analysis. It is concluded that integrated SDM of the transport system and related systems is a promising way to improve current transport CBA practice in the case of transport initiatives that are expected to produce significant indirect effects (e.g., because they are large projects). In the following, the idea of a dynamic CBA is developed and demonstrated on the basis of the ASTRA model.

The ASTRA model was developed in the ASTRA project, which was financed by the European Commission former Directorate General VII (*1, 2*). The objective of ASTRA was to develop a tool for analyzing the long-term impacts of the European Common Transport Policy (CTP). The spatial scope for ASTRA covers the 15 countries of the European Union (EU), and the time horizon is the year 2026. ASTRA is an interdisciplinary, integrated assessment tool based on the principles of SDM.

Since the completion of the ASTRA project at the end of 2000, the so-called ASTRA family of models has been developed. The model discussed here is ASTRA-C, which is extended by a foreign trade module and the CBA features within the welfare measurement module presented in a draft version in 2002 (*15*). The dynamic analysis diverges from the standard comparative static CBA approach in the sense that the evaluation can be based on the continuous time path of the costs and benefits measured by the model. With this approach, it can be shown that for certain comparisons of policies, it is possible that the most advantageous variant can change over time. That means that Variant A may provide the best solution at one time, while at another time Variant B provides the best solution. This highlights that in the comparative static approaches, the selection of the time horizon also can be a crucial issue influencing the outcome of the CBA.

Modular Structure of ASTRA-C

ASTRA-C consists of eight modules that are implemented as much as possible from state-of-the-art models of different research disciplines. The modules are population (POP), macroeconomics (MAC), foreign trade (FOT), regional economics and land use (REM), transport (TRA), environment (ENV), vehicle fleets (VFT), and welfare measurement (WEM) (see Figure 1). The ASTRA population module generates the demographic framework for the MAC and the REM modules from 1-year age cohorts. The aim of the MAC module is to provide an aggregate macroeconomic environment in which the FOT, REM, TRA, VFT, and ENV modules are embedded. The MAC incorporates an endogenous growth component that is able to generate growth effects of policies and a sectoral interchange component that considers the impacts of the sectoral interweaving in an economy. POP, MAC, and FOT integrate the macroscopic information on influences at the national and continental level into the model, while other modules operate on a micro- or mesolevel. This has the advantage that feedback loops, which commence on the micro- or mesolevel in one of the modules (e.g., transport expenditures for one mode in one distance band in the TRA) and then end up with an effect on the national level (e.g., changes in sectoral consumption and gross value added), can influence the originating module such that the feedback loop is closed (e.g., in this case by the integration of the MAC module). Closing the feedback loop then

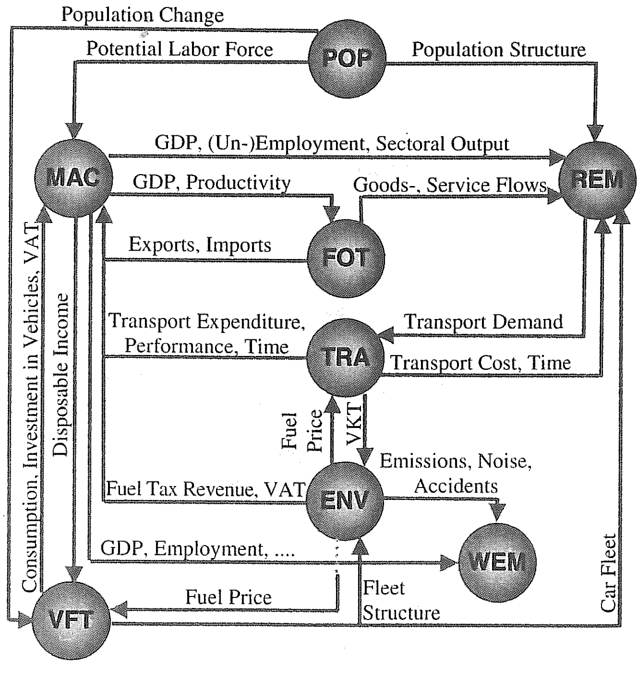


FIGURE 1 Structure of the ASTRA model: modules and main interfaces.

implies establishing either macromicrobridges (e.g., from GDP to goods flows) or, vice versa, micromacrobridges (e.g., from transport investments in vehicle fleets to overall investments).

All monetary values are calculated in real values of 1995 euros. Most variables are calculated net of all taxes, and taxes are treated separately. The basic calculation time period for most modules (e.g., MAC, FOT, VFT) is 1 year.

Spatial Disaggregation of ASTRA-C

For the purposes of analysis, the EU has been spatially split into four macroregions of approximately the same size and containing national economies with roughly similar characteristics:

- Macroregion E1 (EUeast)—Germany and Austria;
- Macroregion E2 (EUwest)—France, Belgium, the Netherlands, and Luxembourg;
- Macroregion E3 (EUsouth)—Italy, Spain, Portugal, and Greece; and
- Macroregion E4 (EUnorth)—United Kingdom, Ireland, Sweden, Denmark, and Finland.

Each of the four regions is modeled using the same macroeconomic framework, which is adapted to regional specifics by different parameterizations. In addition, a so-called functional zoning system is set up that classifies the 201 NUTS-II zones of the EU into six types of functional zones according to their settlement patterns of centrality and population density.

Sectoral Disaggregation of ASTRA-C

Because policies most often do not exhibit their strongest effects on the fully aggregated macrolevel but on the level of economic sectors, the economy is split into 12 economic sectors. The core of the sectoral analysis is based on an aggregated input–output table (I-O table) with the following 12 economic sectors:

- Agriculture, forestry, and fishery;
- Energy, water, mining products, and crude oil;
- Chemical, mineral, plastic, and petroleum products;
- Ferrous and nonferrous ores and metals;
- Steel products, machinery, and transport equipment;
- Electrical and optical goods, office and data processing, and toys;
- Textiles, clothing, paper, and wooden goods;
- Food, beverages, and tobacco;
- Building and construction;
- Services for repair, wholesale and retail, transport, and communication;
- Other market services such as lodging, catering, credit, and insurance; and
- Nonmarket services.

The sectoral disaggregation is applied in the MAC and FOT module and in the part of the REM module that deals with freight transport generation. The concept of an aggregated input–output table is established in the German system of national accounts, in which a detailed I-O table with 58 economic sectors and an aggregated I-O table with 12 sectors are used [e.g., Statistisches Bundesamt (*16*)].

Transport System in ASTRA-C

The transport system is not represented by a link-based network model. Instead it is described with a system of distance bands on which modal competition occurs. However, information on times and costs in the different distance bands and for the alternative modes is taken from the SCENES network model of the European Transport Scenarios project for European Commission. ASTRA-C considers five distance bands for passenger transport and four for freight transport. For both passenger and freight transport, the two longest distance bands are treated as interzonal flows, while all shorter distance bands represent intrazonal flows. The definitions of the distance bands and the available modes are given in Figure 2.

Passenger demand is divided into three trip purposes, which are not all available in every distance band. The purposes are

- Business trips,
- Tourism trips, and
- Private trips that include all other trips such as shopping and nontourism leisure trips.

Freight demand is divided into three goods categories, which exist in all distance bands:

- Bulk goods,
- General cargo goods, and
- Unitized goods.

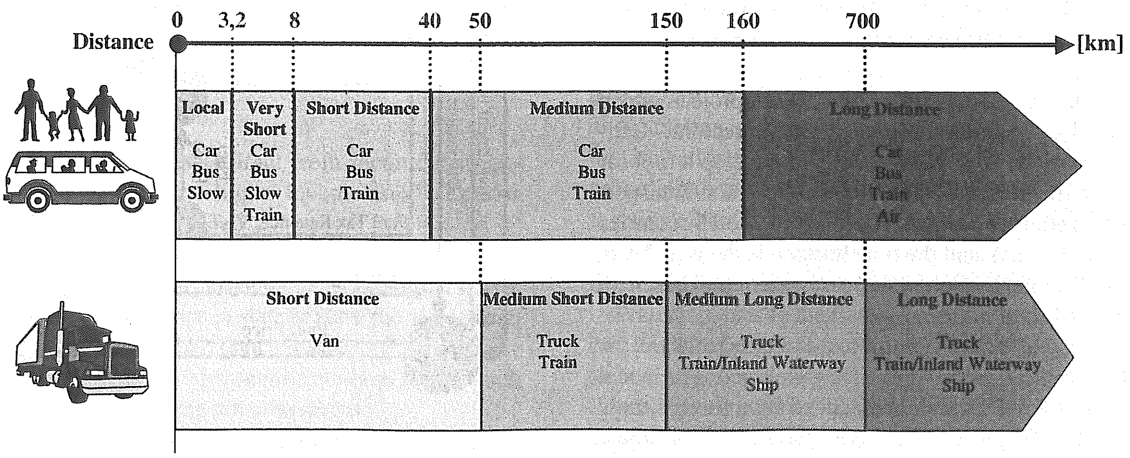


FIGURE 2 System of distance bands and available modes in the ASTRA-C transport module.

Dynamic CBA with ASTRA-C

In principle, most of the necessary indicators to be considered for a transport CBA (TCBA) have already been implemented in ASTRA. Hence, to develop the dynamic CBA, only the standard calculation scheme for a CBA has to be added to the ASTRA model. The dynamic CBA in ASTRA-C follows the approach of the German Federal Transport Infrastructure Planning procedure (BVWP), which is similar to other European, Japanese, or U.S. evaluation schemes in the core categories of considered benefits. To derive the net present value, the costs and benefits are discounted with a rate of 3% that also stems from the German BVWP (*17*). In total, seven categories of (dis-)benefits are considered in the ASTRA-C TCBA:

- Variable transport costs. This category considers all modes for passenger and freight (except pipelines) in all distance bands.
- Transport times. This category considers all modes for passenger and freight (except pipelines) in all distance bands. The number of trips used for the calculation of time savings is revised by a subtraction of the induced trips per corridor.
- Induced transport. This category considers all modes for passenger and freight (except pipelines) in all distance bands. To estimate the number of induced trips, the total over all modes per corridor (equivalent to an origin–destination pair in ASTRA) from the base scenario is compared with the number of trips in the policy scenario. If number of trips and trip length increase in the policy scenario, the difference is estimated to be induced trips. These are then distributed to the modes proportionally, and their benefits are monetized with the generalized cost of a trip (analogously for freight).
- Transport investments. This category considers all modes for passenger and freight except pipelines. There are two options to consider investments. The usual way is to calculate only the investments in infrastructure. Since ASTRA also estimates all investments in vehicles for all modes, changes in those investments can also be considered.
- Safety. Four categories of consequences of accidents are estimated for all modes: fatalities, serious injuries, light injuries, and material damages. They are all considered in the CBA.
- Environment. CO_2 and NO_x emissions of all modes are estimated with a life-cycle assessment approach that includes electricity and the production stages of vehicles and fuel. For particulate matter, the potential risk of local emission concentrations is estimated and put in relation to affected population. Obviously several important environmental indicators are missing (e.g., noise).
- Employment. The change in overall employment in the economy is calculated and monetized by cost values from the German BVWP. This might be a source for double counting. On the other hand, employment can be seen as rough proxy for equity or changes in fairness.

Results of the dynamic CBA can either be displayed as benefit–cost ratio or as benefit–cost balance. Benefits for the mentioned indicators would be a reduction of (total) transport expenditures, time savings because of a reduction of transport times, induced transport, a reduction of needed investments for transport, a reduction of emissions and accidents, and an increase in employment, all compared with the base scenario. For induced transport, the opposite would be treated as costs or disbenefits. For this demonstration of a dynamic CBA, two policies have been tested:

- Tax for Trans-European Networks (TEN) policy. Gasoline and diesel fuel taxes increase over a period of 15 years to cover the investment costs of implementing the European rail TEN that are part of the priority projects of the TEN. That means tax increases vary according to the funding needs for the TEN investments and the progress in their construction.
- Integrated policy. The rail TEN are implemented in the same way as the Tax for TEN policy. Furthermore gasoline and diesel fuel taxes are stepwise (or incrementally) increased by 5% every 2 years from 2000 through 2010. Additional tax revenues are used to reduce labor cost. On top of this, the tax level of gasoline and diesel taxation is balanced, which leads to a further increase of diesel taxes. New European emission legislation for automobiles is introduced at an earlier point of time (3 years in advance) starting with EURO II. Seat-belt usage of car drivers is increased to a level of 98% for nonurban roads in all countries.

The impact of the two policies on fuel tax revenues for the EU is presented in Figure 3. In the Tax for TEN policy, additional fuel taxes

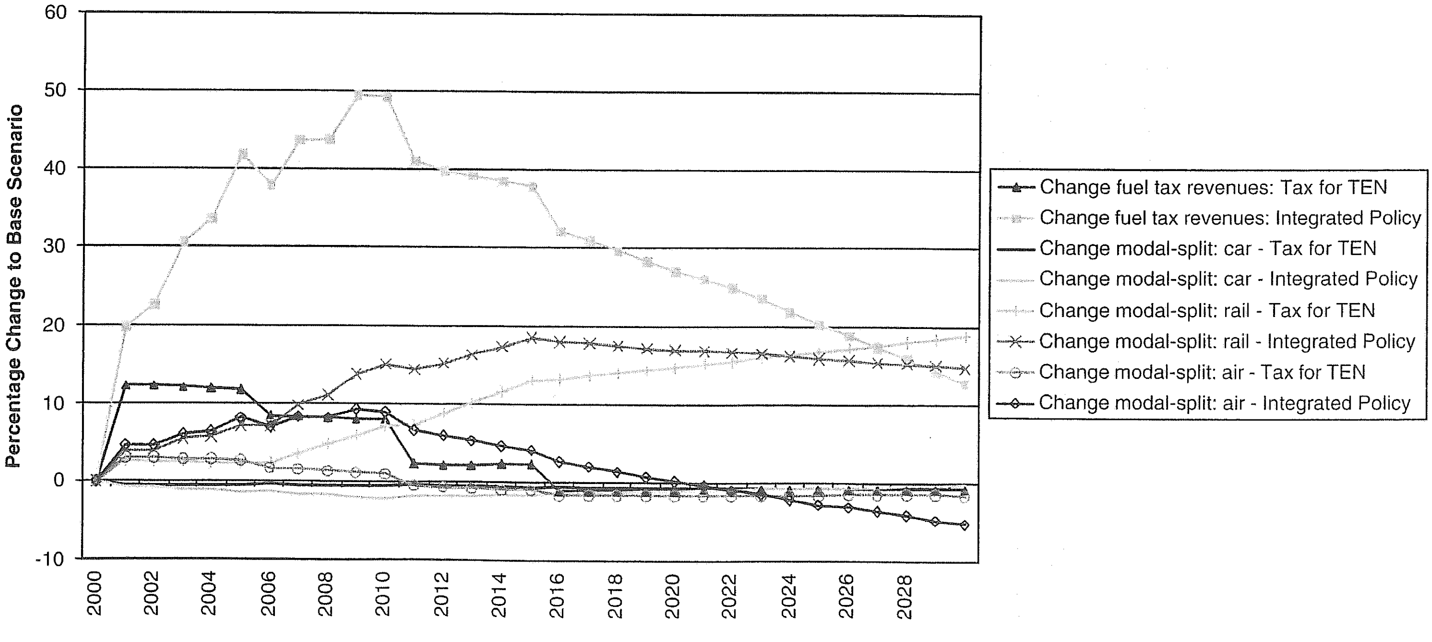


FIGURE 3 Changes of revenues and modal split due to the two policies.

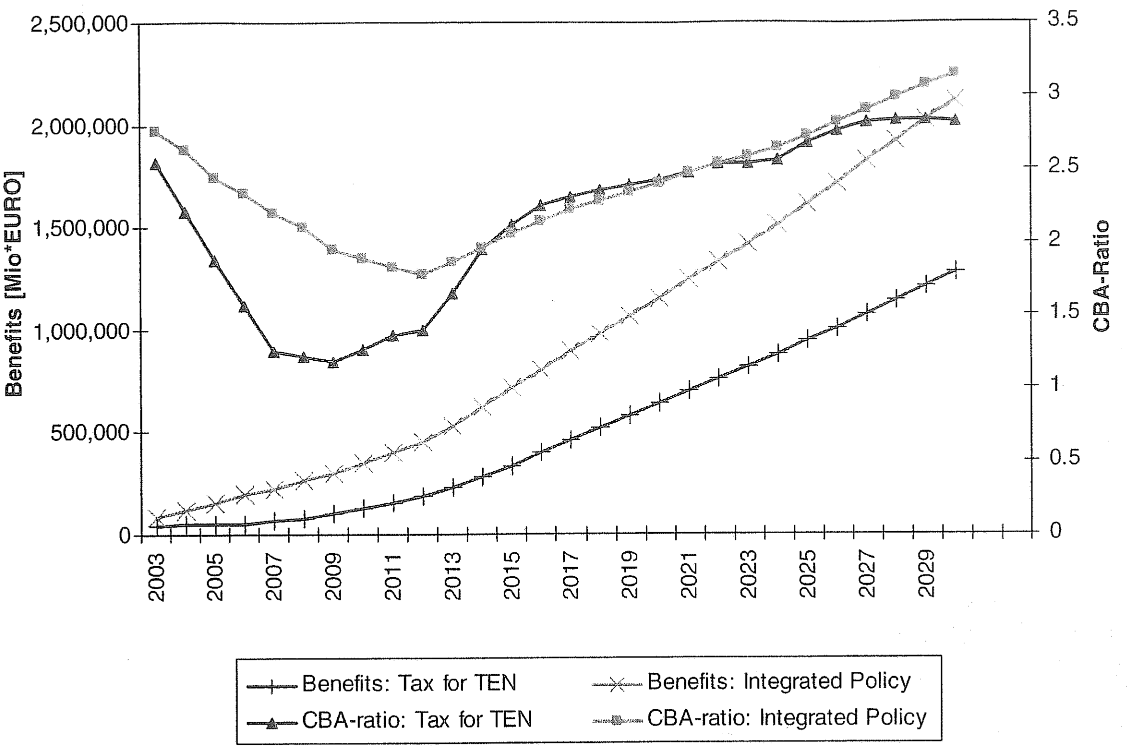


FIGURE 4 CBA ratio and total benefits for the two policies from 2003 to 2030.

are generated in three distinct 5-year periods between 2000 and 2015, with the highest increase of about 12% in the first 5 years. After 2015 the revenues are slightly below the base scenario revenues, since car modal share is reduced because of the increased attractiveness of rail. In the integrated policy, the additional fuel taxes reach a peak level with a 50% increase in 2010, when all tax increases are implemented but the implementation of high-speed rail is not completed so the modal shift toward rail is only partially taking place. Instead, over a 10-year period there is also a strong modal shift toward air that is gradually reduced when the high-speed rail network is completed.

The results of the dynamic CBA are presented in Figure 4, which presents the evolution of the CBA ratio between 2003 and 2030. The period before 2003 is considered for the calculations of costs and benefits but is not shown in the figure as it shows some initial peaks because of the division by small numbers. The results indicate that there is no policy that is superior at all points of time and that the integrated policy provides higher total benefits.

Table 1 shows the numerical values for selected points of time. The grayed cells indicate which policy would have been the best in a comparative static CBA with this specific time horizon. With a time horizon 2010, 2025, and 2030, the integrated policy would be most advantageous, but at 2015, the Tax for TEN policy would be most advantageous. Hence, the result of a comparative static CBA might be rather arbitrary depending on the time horizon chosen. At this stage we leave open how to decide what would have been the "correct" time horizon in this case.

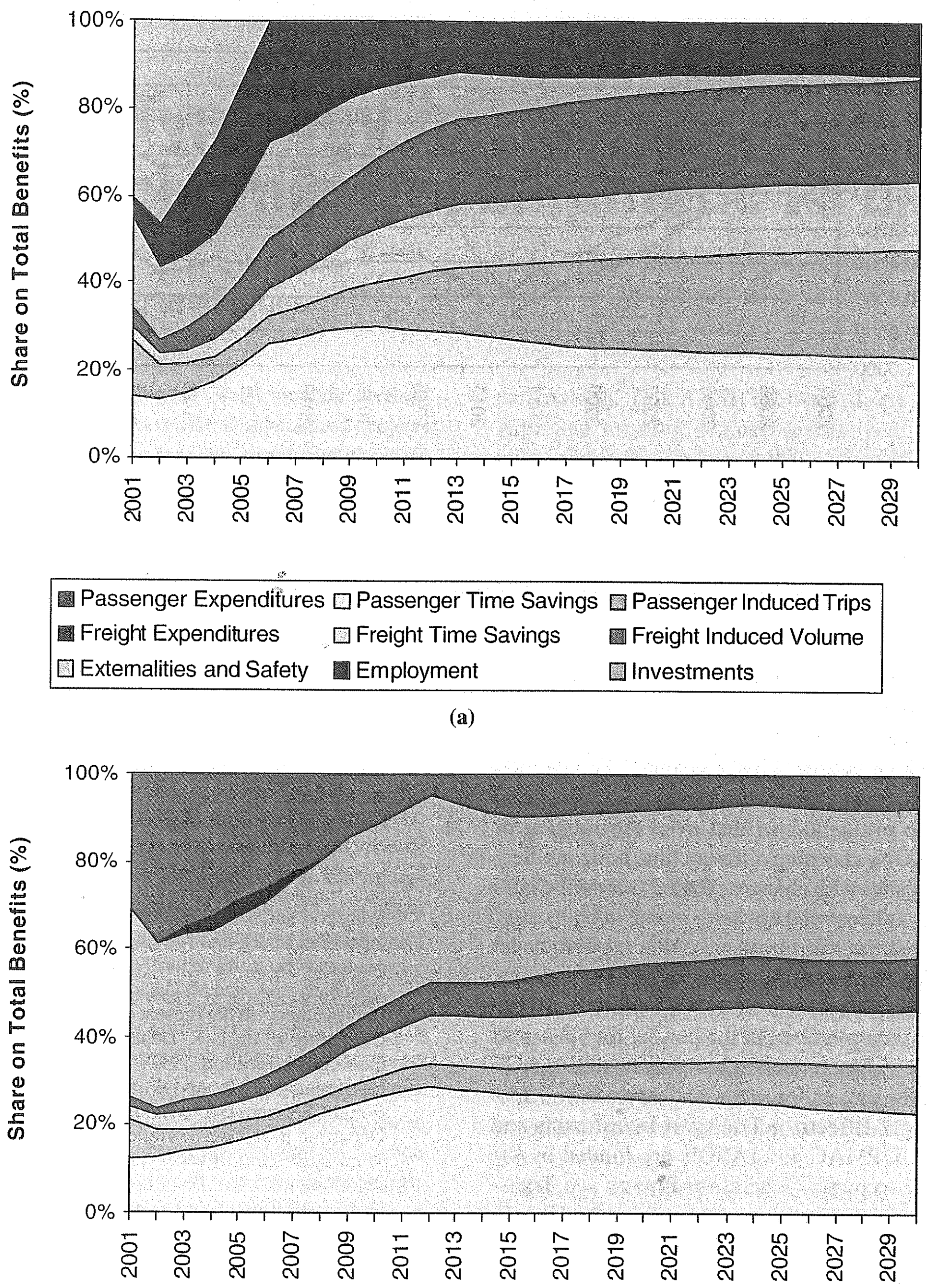
TABLE 1 CBA Ratios for Selected Points in Time

	2010	2015	2025	2030
Tax for TEN	1.272	2.118	2.67	2.824
Integrated Policy	1.882	2.057	2.724	3.137

The picture of the dynamic CBA is completed by an analysis of the distribution of benefits (disbenefits) onto the nine (*7*) categories considered. Figure 5 shows the distribution of the benefits summing up to 100% over all nine categories for the Tax for TEN policy and the integrated policy. It can clearly be identified that in the Tax for TEN policy, time savings plus induced transport for passenger and freight contribute more than 85% of the total benefits, of which about two-thirds is induced transport.

For the integrated policy, however, time savings plus induced transport contribute less than 60% of total benefits, which is still a large share. In this case the benefits of reduced externalities amount to more than one-third of all benefits, while in the Tax for TEN policy these benefits are close to zero percentage in 2030. Reduced externalities in this policy are significant only in the period 2000 to 2015 when the fuel tax is increased to finance the TEN investments. Afterward, despite modal shift toward rail, the overall increased transport activity counterbalances the success of the modal shift.

Looking closer at the size of the shares reveals that in the integrated policy, passenger time savings also plays an accentuated role, producing by far the second biggest share of benefits after the externalities, whereas in the Tax for TEN policy the benefits are similar to the benefits of freight time savings and the benefits of induced transport. This is because in the Tax for TEN policy, fewer persons shift to train mode since the tax level is back to the base scenario level after the TEN construction. Therefore, fewer people benefit from the faster train transport. Also, road transport is less released so that transport times by road are higher than in the integrated policy case in which there is also a significant increase of fuel tax after the termination of the TEN construction. In this case, push (tax increase) and pull (rail quality improvement) forces unfold



(a)

(b)

FIGURE 5 Distribution of discounted gross benefits over the nine benefit categories for (*a*) Tax for TEN policy and (*b*) the integrated policy.

synergies to increase the benefits while in the Tax for TEN policy, only the pull forces are substantial.

The results of the dynamic CBA now will be compared with results for two macroeconomic indicators—GDP and employment. Figure 6 shows the percentage changes of GDP and employment for the two policies compared with their development in the base scenario. In total, the Tax for TEN policy leads to the larger improvements, with 0.2% increased GDP and 0.6% increased employment. Nevertheless, it appears that also in the final years of the integrated policy there is a catch-up process such that, at least for employment, a similar level is reached as in the Tax for TEN policy. In this case the modal shift on the microlevel toward rail leads to a transfer of expenditures toward economic sectors that generate more employment per output and that incorporate higher local contents and less imports as would have been the case if the money were spent for cars. That means more local employment is generated.

CONCLUSIONS

Dynamic CBA with ASTRA-C presents a useful and feasible option of further development of transport CBA in the framework of evolutionary theory using system dynamics models. However, the priority for improvements is not so much with the CBA scheme itself, which is very similar to the current worldwide practice of TCBA approaches except that it is dynamic or time-path related. The priority is with improvements of the underlying models that are generating the quantity structure of the impacts. These models should be able

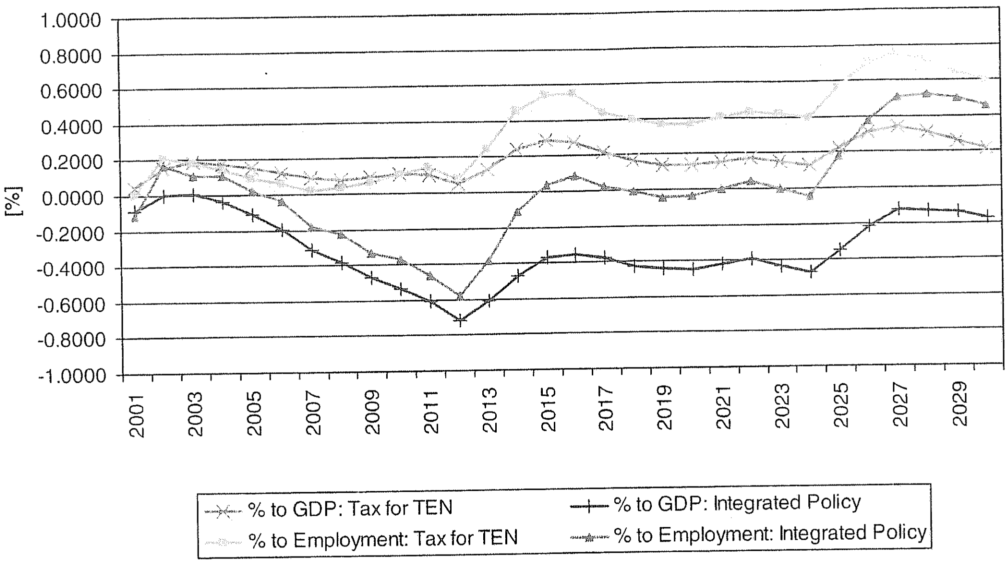


FIGURE 6 Percentage changes of GDP and employment compared with the base scenario.

to depict the various interactions in time and space between the transport system and its interconnected economic, social, and, preferably also, environmental systems.

Two points are interesting to note. First, dynamic CBA demonstrates that the choice of the time horizon in a static CBA may influence the outcome of the evaluation so that even the ranking of alternatives can be changed by choosing different time horizons. Second, in comparing CBA results with changes of macroeconomic indicators, the ranking of the policies need not be the same in both cases. However, in this case the impact mechanisms of the applied model have to be analyzed diligently to verify that all relevant mechanisms are considered and work properly.

ASTRA-C is currently being refined in the project for Transport Infrastructure and Policy: A Macroeconomic Analysis (TIPMAC). It will then be applied in the project for Integrated Appraisal of Spatial Economic and Network Effects of Transport Investments and Policies (IASON). Both TIPMAC and IASON are funded by the European Commission Directorate General for Energy and Transport, DG TREN—in a model competition of the refined ASTRA-C, a spatial CGE, a recursive simulation model, and an econometric simulation model. The purpose is to test and develop further improvements for transport policy assessment with a focus on measuring indirect effects.

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