ASSESS

Assessment of the contribution of the TEN and other transport policy measures to the mid-term implementation of the White Paper on the European Transport Policy for 2010

FINAL REPORT

ANNEX XII MACRO-ECONOMIC IMPACT OF THE WHITE PAPER POLICIES

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Preface

This is ANNEX XII of the final report for '*Assessment of the contribution of the TEN and other transport policy measures to the mid-term implementation of the White Paper on the European Transport Policy for 2010*'.

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Scope

Scope of the ASSESS project

The ASSESS study is about the ***"Assessment of the contribution of the TEN and other transport policy measures to the mid-term implementation of the White Paper on the European Transport Policy for 2010"***.

The European Commission's White Paper of 12.9.2001 "European transport policy for 2010: time to decide" aims to promote a sustainable transport policy. The White Paper proposes to achieve sustainability by gradually breaking the link between transport growth and economic growth, principally in three ways: changing the modal split in the long term, clearing infrastructure bottlenecks and placing safety and quality at the heart of the transport policy.

As foreseen, the White Paper on Transport undergoes in 2005 an overall ***assessment concerning the implementation of the measures it advocates and to check whether its targets*** - for example, on modal split or road safety - ***and objectives are being attained or whether adjustments are needed.***

ASSESS provides technical support to the Commission services for the above mid-term assessment of the White Paper.

The analysis accounts for the economic, social and environmental consequences of the proposed measures and their contribution to sustainable development objectives. It provides also a detailed analysis of those effects of enlargement likely to affect the structure and performance of the EU transport system.

The study takes a three pillar approach based on the use of analysis, indicators and models. National transport policies are reviewed for compatibility and coherence with the White Paper objectives. The models used allow a detailed analysis of the freight market, the passenger market and their infrastructure networks under a number of scenarios.

Scope of this Annex

The specific aim this report is the analysis of the macro-economic impact of four different policy scenarios, representing different degrees of implementation of the White Paper measures.

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ANNEX XII Macro-economic impact of the White Paper policies

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XII.1. Executive summary

XII.1.1. The methodology

The first stage of the task activities has been the analysis of the relationship between transport and economic growth. As remarked by the several approaches in explaining transport effects on economy, the debate about such a relationship is usually not clear and lacks of a universal shared explanation. Besides, it should be taken into account that it is often quite difficult to isolate the effects of transport on national regional and local level, where other kinds of investments and policies influence the economy. Three main theoretical approaches have been analysed: the macroeconomic approach, the microeconomic approach and the general equilibrium approach. Each of them focuses on different economic variables and has a different capability of addressing the multiple dimensions involved in the White Paper measures. A fourth approach, based on the System Dynamics Modelling, has been recently developed and has proved its flexibility and capability of including both micro and macro variables in the analysis. This latter approach, represented by the ASTRA System Dynamics model, is the one adopted for the assessment of the macro-economic effects of the ASSESS policy scenarios.

Given the strategic nature of the ASTRA System Dynamics model and the constraints of the project resources, the methodology adopted has been necessarily simplified, although the three scenarios have been adequately represented by the key model variables. Nevertheless, the results are of some interest.

XII.1.2. The application of the ASTRA model

The ASTRA model is a System Dynamics model at the European scale focused on describing the linkages between transport, economy and environment. The model has been developed in the last years from the original version built in the ASTRA project (1997)[1] and updated within the TIPMAC project (2002)[2] and, recently in the LOTSE study (2004)[3].

The ASTRA model offers the possibility to simulate the effect of transport measures within a complex dynamic structure of direct and feed-back links between transport and the economy. The macroeconomic module of ASTRA is built as a demand-supply interaction model: in the short run, the demand side is dominating (Keynesian approach), while in the long run the supply side determines the path of development (revised Neo-classical approach).

The macro-economic module of ASTRA includes the effect of transport taxes and pricing in terms of reduced disposable income. Furthermore, pricing and taxes make also transport a more expensive input thus, through the Input-Output table affecting the whole economy.

[1] ASTRA: Assessment of Transport Strategies. 4th EU RTD Framework Programme.
[2] TIPMAC: Transport infrastructure and policy: a macroeconomic analysis for the EU, 5th EU RTD Framework Programme.
[3] LOTSE - Quantification of technological scenarios for long-term trends in transport. JRC – IPTS Seville

Private and public investments are modelled separately in ASTRA and the model accepts the existence of a crowding-out effect of public investments. Therefore, financing public investments by means of taxes is positive in terms of multiplier effect, while it is negative in terms of reduction of private investments and reduced disposable income. In other words, the net results of public expenditure and taxes is not defined in advance but depends on the intensity of the multiplier effects and of the crowding-out for the specific policy implemented.

The crowding-out effect is modelled in ASTRA by means of a relationship between the share of government debt on GDP and the private investment. As much as the debt/GDP increases, a larger share of private investments is crowded out. The effect is null up to a debt/GDP ratio of 25%, and then increases. For a 100% ratio, 10% of private investments are suppressed.

The ASTRA model has been applied to assess the macro-economic impacts of the three modelling scenarios (Partial, Full and Extended Scenarios, see annex V to the Final Report for more details), which consider different degrees of White Paper policies implementation.

The model has been used to analyse the impacts on two variables, namely GDP and Employment, for the year 2010 and 2020. Impacts have been estimated for EU25 as a whole, as well as for EU15 as a whole and the ten New Member States as a whole. In addition to the three scenarios, additional sensitivity analysis have been carried out with special reference to the effect of boosting the development of innovative vehicles and of alternative uses of infrastructure charging revenues.

XII.1.3. The estimated macro-economic impact

The effect of the measures of the White Paper on the main macro-economic variables is slightly positive for all scenarios, as it can be seen in the table below, where results are shown as absolute difference between yearly growth rates of GDP and employment in the period 2000 – 2020 with respect to the Null scenario. To understand the size of the effects, one can take into account that a difference of 0.1 in the yearly growth rate leads to a 2% higher GDP at 2020 (see the second table below).

Table 1: ASTRA results for the Assess scenarios: absolute difference between yearly growth rates with respect to the Null scenario

	GDP			Employment		
Scenarios	**EU25**	**EU15**	**NMS**	**EU25**	**EU15**	**NMS**
Partial	0.047	0.047	0.044	0.024	0.026	0.022
Full	0.080	0.081	0.066	0.040	0.044	0.028
Extended	0.100	0.100	0.093	0.049	0.053	0.039

ASTRA model

Table 2: ASTRA results for the Assess scenarios: total % difference with respect to the Null scenario at 2010 and 2020

	GDP						Employment					
Scenarios	**EU25**		**EU15**		**NMS**		**EU25**		**EU15**		**NMS**	
	2010	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Partial	0.5%	0.9%	0.5%	0.9%	0.4%	0.9%	0.2%	0.5%	0.3%	0.5%	0.2%	0.4%
Full	0.8%	1.6%	0.8%	1.6%	0.7%	1.3%	0.4%	0.8%	0.4%	0.9%	0.3%	0.6%
Extended	1.0%	2.0%	1.0%	2.0%	0.9%	1.9%	0.5%	1.0%	0.5%	1.1%	0.4%	0.8%

ASTRA model

The variations of GDP and employment are higher for the Extended scenario and lower for the Partial scenario, while the Full scenario is in between. As the main feature of the Extended scenario is the full implementation of the infrastructure charging (with a correspondent reduction of direct taxes), the better performance of this scenario can be explained by a more efficient distribution of resources between private and public consumptions, obtained by the introduction of pricing policies together with the reduction of direct taxes.

The estimated size of the increment of GDP and employment is small, although it should be remarked that the measures of the White Paper are not aimed at the economic development of Europe rather than at the increase of the general welfare of European citizens. Therefore, it was not expected that the effects on the macro-economic side were largely positive. In brief, the simulations made with the ASTRA model suggest that implementing the measures of the White Paper should not have significant impacts on the economy and, when marginal effects can be detected, they are positive.

The first sensitivity test analysed the option of using the additional revenues of infrastructure charging to finance the TENs projects instead of reducing direct taxes. In modelling terms, this means that the resources needed for financing the new infrastructure are not found increasing the public debt. The difference for the Extended scenario are really tiny (see test a in the 2 tables below), and it might be possible to conclude that infrastructure charging can have positive effects on the economy if revenues are used to reduce either taxes or public debt. The simulation exercise does not produce significantly different outcomes between the two alternative use of revenues, and specific circumstances in the actual economy should suggest the most preferable way to act.

Table 3: ASTRA results for sensitivity test scenarios: absolute difference between yearly growth rates with respect to the Null scenario

	GDP			Employment		
Scenarios	**EU25**	**EU15**	**NMS**	**EU25**	**EU15**	**NMS**
a) Extended scenario + use of revenues for financing TENs	0.099	0.099	0.088	0.047	0.050	0.038
b) Null scenario + TENs investments	0.003	0.003	0.008	0.002	0.002	0.003
c) Extended scenario + boosting of innovative vehicles	0.102	0.103	0.096	0.050	0.054	0.038

ASTRA model

Table 4: ASTRA results for sensitivity test scenarios: total % difference with respect to the Null scenario at 2010 and 2020

	GDP						Employment					
Scenarios	**EU25**		**EU15**		**NMS**		**EU25**		**EU15**		**NMS**	
	2010	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
a) Ext+fin TENs	1.0%	2.0%	1.0%	2.0%	0.9%	1.8%	0.5%	1.0%	0.5%	1.1%	0.4%	0.8%
b) Null+TENs	0.0%	0.1%	0.0%	0.1%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
c) Ext+inn. veh.	1.0%	2.1%	1.0%	2.1%	1.0%	1.9%	0.5%	1.0%	0.5%	1.1%	0.4%	0.8%

ASTRA model

Given these results, it is not surprising that the outcome of the second sensitivity test, where only TENs where implemented (i.e. any other measures have been excluded, see test b in Table 3 and Table 4), shows that the investments in new infrastructures do not produce really different results with respect to the baseline (Null scenario), given the assumption that a crowding out effect exist. If the somewhat controversial crowding out assumption is removed, than the effect of the TENs investment is slightly positive. However, as the theoretical references of the whole Maastricht approach assume that the crowding out effect exists, it seems consistent to include such an effect in the simulation.

In the third sensitivity scenario (test c in Table 3 and Table 4), a faster development of innovative vehicles and of the economic effects of their introduction (i.e. the impulse to private investments in the several sectors linked to automotive industry) have been simulated, in addition to the measures of the Extended scenario. The economic effects of this scenario are slightly positive, although there is not any significant difference with respect to the Extended scenario until 2020 as at that year the share of innovative vehicles in the fleet is still limited. Afterwards, this measure is potentially able to add more to the economic growth.

A further sensitivity scenario has been run to test the effect of a different version of the Partial scenario (called Partial-B scenario) defined at the very end of the project, where infrastructure charging has been quantified according to current tolling and the Eurovignette directive and where measures concerning the harmonisation of checks and penalties on road freight transport have been considered as not having a significant effect on the road freight costs. In brief, road freight costs grow less in Partial-B scenario. The results of the simulation (Table 5 and Table 6) are in line with the other scenarios: the difference with respect to the Null scenario is little but positive, the impact on GDP and employment growth is slightly better than in the original Partial scenario, as the transport costs are lower.

Table 5: ASTRA results for Partial-B scenario: absolute difference between yearly growth rates with respect to the Null scenario

	GDP			Employment		
Scenario	**EU25**	**EU15**	**NMS**	**EU25**	**EU15**	**NMS**
Partial B	0.074	0.075	0.052	0.041	0.046	0.026

Table 6: ASTRA results for the Partial-B scenario: total % difference with respect to the Null scenario at 2010 and 2020

	GDP						Employment					
Scenario	**EU25**		**EU15**		**NMS**		**EU25**		**EU15**		**NMS**	
	2010	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Partial B	0.7%	1.5%	0.8%	1.5%	0.5%	1.1%	0.4%	0.8%	0.5%	0.9%	0.3%	0.5%

XII.2. The relationship between transport and economic growth

There are several good reasons why it is necessary to understand the nature of the relationship between transport and economic growth. First of all, transport investments, as a part of public spending, are usually justified by their capacity in boosting economic growth, promoting sustainable development and pursuing economic and social objectives. Transport improvements are also contributing to market integration. Furthermore, investments in transport sector are usually supposed to be able in influencing economic regeneration of particular areas or particular industrial sectors. As remarked by the presence of several approaches in explaining transport effects on economy, the debate about such a relationship is usually not clear and lacking of a universal shared explanation. Besides, it should be taken into account that it is often quite difficult to isolate the effects of transport on national regional and local level, where other kinds of investments and policies influence the economy.

In general terms, the effects of transport investments and policies on economy could be split in three categories: macro-economic effects, spatial effect, micro-economic effects.

XII.2.1. Macro-economic effects

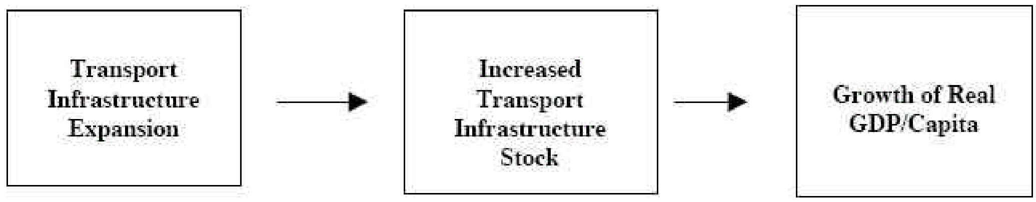
The close correlation between economic growth and increased movement - and, since 1945, the correlation in particular between road traffic growth and economic growth - is seen as evidence of a close link between transport and the economy. But this does not help to clarify the direction of cause and effect: whether increased movement is a sign of economic growth stimulated by other factors; whether traffic growth, facilitated by transport improvements, itself stimulates economic activity; or whether there is some iteration of the two.

Commentators point to the historical contribution of transport improvements to economic development. This is particularly true of the case of developing countries, where transition from a fragmented communications system to even a poorly developed network is of great importance. In this sense, the complete absence of a well developed transport system acts as a serious constraints on growth. It helps to explain why up to 40% of World Bank loans have been used on transport projects an a similar emphasis on transport can be found in the portfolio of the European Investment Bank. The lack of an effective transport system appear, according to some authors, to be a constraint on a regional economy achieving its full production potential in some regions.

Furthermore, a study of the inequalities in and production potential of European regional economies (Biehl, 1986; 1991) explained the differences in per capita GDP as a function of the regional endowments of labour, capital and various forms of infrastructure. While the lack of an effective transport system did appear to be a constraint on a regional economy achieving its full production potential in some regions, it was shown that in many poorer regions this was not the case and thus that simply improving transport would not lead to growth without other parallel interventions

Another line of argument suggests that public investment in transport does in fact have more than a marginal positive impact on GDP. Aschauer (1989) argues that public investment in infrastructures leads to improvements which increase firm's profitability –or rate of return to private capital (such as the capital invested in a company's distribution fleet). Firms then respond to increased profit by expanding the pace of capital investment, in turn leading to higher employment and output, so perpetuating a further virtuous spiral of investment. The result, contends Aschauer, is that public infrastructure investments are important source of economic growth, that in the long run more than outweigh any short run crowding out of private investments.

Figure 1: Infrastructure and Economic Growth



Source: Lakshmanan and Anderson, 2002

Critics, however, claim that these suggested high rates of return on public investment simply defy experience. They also point out that the empirical evidence used by Aschauer (1989) could suggest a different relationship of cause and effect - higher transport investment not causing economic growth but being made affordable by that growth in income.

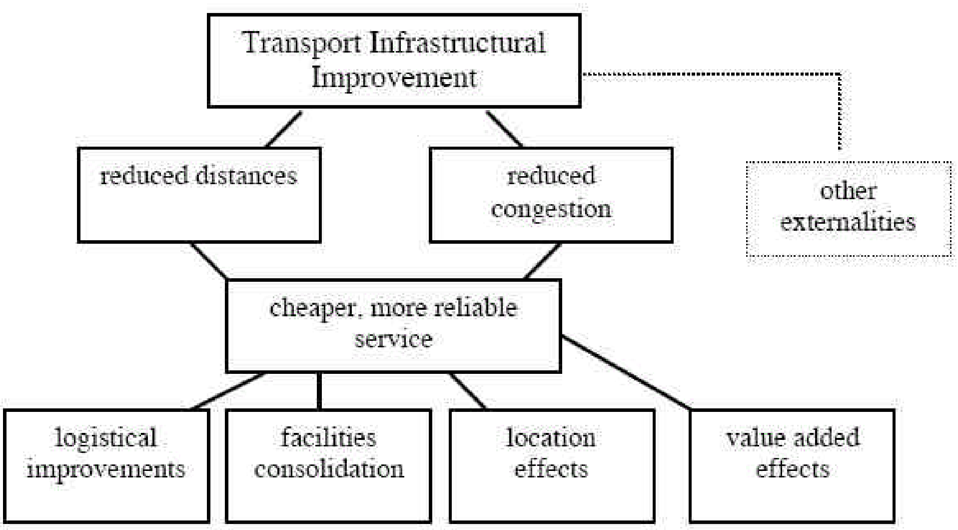
The research carried out by Fritsch and Prud'homme (1997) for French regions comes out with lower production elasticises, in comparison with the one estimated by Aschauer, growth effect could not be identified in terms of additional companies undertakings, but in terms of a clear contribution to an increase in productivity of both labour and capital. Fritsch and Prud'homme have attempted different means of measuring public capital from physical indicators and have used measures of infrastructure relative to population or area of the region to capture differences in presumed infrastructure needs between sparsely and heavily populated areas. These suggest a significant positive rate of return to public capital, but interestingly suggest little or no influence on the location of private capital.

In general, all the macroeconomic analysis suggests that, as a rule, investments in transport infrastructure contribute to a better use of existing resources. Whether this leads to an extension of production activity or higher employment is dependent on further factors. The inclusion of transport policies, other then investments, makes the picture more complicated.

XII.2.2. Micro-economic effects

Transport, as one factor in the production of goods and service, represents a cost to individual business. A traditional theoretical view suggests that a transport improvement, which reduces transport cost, enables firms to sell their products more cheaply by reducing their production cost. This stimulates grater demand, so as firm enjoy scale economies, a virtuous circle of further cost reduction and sales growth is set in motion. However, it should point out that the scale of the effect of transport cost reduction on firm productivity is an issue quite discussed in the economic literature.

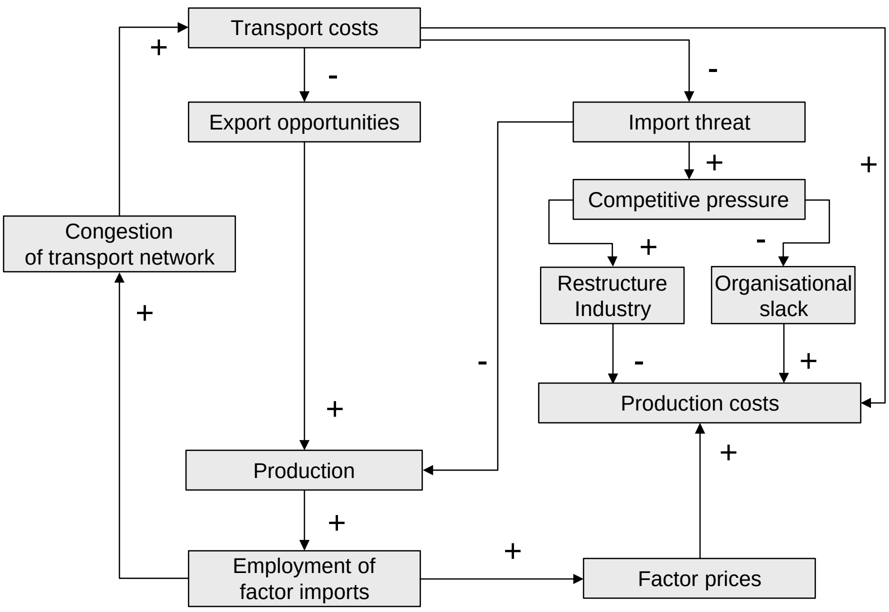
Figure 2: Micro-economic impacts



Source: Lakshmanan and Anderson, 2002

Better transport conditions also allow firms to reach and sell their products in other markets, At the same time, the possibility to be reached by new competitors offers a wider products range to the consumer. In other terms, a improvement of transport boost the market competitiveness. Anyway, it should be mentioned that sometimes, as in the case of local monopolies, the increased market accessibility could be a damaging factor for the local monopolies.

Figure 3: Transport costs and integration of markets: static effects



Source: *SACTRA 1999*

Figure 3 illustrates the way in which changes in transport costs, due to investment policies, changes in level of congestion or pricing policies, might affect productivity. A series of key variables have to be taken into account in order to assess the, positive or negative, impacts of changes in transport costs.

- First of all, whether or not, and to what extent, changes in transport costs are transferred into changes in transport price paid by transport-using sectors or will stay in the transport sector. This will mainly depend on the openness of the transport market.
- Secondly, it is important where the reductions occur, in the links with the rest of the world, thus affecting import and export or within the local market, therefore reducing factor prices and production costs in comparison with other regions.
- Third, changes in transport prices may have effects, which work through onto the demand for factor inputs, including in particular land and labour markets. Transport cost may widen labour market areas, but if there are bottlenecks such as full employment of labour or shortage of developed land, then the impact will be increasing factor prices.
- A fourth relevant aspect concerns the long terms impacts. Firms may re-locate (see the following paragraph on spatial impacts), but also transport technology may change, as transport manufacturing industries may react to new market conditions by speeding up research in innovative or more efficient engines. The increase in fuel prices is already pressing toward more efficient technologies and therefore, in the medium run, some cost increase will be offset either by technological improvements or by industries moving towards cheaper regions.
- Finally, higher production may raise the volume of traffic and end up increasing transport costs by increased congestion, and vice-versa, increase in transport cost may reduce transport and congestion, and end up with a decrease in transport costs.

The diagram in Figure 3 deals mainly with freight transport; another open issue concern passengers travel time and costs, and in particular business travel. It seems that as long as the production drifts toward less and less material content ("brainware" and specialized services), so grows the importance of passenger mobility, both for the efficiency of the ever-increasing executive personnel, and for attracting in non-congested (and polluted) areas "rare", high-skilled workforce at every level. Furthermore when surveyed, business claim that transport improvements are important to competitiveness, and that they are able to use time savings from transport improvements productively, often leading to wider business benefits, for example in the form of restructured logistical operations.

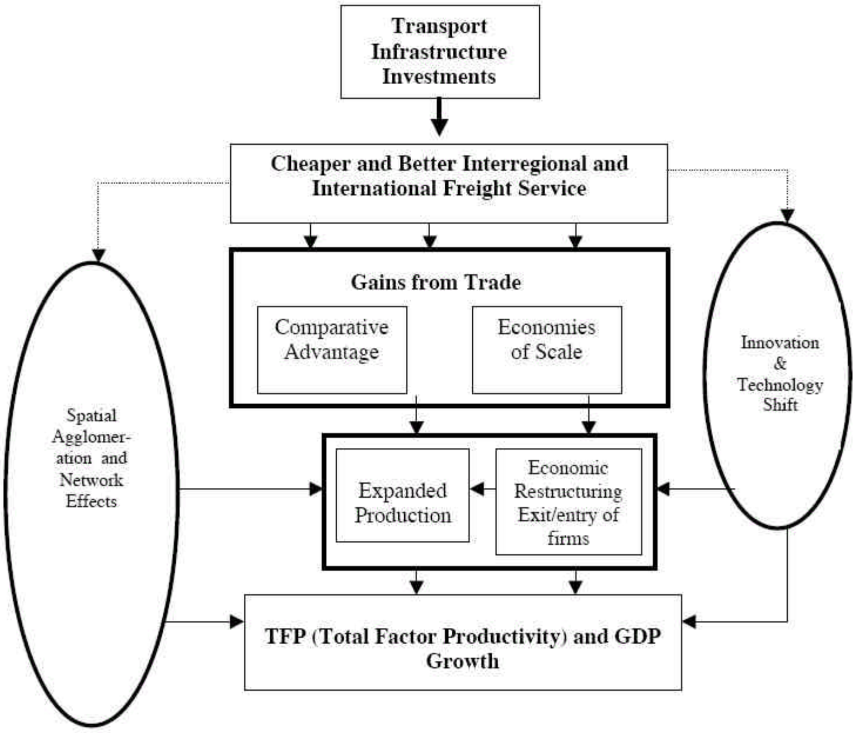
XII.2.3. Competitiveness effects

Competitiveness benefits occur when cost reductions or improvements in transportation services result in a redistribution of resources across firms and regions, in such a way as to increase aggregate productivity.

These benefits arise in the form of gains from trade. One of the main historical consequences of improved transportation services has been a shift from a regime of economic autarky, whereby each region or nation produces a wide variety of goods to satisfy its own demands, to one of specialization and trade, whereby each region or nation concentrates its productive resources on a smaller number of goods and services and trades in order to satisfy it full range of demands.

This may yield economic benefits for two reasons. First, different regions have different resource endowments, which make them most efficient at producing different things. If each region specializes in those things, it can produce most efficiently and overall productivity is enhanced. Second, even if all regions are similarly endowed, specialization implies that each region produces fewer goods, but more of each good it produces. Thus, economies of scale are realized. These two explanations for gains from trade are associated with two streams of economic theory: the theory of comparative advantage and the "new economic geography".

Figure 4: General Equilibrium Effects



Source: Lakshmanan and Anderson, 2002

- *Comparative Advantage*

The theory of comparative advantage has its roots in the 19th century, when the British economist David Ricardo argued against the "corn laws", which restricted imports of agricultural commodities into Great Britain. Ricardo's ideas have been refined by modern economists, but the basic message is the same: all trading partners are better off if they specialize in those things in which they have comparative advantage, than if they seek to achieve self sufficiency by producing a large variety of goods. Note that this is a general equilibrium benefit in that it does not arise due to improved productivity in individual production units, but rather from a redistribution of production that leads to higher aggregate productivity. An important caveat to this, however, is that gains from trade can only be realized to the extent that they exceed the transportation costs needed to achieve them. Therefore, one of the most important benefits of improved transportation infrastructure arises from its role in enabling gains from trade.

The theory of comparative advantage has been the major economic argument in favour of liberalizing international trade. One might assume therefore that economic benefits in the form of gains from trade arise primarily from investments in infrastructure built mainly for international trade: international shipping and air facilities, international bridges, facilities for rapid border clearance etc. In fact, recent experience shows that such infrastructure, along with complementary institutional changes, is critical to the success of regional economic integration initiatives (Lakshmanan Subramanian, Anderson and Leautier, 2001.) The role of infrastructure in trade creation, however, extends more broadly to the national infrastructure system, since domestic transportation is needed to bring export goods to international gateways.

More important, the notion that transportation infrastructure yields economic benefits that come in the form of gains from trade applies just as well to domestic trade as to international trade – especially in an economy as large and diverse as ours. Any project that makes interregional trade easier and cheaper results in improved efficiency (and thereby reduced costs) for those goods that are shipped inter-regionally.

- *The New Economic Geography*

Comparative advantage essentially says that gains from trade arise out of diversity across nations. But many of the most important trade relations occur between places that are in fact very similar, such as the United States and Canada or states within the European Community. Furthermore, in many bilateral trade partnerships, goods in the same industry group flow in both directions across the border. Such intra-industry trade is again inconsistent with the theory of comparative advantage, which envisions only exchanges of dissimilar goods.

In light of the inability of comparative advantage to explain some important trends in trade, a new analytical framework called the "new economic geography" has emerged. Where the theory of comparative advantage is driven by variations in endowments, the new economic geography is driven by scale economies. The crux of this theory is that even if all regions have identical endowments, if each region specializes in unique goods, which it supplies to all other regions, it will achieve higher productivity though economies of scale.

Naturally, the theory is more complicated than this. It is based in a model where product variety is the critical component of competition so that all firms produce distinct but substitutable goods. Consumers' utility functions are defined in such a way that they prefer to consume a variety of goods rather than to concentrate their production on a small number of goods. Thus, goods are imperfect substitutes. This means that each firm has some degree of monopoly power and can therefore set its price above its marginal cost. The cost structure for each firm includes a fixed component and a constant marginal cost, which results in a downward sloping average cost function indicative of scale economies.

By opening up trade, producers in each region are able to reach broader markets for their unique goods, allowing them to move down their average cost curves and earn greater profits. Naturally, this market expansion effect is limited by interregional transportation costs, so any reduction in transportation costs yields increased trade benefits. The model also integrates consumer demand and labour markets.

By stressing the role of product differentiation, it brings theory more in line with modern economies, where homogeneous commodities play shrinking roles. Product differentiation naturally leads to imperfect competition and the inclusion of scale economies permits a formal treatment of spatial phenomena, such as agglomeration economies and regional wage differences. Most importantly from our perspective, the inclusion of space naturally leads to a more central role for transportation.

A recent study commissioned by the Standing Advisory Committee on Trunk Road Assessment in the United Kingdom illustrates some of the new insights that can be gained by applying the analytical framework of the new economic geography to questions of transportation investment. The hypothetical simulations, made in this study, illustrate that:

- Lower transportation costs lead to greater regional specialization;
- Reducing transportation costs along two routes simultaneously yields benefits that are greater than the sum of benefits when they are lowered independently;
- Transport cost reductions that have positive benefits in aggregate may have negative effects on some regions;
- Reduction in transportation cost may reduce or increase interregional wage differences, depending upon the context.

XII.3. Theoretical approaches for analysing economic effects of transport

The previous chapter has highlighted how the impact of transport and the economic growth is complex. A part from the analysis of single case studies, there exists a broad spectrum of approaches that deal with the problem of assessing the impacts of transport on the economic side. However, none of such approaches is really comprehensive and free of criticisms, both on the theoretical side and in terms of predictive capacity. Actually, most of the approaches are focused on the macroeconomic impacts of investments in transport infrastructure, the microeconomic analysis as well as the analysis of the impacts of transport policies are very rare, and normally have a local focus, trying to capture the contribution of transport to the competitiveness of a region.

Originating from different scientific disciplines and intellectual traditions, these approaches presently coexist, even though they are partially in contradiction (Linnecker, 1997). Their main features are presented below.

XII.3.1. Macro-economic approach

National growth approaches model multiplier effects of public investment in which public investment has either positive or negative (crowding-out) influence on private investment, here the effects of transport infrastructure investment on private investment and productivity. In general, only national economies are studied and regional effects are ignored. Pioneered by Aschauer (1989; 1993), such studies use time-series analyses and growth model structures to link public infrastructure expenditures to movements in private sector productivity. An increase in public investment raises the marginal product of private capital and provides an incentive for a higher rate of private capital accumulation and labour productivity growth. Critics of these approaches argue that there may be better infrastructure strategies than new construction, and that policy measures aimed at increasing private investment directly rather than via public investment will have greater impact on national competitiveness.

Regional growth approaches rest on the neo-classical growth model, which states that regional growth in GDP per capita is a function of regional endowment factors, including public capital such as transport infrastructure, and that, based on the assumption of diminishing returns to capital, regions with similar factors should experience converging per-capita incomes over time. The suggestion is that, as long as transport infrastructure is unevenly distributed among regions, transport infrastructure investments in regions with poor infrastructure endowment will accelerate the convergence process, whereas once the level of infrastructure provision becomes uniform across regions, they cease to be important. Critics of regional growth models built on the central assumption of diminishing returns to capital argue that they cannot distinguish between this and other possible mechanisms generating convergence, such as migration of labour from poor to rich regions or technological flows from rich to poor regions.

XII.3.2. Micro-economic approach

Production function approaches model economic activity in a region as a function of production factors. The classical production factors are capital, labour and land. In modern production function approaches infrastructure is added as a public input used by firms within the region (Jochimsen, 1966; Buhr, 1975). The assumption behind this expanded production function is that regions with higher levels of infrastructure provision will have higher output levels and that in regions with cheap and abundant transport infrastructure, more transport intensive goods will be produced. The main problem of regional production functions is that their econometric estimation tends to confound, rather than clarify, the complex causal relationships and substitution effects between production factors. This holds equally for production function approaches, including measures of regional transport infrastructure endowment. In addition, the latter suffer from the fact that they disregard the network quality of transport infrastructure, i.e. treat a kilometre of motorway or railway the same everywhere, irrespective of where they lead.

XII.3.3. General equilibrium approach

Accessibility approaches attempt to respond to the latter criticism by substituting more complex accessibility indicators for the simple infrastructure endowment in the regional production function. Accessibility indicators can be any of the indicators (discussed in Schürmann et al. 1997), but in most cases are some forms of population or economic potential. In that respect, they are the operationalisation of the concept of "economic potential", which is based on the assumption that regions with better access to markets have a higher probability of being economically successful. Pioneering examples of empirical potential studies for Europe are Keeble et al. (1982; 1988). Today approaches relying only on accessibility or potential measures have been replaced by the hybrid approaches, were accessibility is but one of several explanatory factors of regional economic growth. Also, the accessibility indicators used have become much more diversified by type, industry and mode (see Schürmann et al., 1997). The SASI model is a model of this type, incorporating accessibility as one explanatory variable among other explanatory factors.

Regional input-output approaches model interregional and inter-industry linkages using the Leontief (1966) multiregional input-output framework. These models estimate inter-industry interregional trade flows as a function of transport cost and a fixed matrix of technical inter-industry input-output coefficients. Final demand in each region is exogenous. Regional supply, however, is elastic, so the models can be used to forecast regional economic development. One example of an operational multiregional input-output model is the Meplan model (Marcial Echenique & Partners Ltd., 1998).

Trade integration approaches model interregional trade flows as a function of interregional transport and regional product prices. Peschel (1981) and Bröcker and Peschel (1988) estimated a trade model for several European countries as a doubly-constrained spatial interaction model with fixed supply and demand in each region in order to assess the impact of the economic integration of Europe in terms of reduced tariff barriers and border delays between European countries. Their model could be used to forecast the impacts of transport infrastructure improvements on interregional trade flows. If the origin constraint of fixed regional supply were relaxed, the model could be used also for predicting regional economic development. Krugman (1991) and Krugman and Venables (1995) recommended this simple model of trade flows by the introduction of economies of scale and labour mobility. The CGEurope is a model of this type.

XII.3.4. System Dynamics approach

System Dynamics is not focused on the analysis of specific fields like economy or transport, but is a general approach that can be applied to any system that satisfy some basic conditions. Indeed, the starting point of System Dynamics theory was the investigation of some important characteristics of the behaviour of social systems at the micro scale (Forrester, 1995). System Dynamics models assume that the behaviour of systems is primarily determined by their *feedback mechanisms*. Therefore, after definition of the system borders, to distinguish between exogenous and endogenous variables, the description of feedback loops identified is the main step in the System Dynamics modelling process.

In brief, a System Dynamics model consists of a set of hypotheses on the relationship between causes and resulting effects. Hypotheses could be based on theory or only informed by theory, but empirical inputs from statistics, survey or other observation could also be used. Relationships are represented by equations that are declared and solved by mathematical simulation. In other words, a System Dynamic model does not have a specific set of unknown parameters or variables whose value is estimated as solution of the model. Instead, most of the model variables vary over time as effect of the reciprocal links (direct and indirect) existing among them. The model never reaches the equilibrium, but evolves continuously.

Recently, the System Dynamic approach has been applied to the analysis of the transport systems and its links with the economy and the environment. In the ASTRA project (1997) a first version of a System Dynamics model at the European scale focused on describing the linkages between transport, economy and environment was developed. In its first version and in following developments, the model proved its potential for analysing transport policy scenarios and providing measures of their effects on the macro-economic side.

An interesting feature of this model is that it is not constrained within one of the theoretical approaches described above. The open structure of a System Dynamics model allows to incorporate and to integrate different relationships between variables. This feature allows for a wider range of policies that can be analysed.

XII.4. The ASTRA System dynamic model

The ASTRA model is a System Dynamics model at the European scale focused on describing the linkages between transport, economy and environment. The model has been developed in the last years from the original version built in the ASTRA project (1997)[4] and updated within the TIPMAC project (2002)[5] and, recently in the LOTSE study (2004)[6].

XII.4.1. Overview of the model

The ASTRA model consists of eight main modules: Population Module (POP), Macro-economic Module (MAC), Regional Economic Module (REM), Foreign Trade Module (FOT), Transport Module (TRA), Environment Module (ENV), Vehicle Fleet Module (VFT) and Welfare Measurement Module (WEM). The following figure shows the interrelationships between the eight ASTRA modules, highlighting the major output variables coming from, and input variables going into, the modules. Herewith an essential description of the modules is provided; the reader is referred to the documentation of the projects mentioned above for further details.

The Population Module (POP) provides the population development for each modelled country with one-year age cohorts. The model depends on exogenous factors like fertility rates, death rates, infant mortality rates and migration.

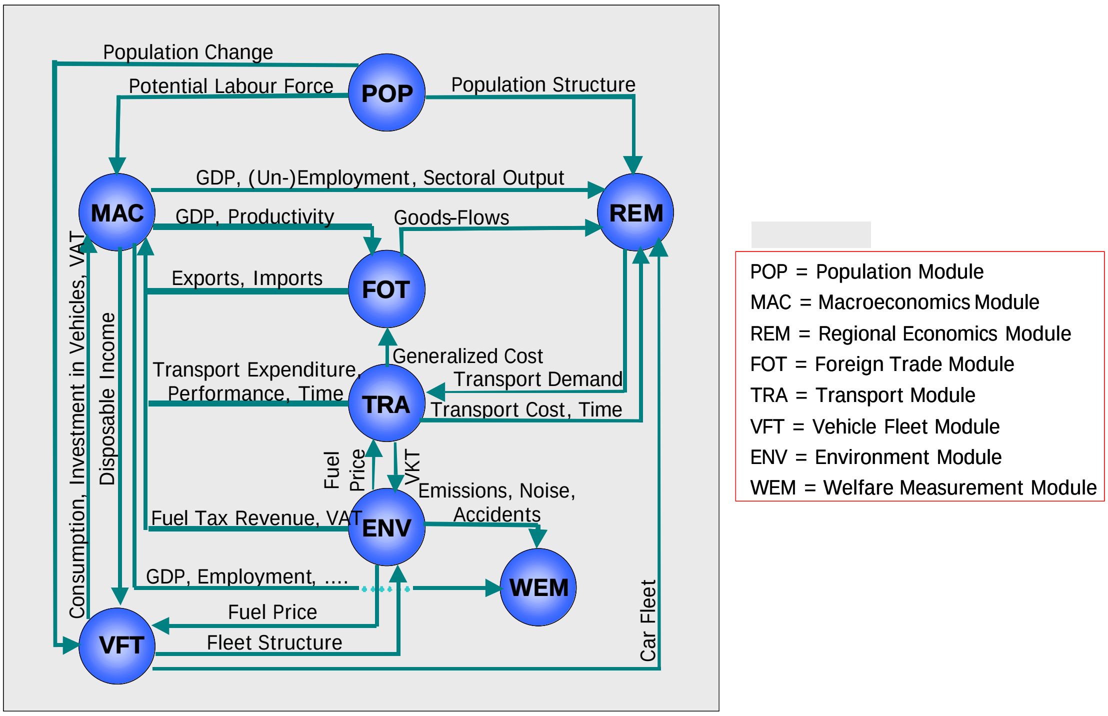
Five major elements constitute the Macro-economic Module (MAC). First, the *sectoral interchange model* reflects the economic interactions between 25 economic sectors of the national economies by an Input-Output table structure. Second, the *demand side model* depicts the four major components of final demand: consumption, investments, exports-imports (which is modelled in detail in the foreign trade module) and the government consumption. Third, the *supply side model* has as basic element a production function of Cobb-Douglas type calculating potential output incorporating three major production factors: labour supply, capital stock and natural resources; technical progress is considered under the from of Total Factor Productivity (TFP), endogenised as depending on sectoral investments, freight transport time-savings and labour productivity changes. The fourth element of MAC consists in the *employment model* that is based on value-added as output from input-output table calculations and labour productivity. The fifth element describes *government behaviour*.

[4] ASTRA: Assessment of Transport Strategies. 4th EU RTD Framework Programme.

[5] TIPMAC: Transport infrastructure and policy: a macroeconomic analysis for the EU, 5th EU RTD Framework Programme.

[6] LOTSE - Quantification of technological scenarios for long-term trends in transport. JRC – IPTS Seville

Figure 5: The structure of the ASTRA model



Source: LOTSE - Quantification of technological scenarios for long-term trends in transport. Final Report

The Regional Economic Module (REM) mainly provides the generation of freight transport volume and passenger trips. The number of passenger trips is driven by the employment situation, the car-ownership situation and the number of people belonging to different age classes. Domestic freight transport depends on output by sector that is translated into flows for the fifteen sectors, which produce goods by means of value-to-volume ratios.

In the foreign trade module (FOT) trades are mainly driven by relative productivity between modelled countries (or between the modelled countries and the rest-of-the-world), GDP growth of importing country and world GDP growth, as external factors to trade. Additionally, the INTRA-EU trade flows depend on the development of averaged generalized cost of transport between each O/D country pair.

The major input of the Transport Module (TRA) is the link based transport demand for passenger and freight transport. Using transport costs and transport time matrices, the transport module calculates the modal split based on a classical Logit functions depending on generalised costs.

The Environment module (ENV) uses the vehicle-kilometres-travelled generated by the TRA module per mode and the information from the vehicle fleet model on the drives, car categories and emission standards to calculate the most important transport emissions - CO_2, NO_x and soot particles as well as fuel consumption and fuel tax revenues. Furthermore, accident rates for each mode form the input to calculate the number of accidents in the European countries.

The Vehicle Fleet Module (VFT) calculates the vehicle fleet composition for all road modes. Vehicle fleets are differentiated into different age classes based on one-year-age cohorts and into different emission standard categories. Additionally, the car vehicle fleet is differentiated into gasoline and diesel powered cars with different cubic capacity categories.

Finally, in the Welfare Measurement Module (WEM) major macro-economic, environmental and social indicators can be compared and analysed.

One of the main features of the ASTRA model is that all main variables describing the state and the development of various systems are endogenous. In general, main input concerns basic parameters, like trip rates, transport costs, transport times, emission factors, vehicle occupancy factors, volume-to-value ratios, labour productivity, etc. Furthermore, there are additional parameters like modal constants, whose value is defined during the calibration phase.

XII.4.2. The ASTRA Macroeconomic module (MAC)

The MAC module is constructed as a demand-supply interaction model: in the short run the demand side is dominating (Keynesian approach), while in the long run the supply side determines the path of development (revised Neo-classical approach). It consists of four major elements:

- demand side model based on the elements of final demand,
- supply side model based on supply of production factors,
- sectoral interchange model based on an input-output table and
- micro-macro-bridges.

The interaction between supply and demand can be exogenously adjusted, such that the model can simulate supply-demand balanced economies but also either a supply side driven or a demand side driven economy. In the current set-up of ASTRA, both sides are treated as their influence is of the same importance.

The aggregated variable on the demand side is the final demand, which is driven by consumption, investments, government expenditures and export-import balance. Consumption and investment are split into a share that is independent from transport (macroscopic view) and a share that is dependent on the development of the transport markets. With this approach, substitution effects between transport and non-transport consumption are considered 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, however this does not mean that there will be a complete compensation because of complementarities between transport and other activities and incentive effects.

Basic element of the supply side is a production function of Cobb-Douglas type calculating potential output that incorporates the three major production factors labour supply, capital stock and natural resources as well as technical progress referred to as total factor productivity (TFP). Labour supply, capital stock and total factor productivity are calculated endogenously. Labour supply in the Cobb-Douglas function stands for an aggregate of the potential labour force and the total number of yearly worked hours. The latter is based on total employment calculated within the employment model and the number of average yearly worked hours. The capital stock depends on the initial gross capital stock, the investment (capital goods including transport investments) and the scrappage of the capital stock. Total factor productivity has been endogenised, at least partially, considering the exogenous sectoral labour productivity changes weighted by the endogenous sectoral gross-value-added (GVA) as well as the endogenous sectoral investments that have been weighted by the sectoral innovation potential.

The objective of the sectoral interchange model is to consider the indirect effects of the sectoral developments e.g. of sectoral final demand in the ASTRA model. Its basic element is an input-output-table (I-O-table) for 25 economic sectors per country. The same sectoral disaggregation as in the I-O-tables is also applied for other economic variables like consumption or investments to be able to consider the direct effects of transport developments within their corresponding sectors as well as the indirect effects in the sectors supplying intermediate products.

The micro-macro bridges provide the most important task of connecting modules that are modelled on a micro-level with modules modelled on a macro-level. The main example is the link between the transport module and the macro-economic module incorporating these results within a few variables, like consumption or investments.

The macro-economic module of ASTRA includes the effect of transport taxes and pricing in terms of reduced disposable income. Furthermore, pricing and taxes make also transport a more expansive input within the I-O table thus affecting the whole economy.

Private and public investments are modelled separately in ASTRA and the model accepts the existence of a crowding-out effect of public investments. Therefore, financing public investments by means of taxes is positive in terms of multiplier effect, while it is negative in terms of reduction of private investments and reduced disposable income. In other words, the net results of public expenditure and taxes is not defined in advance but depends on the intensity of the multiplier effects and of the crowding-out for the specific policy implemented.

The crowding-out effect is modelled in ASTRA by means of a relationship between the share of government debt on GDP and the private investment. As much as the debt/GDP increases, a larger share of private investments is crowded out. The effect is null up to a debt/GDP ratio of 25% and then increases. For a 100% ratio, 10% of private investments are suppressed.

Given this structure, the ASTRA model is able to simulate the effect of transport measures within a complex dynamic structure of links between transport and the economy. For instance, congestion reduces speed and therefore increases transport costs. As such costs are an input for the economic activity, congestion has a negative effect on the economy. However, not any indirect effect of transport policy is simulated in the model. For instance, if a pricing policy reduces traffic and air pollution and reduces the number of working hours lost for illness, this is not recognized in the model.

In brief, the model simulates the main linkages from the transport sector to the economy, like:
- the cost of transport as input for the economic activity;
- the cost of transport affecting competition for external trade;
- the weight of transport expenditure on households income;
- the weight of transport investment on total investments;
- the linkage between the production of transport means and the other industrial sectors.

At the same time, the model does not simulate the linkages from the environment to the economy, for instance it does not simulate effects like:
- the amount of money saved on medical care due to improved health of citizens;
- the increased income due to the attractiveness (e.g tourism) of a less polluted environment.

XII.4.3. The ASTRA zoning system

The zoning system used in ASTRA is a non-ordinary one, as two different spatial categorisations co-exist. The reason for this double segmentation is that it allows to simulate relevant features on the land use side and, at the same time, keeping the spatial description within a level of complexity consistent to the macro level of analysis used in the model.

The first categorisation is based on the countries. The ASTRA model cover the EU25 member states and, to complete the picture, Bulgaria, Norway, Romania and Switzerland. The second categorisation is founded on the system of European NUTS II zones that are grouped into four *functional zones* according to their settlement patterns and population densities: Metropolitan Areas (MPA); High Density Areas (HDA); Medium Density Areas (MDA); Low Density Areas (LDA). Functional zones are “nested” into each European country. This means that up to 4 functional zones (not every country has Metropolitan Areas) exist in every country (Figure 7 shows both countries and functional zones defined in the model).

Macro-economic (MAC) and environmental (ENV) sub-modules work using countries as spatial representation, while passenger generation, distribution (REM) and modal split (TRA) also consider functional zoning. Therefore, an Origin/Destination trip within ASTRA is mainly defined as from one functional zone of country A to another functional zone of country B. However, as the distance of the trip is a major determinant of availability of modes and also of their attractiveness, the origin-destination pairs are not only defined in terms of country/functional zone, but also according the average distance of the trip. This strategy is required as functional zones of each country put together different regions resulting in an entity without a real geographical meaning. Thus, a trip within the same functional zone can be either a very short trip or a long trip between two different regions. To overcome this problem, *distance bands* are used to classify the average distance of trips as depicted in Figure 6.

Figure 6: The distance bands of the ASTRA model

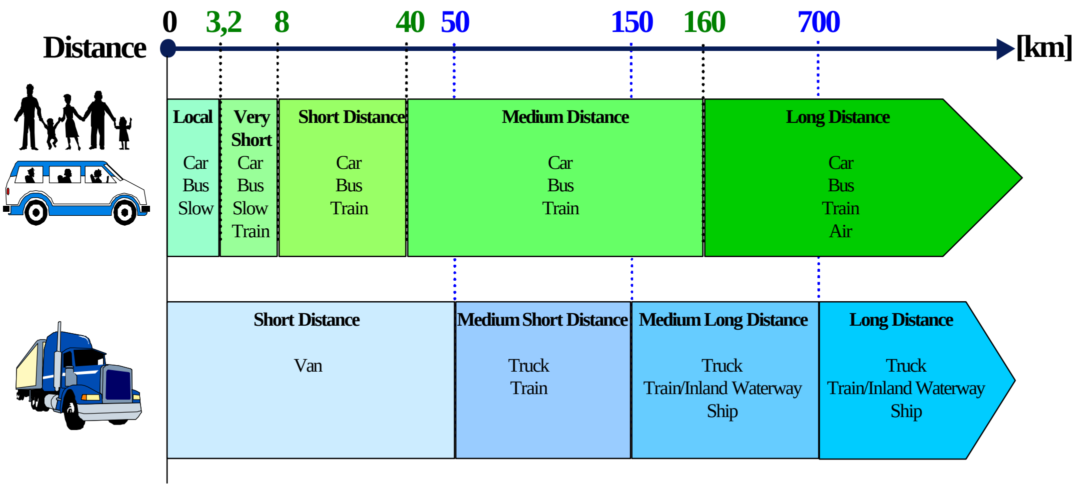
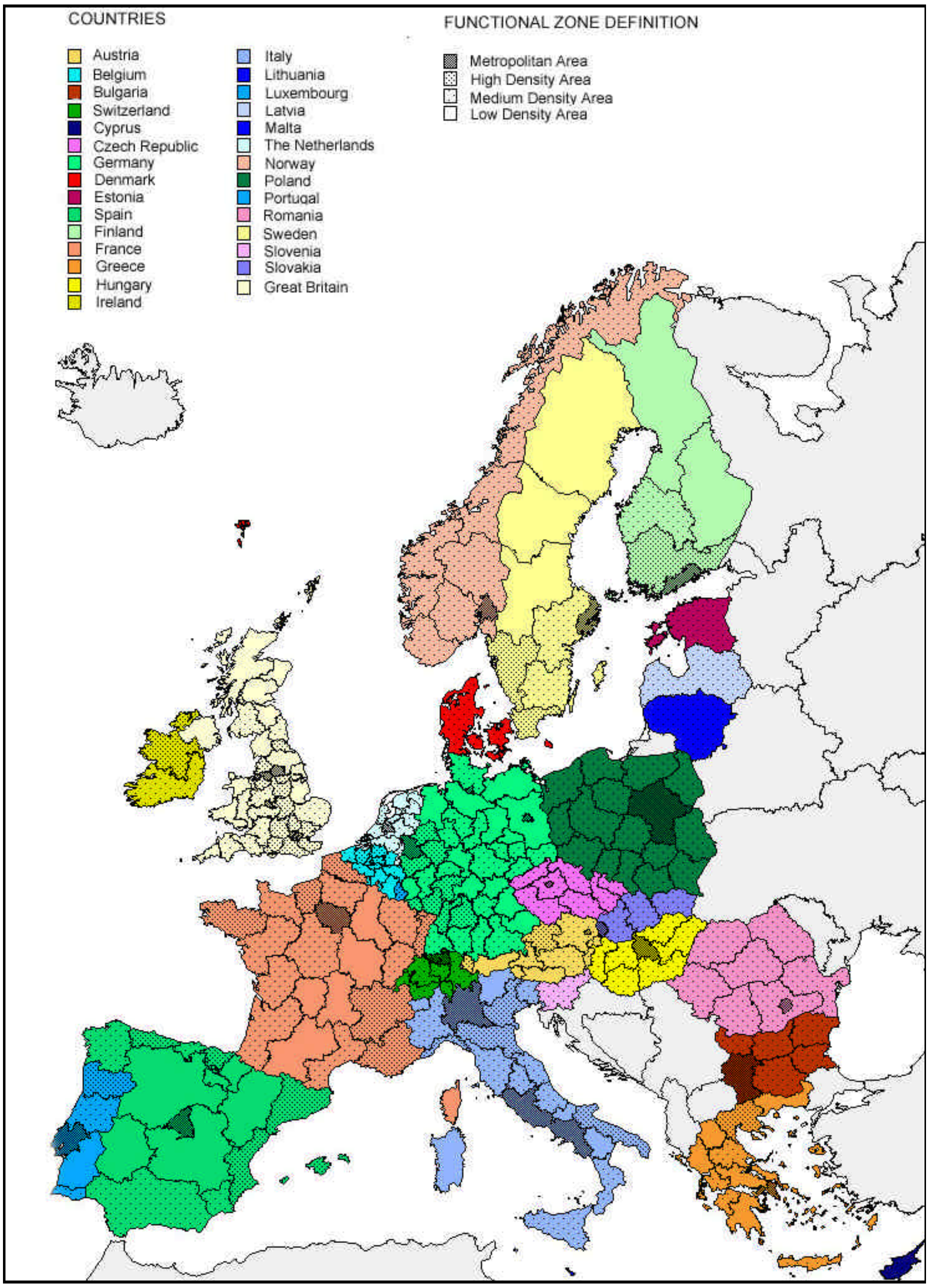


Figure 7: The zoning system of the ASTRA model



Source: LOTSE - Quantification of technological scenarios for long-term trends in transport. Final Report

XII.5. Macroeconomic impact of the ASSESS scenarios

XII.5.1. Implementation of the scenarios

The four modelling scenarios for the ASTRA model have been defined on the basis of the measures packages of the Null, Partial, Full and Extended scenarios described in paragraph V.3.1 of the Annex V. In order to ensure as much consistency as possible with the scenarios simulated by means of the SCENES and TREMOVE models, changes of the variables have been defined using values in table 16 of the Annex V.

The scenarios measures have been implemented by aggregating the packages that affects the same ASTRA model variable. Where the level of detail of the model made this possible, values have been differentiated on a country basis, otherwise average values have been used.

As explained in the previous chapter, the description of the transport system in ASTRA is at strategic level, therefore some specific transport measures (which were explicitly modelled in SCENES) have been implemented in an indirect way: the TENs investments, the effects on time at borders, the effects at freight terminals and for the inland waterway system. In such cases, the effects of measures have been aggregated to the most significant variable. For instance time at borders have been considered in the total travel time. TENs have been implemented as increment of the overall capacity of infrastructures.

At the same time, the capability offered by the ASTRA model to represent the linkages between the transport and the economic systems, have made it possible to better simulate the ASSESS scenarios taking into account two key elements: the use of the revenues of the pricing policies and the precise timing of TEN investments.

- The first element consists in the refunding of the infrastructure charge and additional fuel taxes by means of a correspondent reduction of direct taxes. This aspect is part of the White Paper strategy where it suggests that existing taxes could be lowered to avoid a net increase of taxation. Indeed, the White Paper emphasises that "*it is not so much the overall level of taxes that needs to change significantly, but rather their structure, which needs to be altered radically to integrate external and infrastructure costs into the price of transport*" and therefore the implementation of pricing measure can be neutral in fiscal terms "*by offsetting any increase in infrastructure charges by lowering existing taxes*"[7].

- The second element concerns the timing of the TENs investments. As ASTRA is a dynamic model the flow of investments over time could be implemented. The information concerning the TEN-T investments has been drawn from the 6th TEN-STAC Project Report[8] and from the Deliverable D1 of the TIPMAC Project[9]. Furthermore, the TEN-T investments have been implemented in the ASTRA model according to the status of the TEN projects in each scenario, as defined in table 2 of the Annex V. The total investments estimated after 2002 have been distributed calculating an annual share according to the deadline and the status defined in each scenario. The following pictures show the timing of the development of TEN-T investments.

[7] See White Paper, page 72

[8] TEN-STAC:scenarios, Traffic forecasts and analysis of corridors on the Trans-European Network, D6 Deliverable Part II-Traffic, bottlenecks and environmental analysis on 25 corridors.

[9] TIPMAC Project - Deliverable D1 - Annex I – Quantitative assumptions for the design of transport policy scenarios (DECEMBER 2003)

Figure 8: EU25 - TEN-T investment development

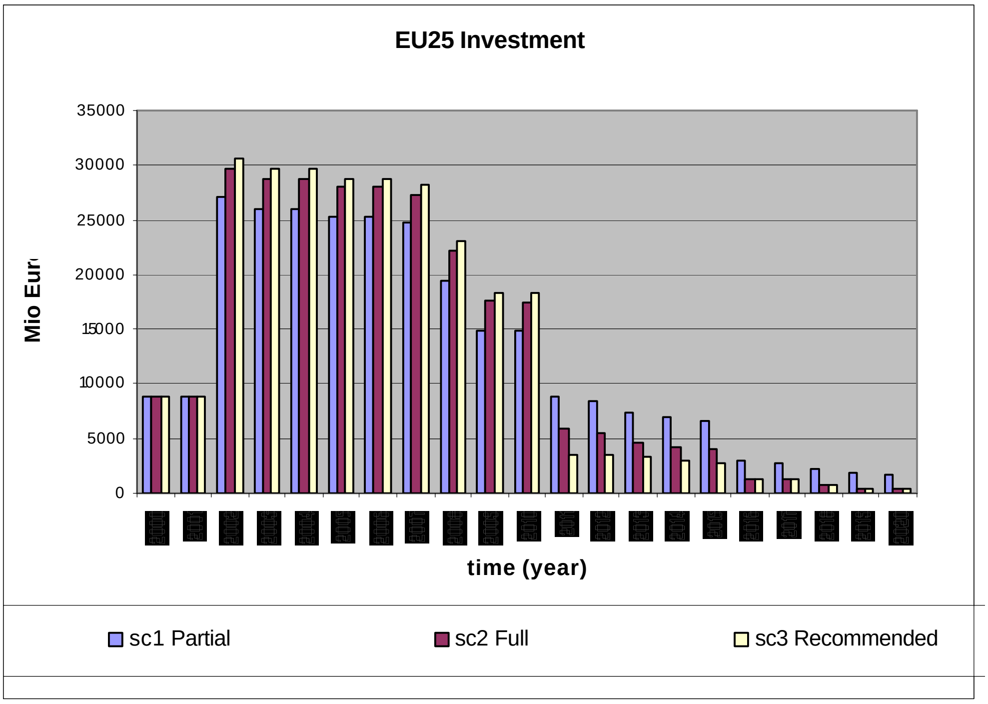


Figure 9: EU15 - TEN-T investment development

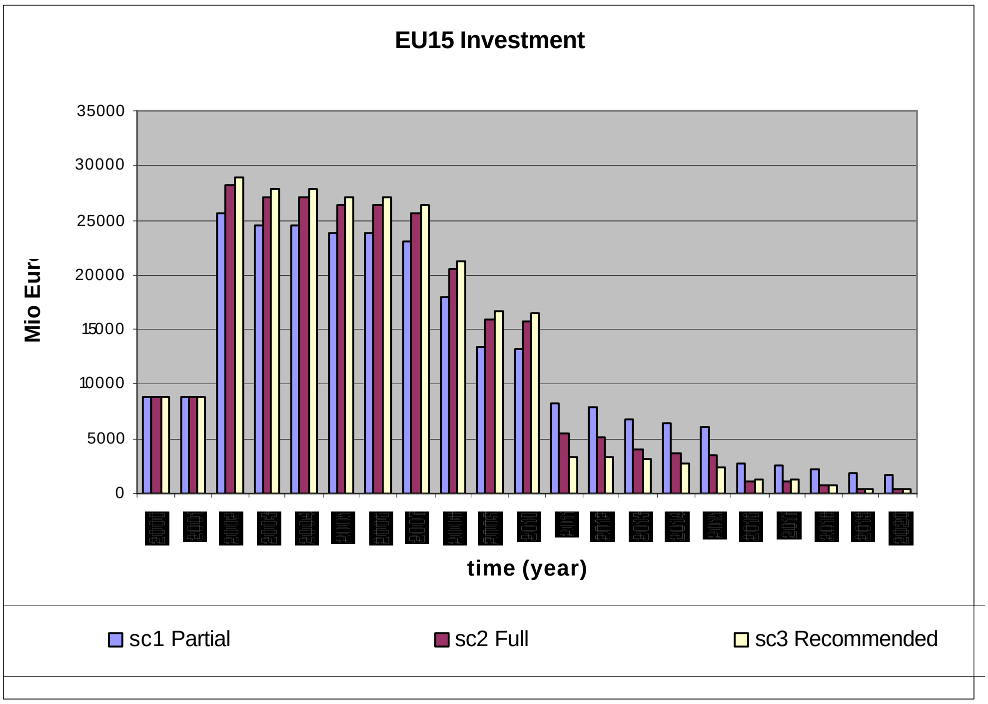


Figure 10: NMS - TEN-T Investment development

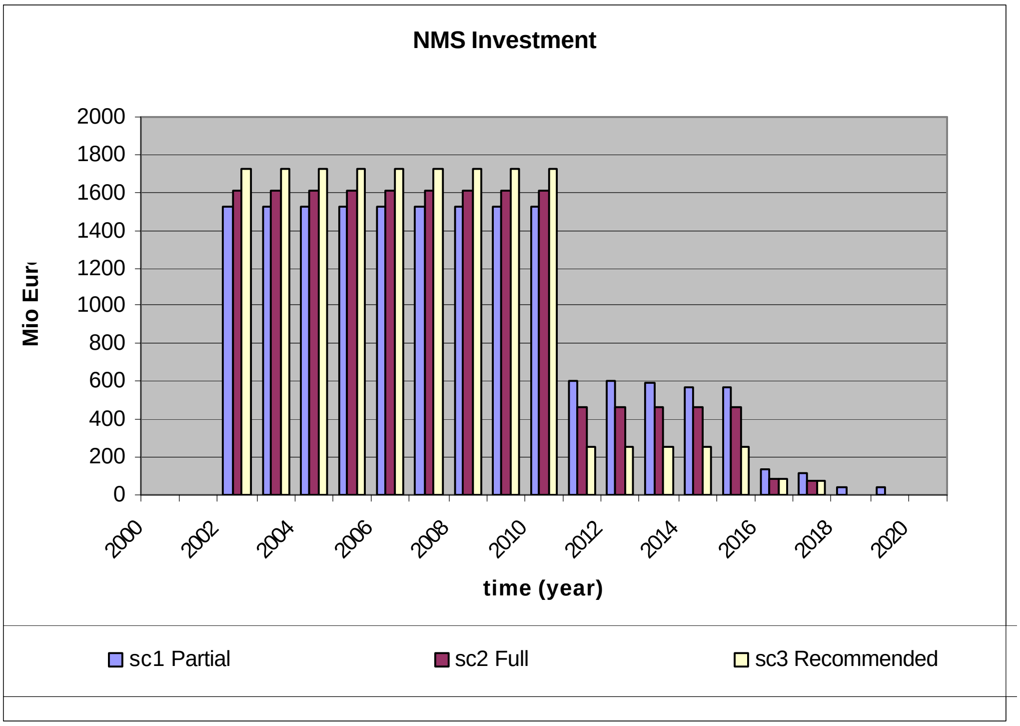


Table 7: TEN-T Total investments

TEN project	Mode	Total investment (Million EURO)
1 High-speed train/combined transport north–south	Railway	48.722
2 High-speed train PBKAL (Paris–Brussels–Cologne–Amsterdam–London)	Railway	23.750
3 High-speed railway axis of south-west Europe	Railway	24.955
4 High-speed train east	Railway	5.334
5 Conventional rail/combined transport: Betuwe line	Railway	4.546
6 High-speed train/combined transport, France–Italy	Railway	37.763
7 Motorway axis Igoumenitsa/Patra-Athina-Sofia-Budapest	Road	13.279
8 Multimodal link Portugal–Spain–Central Europe	Railway	4.829
	Road	4.616
	Air	3.430
9 Conventional rail link Cork–Dublin–Belfast–Larne,Stranraer	Railway	357
10 Malpensa airport,Milan	Air	945
11 Øresund fixed rail/road link between Denmark and Sweden (completed)	Road-Railway	4.158
12 Nordic triangle rail/road	Road	7.976
	Railway	6.190
13 Ireland/United Kingdom/Benelux road link	Road	4.615
14 West coast main line (rail)	Railway	16.952
15 Global navigation and positioning satellite system Galileo	All modes	3.200
16 Freight railway axis Sines/Algeciras-Madrid-Paris	Railway	6.400
17 Railway axis Paris-Strasbourg-Stuttgart-Wien-Bratislava	Railway	10.588
18 Rhine/Meuse-Main-Danube inland waterway axis	IWW	1.833
19 High-speed rail interoperability on the Iberian peninsula	Railway	25.700
20 Fehmarn Belt: fixed link between Germany and Denmark	Railway	7.176
22 Railway axis Athina-Sofia-Budapest-Wien-Praha-Nürnberg/Dresden	Railway	5.875
23 Railway axis Gdansk-Warszawa-Brno/Bratislava-Wien	Railway	4.703
24 Railway axis Lyon/Genova-Basel-Duisburg-Rotterdam/Antwerpen	Railway	16.715
25 Motorway axis Gdansk-Brno/Bratislava-Wien	road	7.251

TEN project	Mode	Total investment (Million EURO)
26 Railway/road axis Ireland/UK/continental Europe	Road-Railway	2.639
27 "Rail Baltica" railway axis Warszawa-Kaunas-Riga–Tallinn	Railway	1.230
28 Eurocaprail on the Bruxelles-Luxembourg-Strasbourg railway axis	Railway	750
29 Railway axis on the Ionian/Adriatic intermodal corridor	Railway	2.469
30 Inland waterways Seine-Scheldt	IWW	2.710
Total		**311.656**

XII.5.2. The results of the simulation

The results in terms of macroeconomic performance of the three policy scenarios are reported in Figure 8 in terms of absolute difference between yearly growth rates of GDP and employment in the period 2000 – 2020 with respect to the Null scenario. To understand the size of the effects one can take into account that a difference of 0.1 in the yearly growth rate leads to a 2.2% higher GDP at 2020 (see Figure 9).

Table 8: ASTRA results for the Assess scenarios: absolute difference between yearly growth rates with respect to the Null scenario

	GDP			Employment		
Scenarios	**EU25**	**EU15**	**NMS**	**EU25**	**EU15**	**NMS**
Partial	0.047	0.047	0.044	0.024	0.026	0.022
Full	0.080	0.081	0.066	0.040	0.044	0.028
Extended	0.100	0.100	0.093	0.049	0.053	0.039

ASTRA model

Table 9: ASTRA results for the Assess scenarios: total % difference with respect to the Null scenario at 2010 and 2020

	GDP						Employment					
Scenarios	**EU25**		**EU15**		**NMS**		**EU25**		**EU15**		**NMS**	
	2010	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Partial	0.5%	0.9%	0.5%	0.9%	0.4%	0.9%	0.2%	0.5%	0.3%	0.5%	0.2%	0.4%
Full	0.8%	1.6%	0.8%	1.6%	0.7%	1.3%	0.4%	0.8%	0.4%	0.9%	0.3%	0.6%
Extended	1.0%	2.0%	1.0%	2.0%	0.9%	1.9%	0.5%	1.0%	0.5%	1.1%	0.4%	0.8%

ASTRA model

The effect of the measures on the main macroeconomic variables is slightly positive for all scenarios. The variations of GDP and employment are higher for the Extended scenario and lower for the Partial scenario, while the Full scenario is in between. As the main feature of the Extended scenario is the full implementation of the infrastructure charging (with a correspondent reduction of direct taxes), the better performance of this scenario can be explained by a more efficient distribution of resources between private and public consumptions obtained by the introduction of the pricing together with the reduction of direct taxes.

The size of the increment is small, although it should remarked that the measures of the White Paper are not aimed at the economic development. Therefore it was not expected that the effects on the macroeconomic side were largely positive. In brief, the simulations made with the ASTRA model suggest that implementing the measures of the White Paper should not have significant impacts on the economy and, when marginal effects can be detected they are positive.

Table 10: ASTRA results for sensitivity test scenarios: absolute difference between yearly growth rates with respect to the Null scenario

	GDP			Employment		
Scenarios	**EU25**	**EU15**	**NMS**	**EU25**	**EU15**	**NMS**
a) Extended scenario + use of revenues for financing TENs	0.099	0.099	0.088	0.047	0.050	0.038
b) Null scenario + TENs investments	0.003	0.003	0.008	0.002	0.002	0.003
c) Extended scenario + boosting of innovative vehicles	0.102	0.103	0.096	0.050	0.054	0.038

ASTRA model

Table 11: ASTRA results for sensitivity test scenarios: total % difference with respect to the Null scenario at 2010 and 2020

	GDP						Employment					
Scenarios	**EU25**		**EU15**		**NMS**		**EU25**		**EU15**		**NMS**	
	2010	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
a) Ext+fin TENs	1.0%	2.0%	1.0%	2.0%	0.9%	1.8%	0.5%	1.0%	0.5%	1.1%	0.4%	0.8%
b) Null+TENs	0.0%	0.1%	0.0%	0.1%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
c) Ext+inn. veh.	1.0%	2.1%	1.0%	2.1%	1.0%	1.9%	0.5%	1.0%	0.5%	1.1%	0.4%	0.8%

ASTRA model

In order to get some more insight on the results of the simulations, some sensitivity scenarios have been tested. The first sensitivity test analysed the option of using the additional revenues of infrastructure charging to finance the TENs projects instead of reducing direct taxes. In modelling terms, this means that the resources needed for financing the new infrastructure are not found increasing the public debt. The results of the model do not change significantly in this scenario (see test a in Table 10 and Table 11). Actually, the increment of GDP is slightly lower than in the Extended scenario. This result is due to the crowding-out assumption existing in ASTRA and of a higher sensitivity of economic growth to investments than to consumptions. In fact, as the financing of TENs by means of infrastructure charging revenues avoids the growth of the public debt, private investments are higher than in the Extended scenario where revenues financed a reduction of direct taxes. As direct taxes are not reduced, disposable income is lower and, in turn, consumptions grow less. As the total effect on GDP is slightly better in the sensitivity scenario, the positive elasticity to additional investments seems higher to that to additional consumptions. However the difference between the two scenarios is really tiny, and so it seems reasonable to say that the infrastructure charging can have positive effects on the economy, if revenues are used to reduce either taxes or public debt. The simulation of the two alternatives do not produce significantly different outcomes and so only the existing specific circumstances in the actual economy could suggest the most preferable way to act.

Given these results, it is not surprising that the outcome of another sensitivity test, where only TENs where implemented (i.e. any other measures have been excluded, see test b in Table 10 and Table 11), shows that the investments in new infrastructures does not produce really different results with respect to the baseline (the Null scenario), given the assumption that a crowding out effect exist. If the somewhat controversial crowding out assumption is removed, than the effect of the TENs is slightly positive. However, as the theoretical references of the whole Maastricht approach assume that the crowding out effect exists, it seems consistent to include this effect in the simulation.

In the third sensitivity scenario (test c in Table 10 and Table 11), a faster development of innovative vehicles and of the economic effects of their introduction (i.e. the impulse to private investments in the several sectors linked to automotive industry) have been simulated in addition to the measures of the Extended scenario. Boosting the development of innovative vehicles is an important aspect of the White Paper approach, where it is stated that "*As the Green Paper on the security of energy supply has already emphasised, the avail-*

able new clean car technologies will in future need to be given greater Community support, especially under the sixth framework programme of research"[10]. This effect have been modelled activating in the model a specific leverage that inform the model that as the research for introducing new technology vehicles is improved, the composition of investments and consumptions change, involving the whole economy through the Input/Output mechanism. In other words, as the introduction of innovative vehicles is supported, investments and productivity increase not only in the automotive industry and then, indirectly in all the several sectors linked in the production chain (including services).

The economic effects of this scenario are slightly positive, although there is not any significant difference with respect to the Extended scenario until 2020 as at that year the share of innovative vehicles in the fleet is still limited. Afterwards, this measure is potentially able to add something to the economic growth.

A further sensitivity scenario has been run to test the effect of a different version of the Partial scenario (called Partial-B scenario) defined at the very end of the project, where infrastructure charging has been quantified according to current tolling and the Eurovignette directive and where measures concerning the harmonisation of checks and penalties on road freight transport have been considered as not having a significant effect on the road freight costs. In brief, road freight costs grow less in Partial-B scenario. The results of the simulation (Table 5 and Table 6) are in line with the other scenarios: the difference with respect to the Null scenario is little but positive, the impact on GDP and employment growth is slightly better than in the original Partial scenario, as the transport costs are lower.

Table 12: ASTRA results for Partial-B scenario: absolute difference between yearly growth rates with respect to the Null scenario

	GDP			Employment		
Scenarios	**EU25**	**EU15**	**NMS**	**EU25**	**EU15**	**NMS**
Partial B	0.074	0.075	0.052	0.041	0.046	0.026

Table 13: ASTRA results for the Partial-B scenario: total % difference with respect to the Null scenario at 2010 and 2020

	GDP						Employment					
Scenario	**EU25**		**EU15**		**NMS**		**EU25**		**EU15**		**NMS**	
	2010	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Partial B	0.7%	1.5%	0.8%	1.5%	0.5%	1.1%	0.4%	0.8%	0.5%	0.9%	0.3%	0.5%

[10] See White Paper, page 82

Appendix: State-of-the-art models for analysing transport and economy

Macroeconomic models

These models attempt to find causality relationship between longitudinal changes in the total amount production inputs, including public capital (like transport infrastructure stock) and annual changes in the performance of the entire economy or a subset (e.g. states or particular sectors). Using the subscript *t* to denote a time period (e.g. a quarter), the general structure of these models has the form:

$Aggregate\ output_t = f(technology_t,\ labour_t,\ private\ capital_t,\ public\ capital_t)$

The potential causality embedded in this expression is based on two fundamental premises: (a) that the expansion of the public infrastructure capital increases the efficiency and profitability of the business sector; (b) that this increase stimulates business investment in private capital (Holtz-Eakin and Schwartz, 1995). Beginning with the seminal paper by Aschauer (1989),empirical models that are based on the above expression basically conjecture that public capital positively affects the rate of return of private capital and, hence, private capital accumulation. Given the technical substitution between private capital and labour inputs, labour productivity rate improves as a function on of the growth rate of the stock of private capital. These effects, in turn, spur greater total output and thus growth. We call this causality linkage “public infrastructure accumulation induced growth”

But what about cases where highly productive countries, states or regions with high growth rates attract private capital and productive labour which, in turn, demand higher levels of infrastructure investments? In such cases, the causality direction is reversed as the present state of high growth stimulates infrastructure investment. Disregarding such causality possibilities might result in problems of simultaneity in the empirical analysis, which, in turn, will generate wrong estimates.

Hence, what models on the type shown above actually demonstrate is that patterns of productivity and public investments growth are similar and that this is what the correlation shows. The model does not demonstrate causality, rather it presupposes it. In the words of Krugman, Aschauer’s finding are “more a matter of correlation than causation” (Krugman, 1994, Chapter 4).

Other problems connected with these type of models concern the possible time delays between timing of investments and when growth benefits are realised, as well as to the proper measurement of public capital stock. These criticism notwithstanding, it has been suggested that the main contribution of the , Aschauer’s type studies has been to draw attention to the importance of public infrastructure in promoting economic growth and private capital productivity. Moreover, the analysis also indicate that, with respect to economic growth, what matters is not the size of the annual investment in public capital stock, but rather the annual per cent increase of the stock. Table 14 shows results from studies using production function type models with transportation capital.

Table 14: Selected results from studies of the impact of transportation infrastructure investment on economic growth

Study	Type of model and data	Effect of transportation investment	Output elasticity of public capital
Aschauer (1991)	Production function growth model (USA data)	1. Total transport capital effect on growth of K_p/L 2. Transit capital effect on growth of K_p/L 3. Highway capital effect on growth of K_p/L	0.166 0.384 0.231
Seitz (1993)	Leontief cost function (German highway data)	Change in average private cost	0.05
Garcia-Milà and McGuire (1992)	Production function (USA data from the 48 contiguous states)	Elasticity of Gross State Product with respect to highway capital	0.04
Munnell (1990b)	Production function (USA data from the 48 contiguous states)	Elasticity of Gross State Product with respect to highway capital	0.06
McGuire (1992)	Production function (USA data from the 48 contiguous states)	1. Elasticity of output with respect to highway capital 2. Elasticity of output with respect to highway capital – controlling for state effect	0.121-0.370 0.121-0.127
Deno (1988)	Profit function model (USA data)	Elasticity of output with respect to highway capital	0.31
Haughwout (1996)	2SLS spatial equilibrium model (USA data from the 48 contiguous states)	Elasticity of output with respect to highway capital	0.08

Source: Banister and Berechman (2000)

As the table shows, the results, which are statistical significant, range from very low to relatively high elasticity parameters. This contributes to the difficulty of establishing an acceptable level of transportation impacts to use policy purpose

A different model type, which can also be characterised as a macro-level model, is the one proposed by Henderson (2000). In this study, he established the analytical relationship between economic growth, level per-capita income and level of urban primacy, defined as the share of the largest metro areas in the national urban population. Applying this model to a sample of 72 countries, he found that when adjusted for income, a significant number of countries (24) have excessive urban concentration, which reduces economic growth. This growth-lessening effect further rises with income, In this study, Henderson assumed that transport infrastructure expansion, mainly of roads, is the major policy mechanism for reducing urban primacy. He further estimated that, for higher income countries, the effect of additional interregional road investment that stimulates further population dispersion will add a 0.68 percentage point to the country's annual growth rate.

We need to recognize that, even if the statistical estimates from macro type models can be regarded as correct. They apply at the aggregate level but not necessarily for individual investment. But for transportation capital improvements that are carried out incrementally (project by project), there is no guarantee that a given growth rate found from the macro-level model will hold for any particular investment project.

Microeconomic Models

In contrast to macroeconomic model, microeconomic models precisely define the causality link between improved accessibility and economic development. User consumers and firms as the elementary economic decision entities. They furthermore delineate the area and the economic sectors which may be effected by a specific project. Typically the key measures of growth used in microeconomic models could be clustered in four main categories: firm-related individual or household-related, technology-related and market-related.

The firm-related real growth measures include changes in output-to-input ratio, changes in partial and full factor productivity, changes in the amount of input factors employed, change in the firm's technical and cost efficiency and changes in agglomeration.

Individual or household related measures include individual utility relative to their consumption and opportunity space. They also include per capita income, in the size of the job market area, in the number of non-work-related spatial opportunities and changes in the amount of time dedicated to leisure activities. Technology-related measures reflect the increase in use of technologies which are complementary to traditional transportation, following infrastructure improvement. Such measures include changes in business production strategy, such as just in time production, increased intermodality in freight movement and improved access to major regional facilities airports.

Markets-related growth measures are a combination of the above measures. They include indicators as the level of equilibrium employment, income per capita, the product range and the number of the new firms coming in to the regional or urban markets. Notwithstanding the importance of the measures mentioned above the most commonly used ones are "the annual changes in the level of the regional employment", followed by "changes in labour productivity".

Computable General Equilibrium (CGE) Models

Computable General Equilibrium (CGE) models provide analysis of the effects of changes in transport costs and of greater economic integration between regions from the perspective of a general equilibrium approach allowing for the role of linkage effects. They are able to model aspects of the role of transport in economic development that were previously too difficult to model but represent cases where it is likely that transport benefits of projects will not be a good estimate of overall economic benefits.

The CGE models also take account of welfare effects coming from changes in firms' market power reflected in adjustments to margins of price over marginal social cost, and of changes in costs from economies or diseconomies of scale.

The general equilibrium case enables consideration of what happens to other imperfectly competitive sectors when one sector expands (or contracts) as a result of transport changes and allows for regional variations in the supply price of factor inputs. In the partial equilibrium model other sectors and inputs are assumed to be in perfect competition such that their prices are given rather than determined by the model. The linkages between sectors, as given by input-output coefficients, become critical. Transport is not modelled as a separate sector and is considered as a derived demand from the inter-regional trade flows. In the case of symmetric (identical) regions, the benefits from transport improvements increase because of the linkages between sectors, but the ratio of total economic benefits to transport benefits is rather smaller than in the partial equilibrium case because it reflects a weighted impact on different sectors with different degrees of imperfect competition.

The general equilibrium case also allows for the further analysis of industrial agglomeration. If the linkages between sectors are strong, the regions will retain a balance of sectors; if, however, the linkages between sectors are much weaker than they are within sectors, there is the increased probability of agglomeration of each sector in a single region. Thus a given change in transport costs beyond a certain level may lead to an asymmetric result with one region gaining welfare at the (relative) expense of the other.

Applications

A few applications of the theoretical approaches outlined in the previous paragraph will be introduced here. From the presentation it will emerge that the majority of the experiences are dedicated to analyse the effects of one specific transport policy, namely infrastructure investments.

There are several reasons why the approaches are mainly focusing on investments impacts. First of all transport investments, as a part of public spending, is usually justified by their capacity in boosting economic growth, promoting sustainable development and pursuing economic and social objectives. Furthermore investments in transport sector are usually supposed to be able in influencing economic regeneration of particular areas or particular industrial sectors. As remarked by the presence of several approaches in explaining transport effects on economy, the debate about this relationship is usually not clear and lacking of a universal shared explanation. Besides, it should been taken into account that in explaining this relation many difficulties raise by the fact that its often quite difficult to isolate the effects of transport on national regional and local level where other kinds of investments and policies influence the economy.

The second and third paragraphs are dedicated to the description of two previous EU projects, IASON and TIPMAC. Both projects aim at overcoming the limit of analysing only investment policies, as they are fed with information from transport simulation models and for this reason are considered particularly relevant for the analysis of the White Paper scenarios.

Models to measures economic impacts of transport infrastructure investments and policies.

Various models have been developed mainly in order to assess regional economic effects of transport infrastructure provisions, as they do not include a full transport model. Each of these models presented have different focuses. QUEST II focuses on forward-looking and international trade balance. Venables & Gasiorek focuses on microeconomic behaviour of firms in space. REMI focuses on explicit structures based on maximizing behaviour of actors in response to current conditions, and key statistical parameters based on large data sets. HERMIN focuses on special characteristics in different countries as revealed in recent year relationships between variables in aggregate time-series estimates. A short description of these models is given below;

QUEST II

The QUEST II model is designed to make short and long term projections for countries in the EU and to look at the consequences of EU intervention on the economies of the EU countries. The model is entitled "A Multi Country Regional Business Cycle and Growth Model". In line with its purposes, it gives special attention to the ways that actors in the economy make short and long-term decisions. This focus on timing heavily on neo-classical economy theory, which assumes rational and foresighted decisions by consumers who maximize their utility in the short and long run and firms that want to maximize long-term profits. In implementing the model the authors have used their judgment (and statistical evidence) as well as neo-classical theory in restricting some of the equation's coefficients, as well as in specification of some of the functional form. For example, they partition the consumption function into two parts. The first uses the neo-classical assumption of life cycle income and financial assets. The second uses current disposable income to explain consumption as well as expected lifetime income. This model is limited to National/International analysis and, therefore, does not include some modelling features that are important for explain features in local and regional economies.

Venables & Gasiorek model

This second model is a computable general equilibrium model by A. J. Venables and M. Gasiorek. Its focus is on implementing the "New Economic Geography" theories that have been developed in the last decade. This new line of thinking about regional economics rests strongly on Dixon and Stiglitz's work on monopolistic competition. It is based on microeconomic assumptions and explains why concentrations of economic activities can be competitive despite higher wages and land costs. In particular, it provides an explanation for why firms can have lower costs if they have many suppliers to drawn upon. Good access improves the probability that firms can buy the supplies ore services that exactly meet their needs and thus enhance their efficiency and productivity. The model gives special attention to firm size and the idea that as market size grows, profits per firm grow until a new firm can enter. This model has a strong theoretical basis and its building blocks are based on individual firms. It also includes (in its Spanish version) industry trade flows to and from each region to each region as well as to two ports. In its focus on new economic geography and short and long term equilibrium it has limited the parts of the economy to those aspects that are necessary for explaining the variables that the designers chose for the model.

REMI

The REMI model was initially created in the U.S. twenty-two years ago and has been continuously refined with two major changes, the first in 1993 and the second in 2002. As computers and economic research have advanced and as hundreds of users have given REMI important feedback, the model and the database grown. With the creation of EMU, much of the development work done by REMI to develop the basic structure of a model for heterogeneous economic regions in a single monetary union for the U.S. provides a good basis for EU regional modelling. The model has a fixed structure but is calibrate to the nations, regions or territories that are included for the model in question. The key parameters are estimated with a large data time-series sets pooled from as many relevant areas as possible.

The 2002 model has a basis in microeconomic theory as represented in the new economic geography while retaining linkage based on household labour force, and business behaviour based on utility and profit maximization assumptions. The model structure is the same for all models in market-based economies except for differences in a few key parameters such as the speed of migration response to changes in economic conditions and the response of wage rates to labour market conditions. The regional model parameters are estimated over a large sample of regions and are used for all implementations of the model.

HERMIN

"The theoretical underpinning of HERMIN model is the two-sector small open economy model with a Keynesian role for domestic demand" (Bradley, *The impact of Community support*, p5-6). Unlike the others models its structure is modified from one application to the next. The coefficients are estimated for the country in question and the functional form may be changed one country to another. For example, output in the traded-goods sector depends on comparative cost, world output, and a time trend for Ireland, but depends on final demand in Portugal and final demand and cost competitiveness in Spain.

The core of HERMIN model consists of approximately 20 economic behavioural equations. In general the HERMIN model is disaggregated into four sectors: (1) manufacturing (traded), (2) market service (non-traded), (3) agriculture, and (4) public (non-market). The manufacturing sector includes earnings, a deflator, and demand for employment and investments. The market services sector includes the same components as manufacture except for average annual earnings.

The agriculture sector includes labour, GDP, and investments; the demographics sector has three age cohorts and net migration (for Ireland). The changes in structure are made based on empirical results as well as special considerations of differences or perceived differences in the economies. The public sector in the HERMIN model is constrained by the debt to GNP ratio or other budget constraints. In summary the HERMIN model gives high importance to the results from available time series data and is flexible in its specification of the model from one country to another.

Table 15: Detailed comparisons of four models used for EU investment evaluation

	Quest II	**Venables & Gasiorek**	**REMI**	**HERMIN**
Geographic scope:	All Nations or groups of Nations in the World or in E.U.	Regions, Territories	European Nations, Regions, Territories	EU, Nations, Regions, Territories
Number of Private Industries:	One?	16 in Spain	26-53 all sectors local, other regions, rest of EU, rest of world	3 private: 1 manufacturing "tradable" 2 agriculture 3 other "non tradable"
Number of Regions:	18+ nations	22 in Spain	1-67	Single region models only?
Endogenous Intermediate Agglomeration Productivity:	No	Only a Composite Price Effect?	Yes	No
Investment:	Optimal calculation using CES Function, adjustment cost, efficiency and labor augmenting technical progress. Ideal final equation not implemented so far.	Not shown in equation list.	Optimal capital versus actual capital stock adjustment process. Optimal based on relative labor and capital intensity of production.	Partial adjustment correction method without an explicit capital stock.
Consumption equation:	Life cycle income and financial wealth for 70%; real disposable personal income for 30%	After tax income, Cobb-Douglas shares by industry, shares by location, service and varieties using a CES hierarchical format and the Armington assumption		
Government:	Exogenous spending pattern	Tax rate set to balance budget	Consumption by categories by per capita income elasticities and Cobb-Douglas substitutability among categories based on delivered prices; for supply sources see industry shares below.	Personal disposable income, financial wealth (in some countries).
Exports and Imports:	Constrained by world total exports = total imports. Respond to relative prices—short run elasticities less than 1, long run elasticities = 1; also to demand changes.	Relative costs through ports and demand source	Export share of baseline, imports share of local demand: both change depending on relative prices.	Only tradable goods—international demand and competitiveness—in Spain; tradable sector output in Ireland
Exchange Rates:	Endogenous with exogenous risk premiums	Assumed fixed	Assumed fixed at rates in baselines	Imports at fixed exchange rates: as a residual (in some countries)
A hybrid equation including both supply and demand variables:	No	No	No	A single equation of output as a function of world demand, domestic absorption, labor costs, domestic relative to world prices, and a time trend.
Equilibrium Conditions:	All imports add up to all exports	All markets clear at market prices each year	Output by industry is all absorbed by demand at market prices each year	Keynesian demand determines output.

Types of Labor by Occupation:	1	No explicit employment	8-11	
Types of Labor by Industry:	1		26-53	4
Employment:	Positive function of output, negative function of real wage (Cobb-Douglas)	Not included	Output, labor productivity (trend from national baseline, agglomeration effect endogenous), relative costs of capital, labor and fuel with Cobb-Douglas substitutability as new equipment is purchased	Production with CES substitutability of capital and labor-agriculture exogenous
Endogenous Productivity:	Implied by relative labor/capital intensity.	Not included	Baseline with endogenous change in productivity based on access to labor (new economic geography formulation) and labor/capital substitution.	
Types of Labor by Occupation:	1	No explicit employment	8-11	
Types of Labor by Industry:	1		26-53	4
Employment:	Positive function of output, negative function of real wage (Cobb-Douglas)	Not included	Output, labor productivity (trend from national baseline, agglomeration effect endogenous), relative costs of capital, labor and fuel with Cobb-Douglas substitutability as new equipment is purchased	Production with CES substitutability of capital and labor-agriculture exogenous
Endogenous Productivity:	Implied by relative labor/capital intensity.	Not included	Baseline with endogenous change in productivity based on access to labor (new economic geography formulation) and labor/capital substitution.	Not included
Capital Demand:	Cobb-Douglas substitutability	Not included	Based on relative cost of capital, labor, and relative capital using economic activity, relative to baseline optimal for the nation. Baseline optimal for the nation is calculated using actual capital stock in t-1 plus investment in the baseline divided by the adjustment speed.	CES production function with capital and labor
Population:	Not explicit	Not explicit	Single year/age/gender (200 cohorts)	Not explicit
Participation Rates:	See labor force below	Not explicit	Unemployment and real wage coefficients by aged gender cohorts.	In Spain, different for men and women and a function of unemployment
Labor Force:	Responds to bargaining power, life cycle income, and financial wealth??	Not explicit	Participation rates by age and gender that are multiplied by the size of each respective cohort.	See participation rate above
Labor Mobility:	Not included	Completely mobile or completely immobile?	Over time through migration	Ireland migration from the UK
Equilibrium Condition:	World wide imports equal world wide exports	Local wage rate is calculated to employ all local labor or: wages the same in all locations	Real expected relative earnings times the consumer commodity access index = compensating differential in the very long run (depends on speed of adjustment)	Not explicit
Nominal Wage Rates:	Productivity with bargaining power index and reservation wage determinants.	Wage rate to clear factor markets, calculated separately for each area in the model	Employment labor force ratio and current occupational demand, divided by expectation based on past demand	Negotiation depends on the level and rate of change of unemployment, fiscal leakages, prices, productivity (and in Ireland non-tradable wages respond to tradable wage inflation)
Price Index:	Based on local and import prices		Categories based on delivered price.	Non-tradable prices depend on labor costs and profit margins
Composite Prices:	Not computed	Use direct CES Function and Armington Assumption to incorporate variety availability in price	Delivered prices (production + transportation from production location) divided by an access index that captures availability of variety.	Cobb-Douglas function of prices for consumers

Cost of Capital:	A shadow price based on forward-looking real interest rates, profitability, tax rates, and markup rates.	Not explicit.	Relative cost depends on baseline cost and changes in construction costs.	Exogenous
International trading partners:	All countries and trading blocks	Rest of world and rest of European Union	Rest of the nation, rest of the world and the rest of the European Union	Rest of the world
Trade flows to and from all regions and exterior markets (international):	Yes	For 'tradable' goods only?	Yes for all industries and all regions	Single area modeled and rest of the world
Types of Industries:	Monopolistic Competition	Perfectly competitive and monopolistic competition	Monopolistic competition for all industries (Imperfect competition increasing returns at firm level)	Not specified?
Determinant of trade:	Relative cost changes and changes in demand?	Different products defined by region in which produced. Armington assumption.	Variety and delivered price	Not specified?
Adjustment speed:	Not specified?	Short run—number of firms constant; in long run number of firms flexible	Adjustment based on adaptive expectations	Not specified?
Trade Flow Estimates:	Measured	Based on estimated distance transport costs	Based on dynamically estimated gravity coefficient and travel times matrix (US or EU)	Measured for country exports and imports
Accessibility Estimates Based on Agglomeration:	No	Composite prices reflect variety access	Yes—based on CES from New Economic Geography (variety access)	No
Elasticity Estimates:	Short term estimates—long term set at 1	Not found	Dynamic change in shares following production cost changes (US or EU)	Single time series for shift in trade explained key cost changes

The IASON project

The goal of the project IASON (Integrated Appraisal of Spatial economic and Network effects of transport investments and policies) is to improve the understanding of the impact of transportation policies on short- and long-term spatial development in the EU, simultaneously developing a unified assessment framework for the European level, integrating the network, the regional economic and macro-economic impacts. According to this goal the project provide a new input to assessments by studying spatial impacts of transport investments and policies.

The modelling tools used in IASON for the analysis of spatial impacts of transport investments and policies are SASI and GCEurope.

SASI model design

The SASI is a dynamic model of the spatial European economy, the kernel of which is a so-called quasi-production function quantifying the relation between accessibility and output by region and sector. Transport initiatives lead to changing transport cost and hence to changing spatial patterns of accessibility. This influences output via the econometrically estimated quasi-production function. The production part of the model is connected to a migration model such that a fairly comprehensive picture of the impact of transport initiatives on the spatial economic system emerges.

The SASI model differs from others approaches to model impact if transport on regional development by modelling not only production (the demand side of regional labour markets) but also population (the supply side of regional labour markets), which makes it possible to model regional unemployment. A second distinct features is its dynamic network database based on a strategic subset of highly detailed pan-

European road, rail and air networks changes according to the most recent EU documents on the future evolution of the trans-European transport network.

The SASI model has six forecasting submodels: European Developments, Regional Accessibility, Regional GDP, Regional Employment, Regional Population and Regional Labour Force. A seventh submodel calculates Socio-Economic Indicators with respect to efficiency and equity.

The spatial dimension of the model is established by the subdivision of the European Union and the 12 candidates countries[11] (CC) countries in Eastern Europe in 1.321 regions and by connecting these by road, rail and air network. For each region the model forecasts the development of accessibility, GDP per capita. In addition indicators expressing the impact of transport infrastructures investments and transport improvements on the convergence (or divergence) of socio-economic development in the regions of the European Union are calculated.

The temporal dimension of the model is established by dividing time into periods of one year duration. By modelling relatively short time periods and long-term lagged impacts can be taken onto account. In each simulation year the seven submodels of SASI model are processed in a recursive way, i.e. sequentially one after another. This implies that within one simulation period no equilibrium between model variables is established; in others words, all the endogenous effects in the model are lagged by one more years.

CGEurope model design

The CGEurope model is a computable general equilibrium (CGE) models of a multiregional economy. Models in this family are routed in modern neoclassic economic theory assuming that the behaviour of firms and households is the outcome of rational choice under technological and financial constraints. Firms choose supply and demand such that profits are maximised, households choose consumption of goods, service and travel such they attain a maximal utility. In a multiregional setting all these choices are affected by transport costs including time costs. Therefore changes of these costs, as represented by the scenarios, change all endogenous variables in the system such as prices, outputs, trade and travel flow, and – most importantly – utility. Utility is the ultimate variable of interest in CGEurope. As utility has meaning only in a ordinal sense of “more” or “less”, it is translated in a monetary equivalent for project evaluation.

CGEurope is a static general equilibrium model for a closed system of regions covering the whole world, consisting of the 1.321 Europe regions (the same in SASI) plus one region representing the rest of the world. In each region reside identical immobile households owing the regional stock of production factors that are immobile as well. Their incomes stem from regional factor returns as well as from an interregional income transfer that can have a positive o negative sign. Income transfers are exogenous (in real terms) and add up to zero for the entire world. They are negligible with regards to quantitative results, bur needed for keeping budget constraints closed. Households spend their income for buying goods and services partly produced in their own region and partly produced in other regions. Households’ demand represents total final demand, i.e. private as well as public consumption and investment. There is no separate public sector in the model; that is households have to be regarded as an aggregate of private and public households, their budget constraint is the consolidate budget constraint of private and public households in the region.

Households are price takers on all markets. They maximise a Cobb-Douglas utility depending on the quality of local goods and the quantity of an index of diversified tradable goods. Hence, they spend fixed

[11] In the moment in which the model was designed CY, CZ, EE, HU, LT, LV, MT, PL, SI, SK were just candidates countries. Since they have joined the EU in 2004 they are now NMS, while BG and RO still remain candidate countries. For the future we will use “12 CC” to indicate this group of countries.

shares of their income for local and tradable goods, respectively. Utility changes of households, measured in monetary terms by Hicks equivalent variation concept[12], are the model measure of regional welfare effects of transport initiative.

Firms, whose technologies are identical up to a region-specific productivity scaler, represent the production sector. There are two types of firms: firms producing local goods and firms producing tradable product varieties. There is no further sectoral differentiation. Local goods are produced under constant returns to scale and, as the name says, can only be used within the region itself. Tradable goods, however, are produced by "Dixit- Stiglitz – Industry"[13] under monopolistic competition and increasing returns to scale.

Analogous to households consumption, firms use tradable goods as a composite index that is composed of all variants produced anywhere in the world. The same index is used for final demand as for intermediate inputs. As usual, varieties are composed by a symmetrical CES[14]-Index, with elasticity of substitution between varieties greater than one.

The decisive assumption of the model is that there are transaction costs for goods delivered between regions. Transaction costs have two components, one depending on costs of transportation and business travel, and another representing the extra cost of international trade.

The IASON Scenarios

The two models have been used to analyse several scenarios, including different types of transport measures. In particular, the following categories of scenarios have been analysed.

Reference scenario. It is the benchmark scenario for comparing the results of the policy scenarios. For the period between 1981 and 2001, the reference scenario represents the actual development of the road, rail and air network in Europe. For all future years the reference scenario preserves the state of the network in the year 2001, i.e. no further network development after 2001 is foreseen. Thus, the reference scenario is a not realistic scenario but is used only as a benchmark for all the others scenarios.
Network Scenarios. These scenarios implement different assumption about the further development of the European transport networks. Twelve different scenarios are defined according to a different selection and timing of TEN and TINA projects.
Pricing scenarios. The pricing scenarios examine the effect of social marginal cost (SMC) pricing regimes applied to different parts of the networks and different types of vehicle (only road freight vehicles or all modes). These scenarios do not assumes further network development, i.e. the pricing schemes are applied to the reference scenario. To be noted that in these two models only the cost effects of pricing schemes are taken in to account , so, the way the revenues of the toll are earmarked is not considered.
Other scenario. Include a combination of the scenario assuming the implementation of all TEN priority projects and the scenario assuming SMC pricing applied to all modes, a special kind of scenario focussing on the development of the dedicated rail freight network and also the TIPMAC Scenarios (see below).

The TIPMAC project

In the TIPMAC project transport modelling with macroeconomic modelling have been combined to study the direct impacts of transport infrastructure investments and transport pricing policies in the EU.

[12]**Hicks Equivalent Variation (EV)**: the minimum (maximum) amount of money which would have to be given to (taken away) an individual to make them as well off as they would have been after the price fall (rise)
[13] **Dixit- Stiglitz – Industry models**: only one firm produces each input and each firm produces only one product
[14] **CES**, Constant Elasticity of Substitution

Two parallel analyses employing contrasting methodologies have been undertaken in this project, employing two different classes of models. In one analysis, the SCENES transport network model has been linked to the E3ME macroeconomic model. In the other, the ASTRA system dynamics model has been used[15].

SCENES/E3ME combined model design

E3ME is an econometric model where 41 economic sectors are considered. For the TIPMAC project a representation of freight and passenger demand with mode choice on aggregated basis has been considered. SCENES is a transport network model at the European scale and provide a detailed description of passenger and freight demand and supply in Europe. The two tools have been combined as follows.

The SCENES model receives macroeconomic data as an exogenous input from the E3ME. SCENES uses this data to estimate freight and passenger demand at the NUTS2 level and carries out modal choice and route choice simulations. Results of the SCENES model are passed to E3ME that uses this data to define aggregate input concerning transport costs, etc..

As a result of the combination of the two models, the system delivers results that combine the comprehensive forecasting of a dynamic macroeconomic model with a detailed network model of the EU transport system. This provides a combined output of macroeconomic forecasts with a high quality transport information.

ASTRA model design

The ASTRA model is a System Dynamics model at the European scale[16] focused on describing the linkages between transport, economy and environment. The ASTRA model consists of eight main modules; several interrelationships exist between the modules so that they form a single integrated framework.

The macroeconomics sub-module (MAC) estimates the economic framework data of the EU respectively the member countries. The results of the MAC key indicators (e.g. GDP, employment) are transferred to the regional economics and land use sub-module (REM). Within the REM basic data for transport demand modelling (e.g. population, car-ownership) is calculated. Both data forms the input of the first two steps of the classical 4-stage transport model: trip generation and trip distribution on the basis of the previously described spatial representation. The resulting transport demand is transferred to the transport sub-module (TRA), which includes the final two stages of the transport model: modal split and a simplified assignment. The environmental sub-module (ENV) is mainly fed by data from the TRA (e.g. traffic volumes). It includes the vehicle fleet models and models for description of changes in technology. Environmental indicators (e.g. CO2 emissions) are calculated and the welfare consequences performed by the environmental impacts are estimated in the ENV. Finally the aggregated welfare situation based on economic, social and employment indicators is presented.

The TIPMAC scenarios

Four transport policy scenarios have been analyzed in the TIPMAC project. Scenarios, which were the same both for SCENES/E3ME and ASTRA, have been identified on the basis of the strategy outlined in the White Paper. A common set of transport measures identified in the White Paper that were expected to

[15] Details on the methodology and the results of TIPMAC can be found in “Cambridge Econometrics et.al., 2003, Transport Infrastructure and Policy: a macroeconomic analysis for the EU. TIPMAC Final technical Report

[16] Currently the ASTRA model covers the EU25 member states plus Bulgaria, Norway, Romania and Switzerland. The model version used for the TIPMAC project covered EU15 only.

be smoothly introduced in the next years (without requiring major changes in domestic transport policies) were assumed in all scenarios.

Each scenarios was characterised by coupling specific options concerning timing and type of investments in the completion of the Trans European transport network programme (TEN-T) with alternative strategies that can be considered for its funding.

The four scenarios, the reference one included, are the follows:

a) **Business-As-Usual**. The reference scenario described a do-nothing hypothesis in which, in the absence of further Commission action, future evolution in transport demand and supply is the results from continuation in to the future of past trends. Within EU regulation on place in year 2002, the evolution of the *status quo scenario* reflects a variety of national approaches to transport taxation, charges and investments. In such BAU context, investment on the TEN-T projects is spotted among different projects, that are assumed to be completed until 2020.
b) **Social Marginal Cost Pricing (SMCP) scenario**. This scenarios was designed to test the macroeconomic impacts of completing the same amount and type of TEN investments as scheduled in the BAU scenario but in a context in which Social Marginal Cost Pricing is adopted as the key criterion to harmonise infrastructure pricing in the EU. Differently from the SCMP scenarios in IASON model, in TIPMAC this policy is accompanied by measures that compensate the increased charging on transport activity.
c) **TEN-T core project speed up plus fuel tax**. In this scenario the bulk of additional funds needed is made available by means of increasing taxation on fuel
d) **TEN-T core project speed up plus SMCP**. In this scenario the additional funds needed in order to speed up TEN-T core projects is made available by means of implementing SMCP schemes.

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