Assessing Economic Impacts of Large-Scale Transport Infrastructure Projects

Case of Lyon–Turin Corridor

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Assessment of large-scale transport infrastructure projects by a classical four-stage transport network model is meant to capture only the direct benefits of transport policies, while the additional indirect economic effects in nontransport markets would be partially neglected. The intent of this paper is to apply an integrated economy–transport–environment assessment model focusing on the assessment of economic impacts of national or supranational transport policies to the question of the size of indirect economic impacts of a single large-scale project. Such a model makes it possible to consider the interaction between transport and the economy as well as between the economy and transport, closing the transport–economy feedback loop. For this purpose, the European assessment of transport strategies (ASTRA) model is refined to model the implementation of the planned high-speed railway link on the Lyon–Turin corridor. This line forms part of the Trans-European Transport Networks. The estimated cost of the 257 km of new tracks is €13 billion over 10 years, which would be a sufficient size to make it a large-scale project. The results of the analysis indicate the feasibility of applying the ASTRA model for such a project assessment. Economic impacts on the country level can be detected as well as impacts for the 15 Western European Union countries, although the latter are rather small if they are measured as percentage changes to a reference scenario. A crucial task remains the analysis of impact chains that have caused and explain the model results.

In the framework of developing the European Union (EU) and of fostering the cohesion between the various European countries, transport infrastructure that connects the member states with a high quality of service is of great importance. Such connecting infrastructure most often affects not only two neighboring countries but a chain of countries stretching over six or more states. Therefore the EU heads of state have agreed to develop the Trans-European Transport Networks (TEN-T), which was first defined by the so-called Essen list of projects in 1994 and updated in later policy decisions. Projects contributing to TEN-T constitute large-scale infrastructure measures requiring usually significant investments.

The question addressed in this paper is whether the assessment of transport strategies (ASTRA) model, which so far has been applied for national and supranational policy analyses of transport policies, could also be applied for an assessment of a single large-scale project. The Lyon–Turin corridor, which is foreseen to build a high-speed railway link through this corridor as part of TEN-T, has been selected for this analysis.

The paper is structured in five sections after this introduction. First, an overview on the Lyon–Turin project is given. Second, the policy framework relevant for EU analysis is explained. Third, the applied ASTRA model is described to understand better the meaning of the results of the analysis. Fourth, the actual policy analysis is performed, starting with the results for the business-as-usual scenario and followed by the policy scenarios, which then cover the three aspects: transport impacts, trade impacts, and economic impacts. Finally, some conclusions are presented on the applicability of the ASTRA model for such a single project evaluation. Unless otherwise indicated, euro amounts relate to 1995 levels ($1.3 = €1).

LYON–TURIN CORRIDOR

The Lyon–Turin corridor is located in the southeast of France and the northwest of Italy, connecting those two countries by a conventional railway line and a major road link. On its way, the corridor has to cross the Alps such that the railway line has to follow the significant slopes and the winding route defined by the mountains and valleys of the Alps. The Lyon–Turin railway link is part of several large trans-European transport axes, such as a west–east axis commencing in Portugal and leading until the Ukraine or a north–south axis starting in the Benelux countries and ending in southern Italy.

In 1994 the Lyon–Turin railway link was put on the list of 14 priority projects defined by the European heads of state to become the core elements of TEN-T. Because of the main objectives of the 2001 White Paper on European transport policy (*1*) of shifting the balance of modal split toward more environmentally friendly modes and of eliminating bottlenecks, the bottlenecks in the EU railway infrastructure especially increased in importance as railways belong to those more environmental modes.

The Lyon–Turin link constitutes one of these bottlenecks as transport studies forecast that around 2015 both road and railway capacity on the link will reach their limits (*2*). Additionally the Alps crossed by the link constitute a sensitive area for environmental impacts caused by transport. For both reasons, plans for implementing a new high-speed railway link for mixed passenger and freight transport gained momentum because of the White Paper and the corresponding updated list of TEN-T priority projects (*3*), which has been refined by a decision process set up by the European Commission. In this process

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the Van Miert High-Level Group on the level of policy makers preselected a number of priority corridors for TEN-T (*4*), and the Trans-European Network Scenarios, Traffic Forecasts, and Analyses of Corridors project (TEN-STAC) carried out a detailed, model-based analysis for a number of potential priority projects (*5*). Both recommend the construction of the Lyon–Turin railway link as part of a larger framework, the Lyon–Budapest corridor, although the TEN-STAC analysis is estimating lower benefits and a smaller modal shift than the studies of the involved companies (*2*). In 2004 (when $1.24 = €1) a memorandum between France and Italy agreed on an investment plan for a public–private partnership amounting to €13 billion, of which the EC should fund at least 20%. The whole link is not planned to be implemented until 2015.

The high cost for the 257 km of new high-speed track is caused by the fact that several bridges and tunnels, including a 52-km-long tunnel, have to be constructed. Transport forecasts foresee a rise in freight volume over the Alps of 80% in the next 15 years. By 2030, 40 million tons are expected to be transported on the link by rail compared with 10 million tons today. Passenger transport time between Lyon and Turin will be decreased by 2 h 15 min, also making it possible to connect Paris and Milan in the future by a 4-h train trip, compared with 7 h today.

POLICY FRAMEWORK FOR ANALYSIS

The policy analysis presented in this paper was part of the study *Transport-Related Impacts and Instruments for Sensitive Areas* conducted on behalf of the European Commission (*6*). It has been modified for this paper to include the following:

- Business-as-usual scenario (BAU) with the implementation of EU transport policies according to the White Paper and described in Ponti et al. (*7*) and Schade (*8*), but excluding the Lyon–Turin link. Transport policies from the White Paper such as harmonization of weekend bans on truck traffic, interoperability of cross-border railway traffic, and deregulation of road haulage have been made operational for the scenario implementation in the ASTRA model by transforming them into cost and time changes for different modes, different transport distances, and different transport purposes. The measures than have been implemented in the model according to the schedules foreseen in the White Paper.
- Lyon–Turin railway infrastructure-only scenario (RIO), which is based on the BAU but also includes the construction of the Lyon–Turin high-speed rail link over a 10-year period until 2013 according to current construction and investment plans (*9, 2*).
- Lyon–Turin railway infrastructure plus motorway toll scenario (RIPT), which additionally imposes road pricing of €0.0105/t-km on trucks passing the corridor. This should encourage modal shift toward rail and better use of the "rail motorway" carrying trucks. The cost value is taken from the European UNITE study (*10*).

For the two policy scenarios, the current plans have been translated into an investment time profile and a completion time profile of the new high-speed link, as shown in Figure 1. These profiles have then been implemented in ASTRA.

APPLIED ASTRA MODEL

ASTRA is a system dynamics model generating time profiles of variables and indicators needed for policy assessment. Originally it was developed on the basis of existing models that have been converted into a dynamic formulation feasible to be implemented in system dynamics. Among these models have been macroeconomic models (QUEST) and classical four-stage transport models such as SCENES (*11*).

ASTRA runs scenarios for the period 1990 until 2020 using the first 12 years for calibration of the model. Data for calibration stem from various sources, with the bulk of data coming from the online databases of Eurostat (*12*) and the Organisation for Economic Co-operation and Development (OECD) (*13*).

Dynamic Formulation of ASTRA

Structuring elements of system dynamics models are feedback loops, with positive feedback loops fostering reinforcing model behavior and negative feedback loops providing dampening model behavior. The feedback loops are built of three basic variable types: level vari-

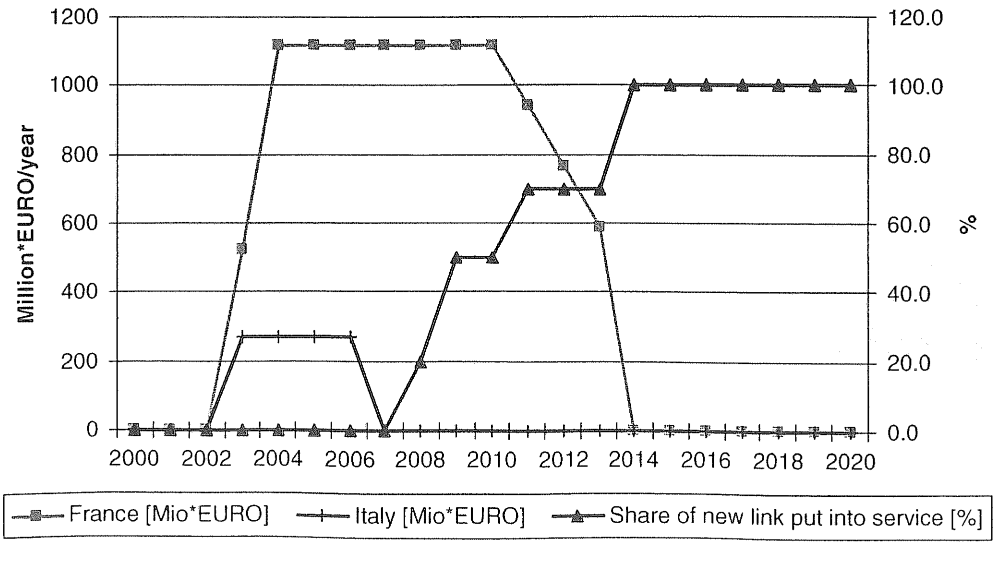

FIGURE 1 Investment and completion of Lyon–Turin rail link.

ables being integral variables, rate variables constituting functions within the integrals, and auxiliary variables (*14*).

Mathematically, system dynamics models are systems of nonlinear differential equations. However, because of the size of complex models of socioeconomic systems, analytical solutions will not be found, such that results have to be computed by numerical integration replacing the differential equations by difference equations. The simplest mechanism applied in all standard system dynamics tools, as well as in ASTRA, is provided by Euler integration, which takes the current value of the rate variable and projects it into the future for the next integration interval as shown in Equation 1:

$$L(t) = L(t - dt) + [I(t) - O(t)] * dt \qquad (1)$$

where

- L = level variable (units),
- I = rate of inflow to level (units/time),
- O = rate of outflow to level (units/time), and
- dt = integration interval (time).

Although other methods, such as Runge–Kutta fourth order method, can produce better results than Euler integration, Sterman concludes: "Euler integration is almost always fine in models of social and human systems where there are large errors in parameters, initial conditions, historical data" (*15*, p. 911).

A further important element in system dynamics models generating the dynamic behavior of such models are the lag variables, which take account of time lags between variables within one feedback loop.

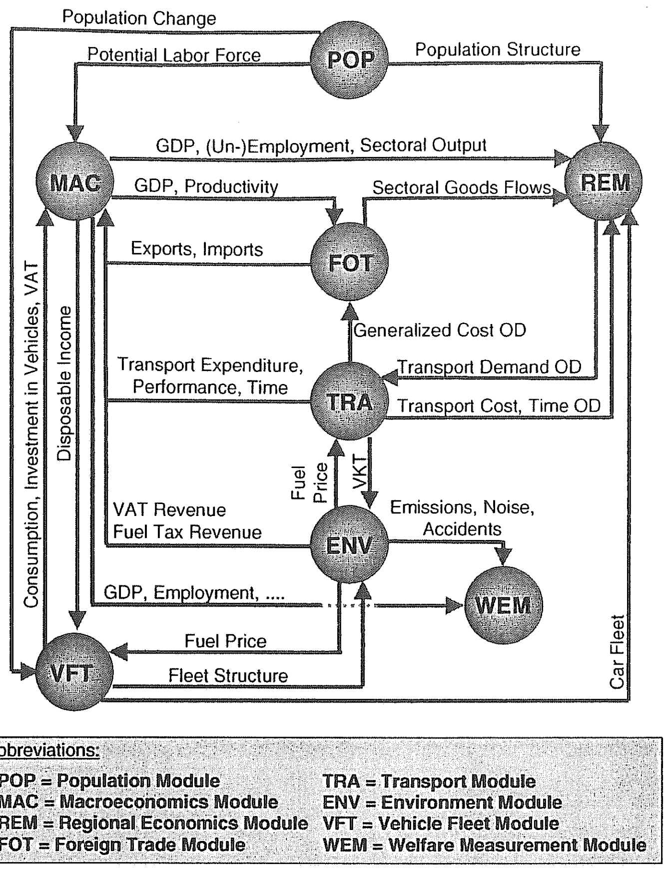

FIGURE 2 Overview of ASTRA model.

Overview of ASTRA Modules

The ASTRA model consists of eight modules, and the version presented in this paper covers the 15 Western European Union countries (EU15). A detailed description of the ASTRA model is provided by Schade (*8*). The following paragraphs briefly describe the concepts of the eight modules for which the main interlinkages are shown in Figure 2.

The population module (POP) calculates the population development for the EU15 countries with 1-year age cohorts. The model depends on fertility rates, death rates, and immigration. On the basis of the 1-year age cohorts for each country, important information is provided for other modules, such as the number of persons of working age. POP is calibrated to Eurostat population predictions (*7, 12*).

The macroeconomics module (MAC) provides the national economic framework. MAC combines different theoretical concepts as it incorporates neoclassical elements, such as production functions; Keynesian elements, such as the dependency of investments on consumption extended by influences from exports or government debt; or elements of endogenous growth theory, such as the implementation of endogenous technical progress as one important driver for long-term economic development.

Six major elements constitute the functionality of the macroeconomics module. The first is the sectoral interchange model that reflects the economic interactions between 25 economic sectors of the national economies. Demand–supply interactions are considered by the second and third element, in which the demand side model depicts the four major components of final demand (consumption, investments, exports–imports, and government consumption), and the supply side model reflects influences of three production factors (capital stock, labor, and natural resources) as well as the influence of technological progress that is modeled as total factor productivity (TFP). Endogenized TFP depends on investments, freight transport times, and labor productivity changes. The fourth element is constituted by the employment model that is based on value-added as output from input–output table calculations and labor productivity. Employment is differentiated into full-time equivalent employment and total employment to be able to reflect the growing importance of part-time employment. In combination with the population module, unemployment can be estimated. The fifth element of MAC describes government behavior. As far as possible, government revenues and expenditures are differentiated into categories that can be modeled endogenously by ASTRA.

The sixth and final elements constituting MAC are the micro–macro bridges. These link micro- and meso-level models (for instance, the transport module or the vehicle fleet module) to components of the macroeconomics module and enable calculation of the indirect economic effects of transport changes originating on the micro level. Hence, the micro–macro bridges and their counterparts, the macro–micro bridges, form important elements to close the feedback loops between transport and the economy.

MAC provides several important outputs to other modules. The most important output is endogenous gross domestic product (GDP) for each EU15 country (e.g., influencing trade flows between the European countries). Employment and unemployment are two influencing factors for passenger transport generation. Sectoral production value drives national freight transport generation. Disposable income exerts a major influence on car purchase affecting finally the vehicle fleet module and passenger transport emissions.

The regional economics module (REM) mainly calculates the generation and distribution of freight transport volume and passenger trips. The number of passenger trips is driven by employment situation, car-ownership development, and number of people in different age classes. Trip generation is performed individually for each of the 53 zones of the ASTRA model. Distribution splits trips of each zone into three distance categories within the zone and two distance categories crossing the zonal borders and generating origin–destination (O-D) trip matrices with 53 × 53 elements for three trip purposes. Freight transport is driven by two mechanisms. First, national transport depends on sectoral production value of the 15 goods-producing sectors where the monetary output of the input–output table calculations is transferred into volume of tons by means of value-to-volume ratios. For freight distribution and further calculations in the transport module, the 15 goods sectors are aggregated into three goods categories. Second, international freight transport (i.e., freight transport flows that are crossing national borders) are generated from monetary intra-European trade flows of the 15 goods-producing sectors calculated by the foreign trade module (FOT).

FOT is divided into two parts: trade among the EU15 member states of the year 2003 (INTRA-EU model) and trade between the EU15 countries and the rest of the world (RoW), which is divided into 12 regions (EU-RoW model). Both models are differentiated into 25 economic sectors and relationships between country pairs. The INTRA-EU trade model depends on three endogenous factors and one exogenous factor. World GDP growth exerts an exogenous influence on trade. Endogenous influences are provided by GDP growth of the importing country of each country pair relation, by relative change of sectoral labor productivity between the countries and by averaged generalized cost of passenger and freight transport between the countries. The latter is used as a kind of accessibility indicator between the countries. The resulting sectoral export–import flows of the two trade models are fed back into MAC as part of final demand.

Major input of the transport module (TRA) constitutes the demand for passenger and freight transport that is provided by REM in the form of O-D matrices. By using transport cost and transport time matrices, the transport module, applying a logit function, calculates the modal split for five passenger modes and three freight modes. Cost and time matrices depend on influencing factors such as infrastructure investments, structure of vehicle fleets, transport charges, fuel price, or fuel tax changes. For road transport, network capacity and network loads are considered for four road types such that congestion effects may affect the road transport time matrices in a simplified way. For other modes, rough capacity models and capacity constraint functions are developed such that interactions between load and travel times can also be taken into account. Depending on the modal choices, transport expenditures are calculated and provided to MAC as well as changes in freight transport times such that the latter can influence total factor productivity. Considering load factors and occupancy rates, respectively, vehicle kilometers are calculated.

Major output of TRA provided to the environment module (ENV) are the vehicle kilometers traveled (VKT) per mode and per distance band and traffic situation, respectively. On the basis of these traffic flows and the information from the vehicle fleet model on the different vehicle fleet compositions and hence on the emission factors, the environmental module is calculating the emissions from transport. Besides emissions, fuel consumption and fuel tax revenues are estimated. Expenditures for fuel, revenues from fuel taxes and value-added tax (VAT) on fuel consumption are transferred to the MAC.

The vehicle fleet module (VFT) describes the vehicle fleet composition for all road modes. Vehicle fleets are differentiated into age classes on the basis of 1-year age cohorts and into emission standard categories. Additionally, car vehicle fleet is differentiated into gasoline- and diesel-powered cars of different cubic capacity. Car vehicle fleet is developed according to income changes, development of population, and fuel prices. Vehicle fleet composition of buses, light-duty vehicles, and heavy-duty vehicles mainly depends on driven kilometers, and the development of average annual mileage per vehicle. The purchase of vehicles is translated into value terms and forms an input of the economic sectors in MAC that cover vehicle production.

Linking Trade and Transport in ASTRA

ASTRA includes two trade models: one for intra-European trade and one for trade between the EU and the rest of the world. In the context of this paper, only the intra-European trade model is relevant and explained. In this model, trade flows are calculated on a sectoral binational base, that is, for a matrix of 15 × 15 × 25 flows (country × country × sector). Influencing factors on trade include

- GDP of importing country;
- Relative sectoral productivity between the two trading partners, which is also considered as a proxy for exchange rates for countries that have currencies other than the euro and for the period before introduction of the euro, since ASTRA is calibrated for the period 1990 until 2002, which includes a period before introduction of the euro;
- World GDP development;
- Transport cost for passenger and freight between the trading partners; and
- Transport times for passenger and freight between the trading partners.

This leads to the following set of equations describing the trade model and its influences generated by either the macroeconomics module or the transport module. Several elements of the equations include lags, such as the influence of productivity changes that affect trade flows with a lag of up to 1.5 years (individually calibrated for each flow) or the changes in transport cost and times, whose influence is spread over a period of up to 3 years.

Sectoral intra-EU exports:

$$\begin{aligned}\mathrm{Ex}(t)_{\mathrm{EC,EC2},s} = {} & \mathrm{Ex}(t-dt)_{\mathrm{EC,EC2},s} * \{1+[\Delta \mathrm{rPRO}(t)_{\mathrm{EC,EC2},s} \\ & + \Delta \mathrm{GDP}(t)_{\mathrm{EC,EC2},s} + \Delta \mathrm{ex\,WGDP}(t)_{\mathrm{EC,EC2},s} \\ & + \Delta \mathrm{fGC}(t)_{\mathrm{EC,EC2},s} + \Delta \mathrm{pGC}(t)_{\mathrm{EC,EC2},s}]\}\end{aligned} \tag{2}$$

Productivity influence:

$$\begin{aligned}\Delta \mathrm{rPRO(t)}_{\mathrm{EC,EC2},s} = {} & \mathrm{cPROD}_{\mathrm{EC,EC2},s} * \{[\Delta \mathrm{PRO}(t-\mathrm{LAG}_{\mathrm{EC,EC2},s})_{\mathrm{EC},s} \\ & - \Delta \mathrm{PRO}(t-\mathrm{LAG}_{\mathrm{EC,EC2},s})_{\mathrm{EC},s}]\}\end{aligned} \tag{3}$$

GDP influence (endogenous):

$$\Delta \mathrm{GDP(t)}_{\mathrm{EC,EC2},s} = \mathrm{cGDP}_{\mathrm{EC,EC2},s} * \Delta \mathrm{iGDP}(t)_{\mathrm{EC2}} \tag{4}$$

World GDP influence (exogenous):

$$\Delta exWGDP(t)_{EC,EC2,s} = cWGDP_{EC,EC2,s} * \{\Delta WGDP(t) - thWGDP + [\Delta WGDP(t) - \Delta WGDP(t-0.5)]\} \quad (5)$$

where

- ex = sectoral exports between two EU15 countries (€ million),
- cGDP = calibrated coefficient for influence of GDP on export (dimensionless),
- cPROD = calibrated coefficient for influence of productivity on export (dimensionless),
- cWGDP = calibrated coefficient for influence of world GDP growth on export (dimensionless),
- LAG = time lag between change of productivity and impact on exports [year] (dimensionless),
- ΔfGC = influence of changes in accessibility of freight transport (dimensionless) (see Equation 6),
- ΔGDP = influence of GDP growth of importing country (dimensionless),
- ΔiGDP = change of GDP of importing country over a period of 1 year (dimensionless),
- ΔpGC = influence of changes in accessibility of passenger transport (dimensionless),
- ΔPRO = change of productivity over a period of 1 year (dimensionless),
- ΔrPRO = influence of relative sectoral productivity on exports (dimensionless),
- ΔWGDP = world GDP growth over a period of 1 year (dimensionless),
- ΔexWGDP = influence of world GDP growth on exports (dimensionless),
- thWGDP = threshold above which world GDP growth exerts a positive influence on exports,
- s = index for 25 economic sectors,
- EC2 = index for importing EU15 country, and
- EC = index for exporting EU15 country.

The following transport-related Equations 6 and 7 add new influences to the trade model. Transport flows are generated on a zonal origin–destination base consisting of four zones per country. Furthermore, modes, distance bands, trip purposes for passenger transport, and goods categories for freight transport are differentiated. The rationale behind the equations is that changes of generalized cost of transport composed out of cost and time changes provided in the above differentiation are after a time lag affecting trade flows due to restructuring of trade relationships because of changes in transport accessibility, which is represented by the aggregated generalized cost. Furthermore, the model considers that trade of goods is affected more strongly by changes in freight accessibility while trade of services depends more on passenger accessibility. The following are equations for freight.

Transport influence in trade model in Equation 2:

$$\Delta fGC(t)_{EC,EC2,s} = cfGC_{EC,EC2,s} * \left\{ \exp\left[\frac{\sum_{DB} wDB_{DB} * \Delta sfGC(t)_{DB,GC,EC,EC2}}{\sum_{DB} wDB_{DB}} * wGS_s \right] - 1 \right\} \quad (6)$$

$$sfGC(t)_{DB,GC,EC,EC2} = \text{smooth}\left[\frac{\sum_{m,OC,DC} Gcost(t)_{DB,GC,m,EC,OC,EC2,DC}}{\sum_{m,OC,DC} ton(t)_{DB,GC,m,EC,OC,EC2,DC}}, RT \right] \quad (7)$$

where

- cfGC = calibrated coefficient for influence of freight generalized cost on export (dimensionless);
- exp = exponential function;
- ΔfGC = influence of smoothed freight generalized cost on sectoral export (dimensionless);
- ΔsfGC = change of smoothed freight generalized cost per country pair over a 1-year period;
- Gcost = generalized cost per time period per O-D pair (€ million);
- sfGC = smoothed and weighted averaged freight generalized cost per country pair (€/t);
- smooth = function providing smoothing and spreading of impacts over time (dimensionless);
- RT = smooth time used here as reaction time of exports to changes in generalized cost (a reasonable value used in the model is 3 years, implying that some changes appear directly, but other changes occur after 3 years or later; the peak of yearly changes is then in the 3rd year);
- ton = volume transported per O-D pair (millions of metric tons);
- wDB = weight of distance bands weighting long-distance band double (dimensionless);
- wGS = weight of freight transport on sectors—introduces higher weight of freight for goods sectors and lower weight for service sectors (dimensionless);
- DB = index for distance bands;
- GC = index for goods categories;
- m = index for modes (road, rail, ship);
- OC = index for origin functional zone; and
- DC = index for destination functional zone.

The variable Gcost in Equation 7 actually transfers the transport policy influences to the trade model as it incorporates the time changes due to new infrastructure and the cost changes due to road pricing.

ASSESSING POLICIES FOR LYON–TURIN CORRIDOR IN ASTRA

Given the described structure, the ASTRA model is not suitable for identifying regional economic impacts of small-scale transport projects that should have no measurable impact on a national level. However, the Lyon–Turin link, with a length of 257 km and the corresponding high-speed and combined-rail project involving investments of €13 billion over 10 years as part of the TEN-T corridor Lyon–Turin–Trieste–Budapest, reveals a size that should be substantial enough to provide national impacts such that the usage of ASTRA would be promising.

The ASTRA model does not include a transport network model that would enable addressing transport cost and time changes of specific network links. Instead, ASTRA incorporates modal origin–destination matrices indicating the point of origin of a trip and the point of destination for different distance bands that provide the cost, time, distance, and demand information for each O-D pair linking the four zones considered for each European country. ASTRA calculates travel times and modal demand completely endogenously for each O-D pair. Cost is modeled partially endogenously and partially by exogenous trends. Distance development is provided exogenously, though by shifting demand between different distance bands an endogenous component of distance modeling also is implemented.

Policy implementation for the Lyon–Turin corridor has to consider the O-D matrix structure of ASTRA. This is done by considering international country pair O-D elements that are potentially passing through the Lyon–Turin link and taking into account for policy implementation in ASTRA aggregated results of a detailed transport network model, in this case VACLAV (*16*). O-D country pairs selected for being relevant for policy implementation are:

- France–Italy,
- France–Austria,
- Belgium–Italy,
- Spain–Italy,
- Portugal–Italy,
- Spain–Austria, and
- Portugal–Austria,

where pairs indicate both directions of trade.

For each of these international O-D pairs, the share of total demand that is passing through the Lyon–Turin link and the share of the distance of the link on the total travel distance of the O-D pair are derived from VÀCLAV results. This information is needed to translate cost and time changes as well as demand results between the link level Lyon–Turin and the level of O-D matrices. For the base scenario this results in the transport demand data shown in Table 1. Total demand refers to the total demand transported between two O-D countries, which includes both demand transported via the Lyon–Turin link and demand transported via alternative routes (e.g., along the Mediterranean coast crossing the French–Italian border at Ventimiglia).

Transport Impacts

Since impacts of the policies can first be measured in the transport system itself, the analysis commences with the results for changes of transport demand between the most affected countries. The following tables present the changes of freight demand (tons) and passenger demand (trips) for road and rail mode. It should be taken into account that these are the aggregate results for all transport between the countries, since the question in this paper is not so much on the Lyon–Turin link itself but on the overall impact of removing a bottleneck on such a major transport link. In looking at the most important road freight changes, Table 2 shows that the strongest change is observed for transport from Italy to France with a reduction of nearly −10% in the year 2020 compared with BAU. Surprisingly, the opposite direction, from France to Italy, shows a reduction of only nearly −3%, while for both directions rail is gaining about +23%. This difference results from ship transport between Italy and France also losing close to −3%, while in the other direction ship transport is almost not affected. This appears to be caused by differences in the export structure between the two directions (e.g., Italy–France chemicals exports account for 16% while in the opposite direction it is only 6%, and in turn France–Italy machinery accounts for 17% while in the opposite direction it is only 9%) and different elasticities of the modal choice functions. The second strongest reaction of road freight transport can be observed for France–Austria in both directions, with road reducing about −3.5% and rail gaining about +8%.

For passenger transport, the changes on the country level are not that significant (see Table 3), which is plausible since passenger transport has more options for alternative route choice than freight transport. As expected, the strongest reactions on the road occur between France and Italy in both directions with −1.4% and −2.8%, while rail is gaining up to 11% compared with BAU, which is plausible because of the difference in the absolute levels for the modes, which are about three times higher for road than for rail.

Especially for the country pairs France–Italy and Italy–France, air transport also is losing demand with −0.75% for the former and −0.6% for the latter direction, both compared with BAU. This number appears to be too low, since this O-D pair involves the Milan–Paris flows, which should be of high relevance for current air transport between France and Italy and which can be expected to change significantly due to the large time savings by high-speed rail.

Trade Impacts

This section deals with the question of whether such a transport infrastructure improvement is able to evoke measurable export changes on the country level. The first analysis concentrates on France and

TABLE 1 Road Freight Demand on Lyon–Turin Corridor and Total Demand for Selected Country Pairs

Road Transport	Unit	2000	2005	2010	2015	2020
Lyon–Turin						
Trucks per day	(vhc/d)	4,993	5,330	6,214	7,201	9,065
Tons per year	(1,000 tons)	19,291	20,315	22,300	24,189	28,691
Total demand						
France–Italy	(1,000 tons)	21,318	21,922	22,645	22,888	24,840
France–Austria	(1,000 tons)	752	923	1,256	1,676	2,367
Belgium–Italy	(1,000 tons)	1,740	1,846	2,030	2,163	2,467
Spain–Italy	(1,000 tons)	1,750	2,016	2,844	3,725	5,416
Portugal–Italy	(1,000 tons)	31	42	80	204	404
Spain–Austria	(1,000 tons)	93	139	232	370	588
Portugal–Austria	(1,000 tons)	2	3	8	29	61
All country-pairs	(1,000 tons)	25,686	26,891	29,094	31,055	36,143

SOURCE: ASTRA results in BAU.

TABLE 2 Percentage Change in Freight Transport Demand (tons) Compared with BAU in Year 2020

	Scenario	Austria	Belgium	Spain	France	Italy	Portugal
Road							
Austria	New rail only (RIO)	0.00	0.01	−0.68	−2.70	0.03	0.00
	New rail plus road toll (RIPT)	0.00	0.01	−0.72	−2.90	0.03	−0.05
Belgium	New rail only (RIO)	0.01	0.00	0.06	0.16	−1.17	0.03
	New rail plus road toll (RIPT)	0.01	0.00	0.06	0.15	−1.36	0.02
Spain	New rail only (RIO)	−0.75	0.05	0.00	0.01	−1.07	0.01
	New rail plus road toll (RIPT)	−0.78	0.05	0.00	0.03	−1.16	0.01
France	New rail only (RIO)	−3.96	0.30	0.04	0.00	−1.97	0.41
	New rail plus road toll (RIPT)	−4.29	0.27	0.04	0.00	−2.80	0.36
Italy	New rail only (RIO)	0.09	−0.88	−0.98	−8.78	0.00	0.31
	New rail plus road toll (RIPT)	0.08	−1.03	−1.20	−10.07	0.00	0.19
Portugal	New rail only (RIO)	−0.10	−0.02	0.01	−0.20	−0.29	0.00
	New rail plus road toll (RIPT)	−0.15	−0.01	0.01	−0.16	−0.33	0.00
Rail							
Austria	New rail only (RIO)	0.00	−0.01	3.68	8.32	−0.12	2.01
	New rail plus road toll (RIPT)	0.00	−0.01	3.71	8.71	−0.12	2.01
Belgium	New rail only (RIO)	−0.01	0.00	−0.36	−0.09	3.20	−0.55
	New rail plus road toll (RIPT)	−0.01	0.00	−0.36	−0.10	3.21	−0.56
Spain	New rail only (RIO)	3.57	−0.40	0.00	−0.45	10.98	−0.05
	New rail plus road toll (RIPT)	3.66	−0.41	0.00	−0.43	11.18	−0.06
France	New rail only (RIO)	7.76	0.14	0.45	0.00	22.70	0.56
	New rail plus road toll (RIPT)	8.20	0.08	0.34	0.00	24.87	0.46
Italy	New rail only (RIO)	−0.02	4.96	6.80	23.07	0.00	2.89
	New rail plus road toll (RIPT)	−0.03	5.09	6.85	24.94	0.00	2.84
Portugal	New rail only (RIO)	1.90	−0.80	−0.08	−0.59	4.47	0.00
	New rail plus road toll (RIPT)	1.92	−0.80	−0.08	−0.55	4.59	0.00

SOURCE: ASTRA results in scenarios.

TABLE 3 Percentage Change in Passenger Transport Demand (trips) Compared with BAU in Year 2020

	Scenario	Austria	Belgium	Spain	France	Italy	Portugal
Road							
Austria	New rail only (RIO)	0.00	0.00	−0.01	−0.13	0.00	−0.03
	New rail plus road toll (RIPT)	0.00	0.00	−0.01	−0.13	0.00	−0.03
Belgium	New rail only (RIO)	−0.02	0.00	0.00	0.02	0.00	0.04
	New rail plus road toll (RIPT)	−0.01	0.00	0.01	0.02	0.00	0.03
Spain	New rail only (RIO)	0.00	0.00	0.00	0.01	−0.01	0.00
	New rail plus road toll (RIPT)	0.00	0.00	0.00	0.01	−0.01	0.00
France	New rail only (RIO)	−0.85	−0.06	−0.09	0.00	−2.80	−0.14
	New rail plus road toll (RIPT)	−0.83	−0.05	−0.08	0.00	−2.79	−0.13
Italy	New rail only (RIO)	−0.02	−0.07	−0.20	−1.40	0.00	−0.07
	New rail plus road toll (RIPT)	−0.02	−0.07	−0.20	−1.40	0.00	−0.07
Portugal	New rail only (RIO)	0.00	0.00	0.00	0.00	0.00	0.00
	New rail plus road toll (RIPT)	0.00	0.00	0.00	0.00	0.00	0.00
Rail							
Austria	New rail only (RIO)	0.00	−0.02	2.62	3.12	−0.04	7.16
	New rail plus road toll (RIPT)	0.00	−0.02	2.61	3.12	−0.04	7.15
Belgium	New rail only (RIO)	−0.03	0.00	−0.25	−0.09	4.43	−0.49
	New rail plus road toll (RIPT)	−0.02	0.00	−0.25	−0.10	4.43	−0.51
Spain	New rail only (RIO)	1.27	−0.10	0.00	−0.05	2.95	−0.01
	New rail plus road toll (RIPT)	1.27	−0.10	0.00	−0.06	2.95	−0.01
France	New rail only (RIO)	5.19	0.08	0.05	0.00	11.89	−0.19
	New rail plus road toll (RIPT)	5.14	0.05	0.03	0.00	11.89	−0.19
Italy	New rail only (RIO)	0.08	5.39	2.61	8.83	0.00	2.37
	New rail plus road toll (RIPT)	0.06	5.37	2.61	8.83	0.00	2.36
Portugal	New rail only (RIO)	2.22	−0.21	−0.01	−0.06	4.57	0.00
	New rail plus road toll (RIPT)	2.22	−0.22	−0.01	−0.06	4.57	0.00

SOURCE: ASTRA results in scenarios.

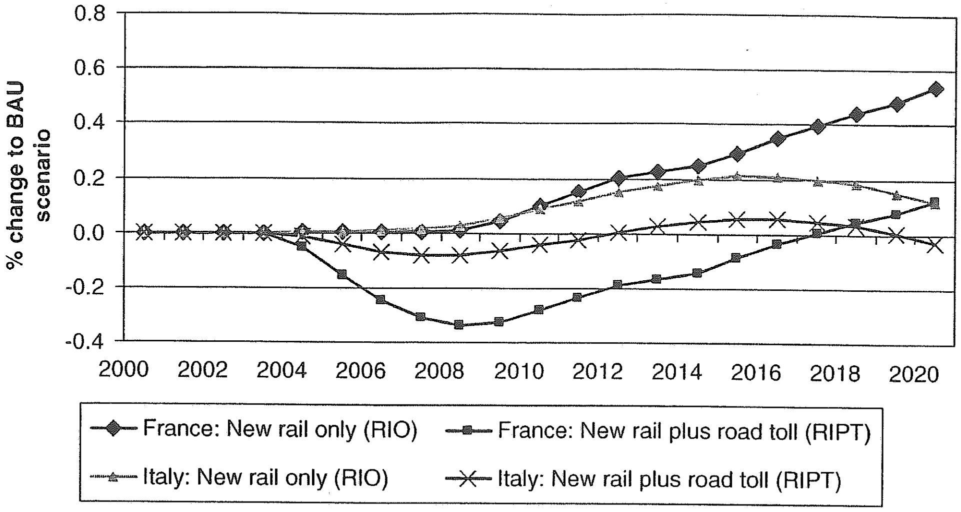

FIGURE 3 Development of total trade changes between France and Italy in two scenarios.

Italy as the two countries potentially benefiting most from the new infrastructure. Figure 3 shows that the two analyzed scenarios generate different patterns of export changes. The infrastructure-only scenario is always positive for both countries, generating in the year 2020 an export increase of +0.55% for France and +0.15% for Italy. In absolute terms this amounts to an increase of exports by €2.4 billion for France and €2.1 billion for Italy over the next 15 years. For this number one has to consider that the new link would have been fully operational for only 6 of those 15 years.

The pattern of the infrastructure-plus-pricing scenario reveals that during the first decade, when only the pricing policy is implemented and the new link is not completed, exports are slightly decreased compared with BAU. With the completion of the link, this changes such that the change of exports also moves to the positive side.

Looking at the level of country pairs for exports, in Table 4 it can be observed that not all combinations gain from the infrastructure improvement. As expected, France and Italy gain for all pairs with at maximum 0.54% of exports. However, there are also significant losses (e.g., for exports from Portugal to France, which is a combination not using the link at all). It appears that the modal shift toward rail for some longer transport distances, such as Portugal–Austria or Portugal–Italy, causes capacity problems on other parts of the rail network (e.g., in France or Spain) such that export flows not benefiting from the Lyon–Turin corridor but suffering from these capacity problems in other parts of France or Spain are reduced.

Economic Impacts

Finally, there is the question of whether the observed significant transport impacts as well as the minor trade impacts would cause measurable economic impacts. For this analysis, two indicators have been selected for France and Italy—GDP and employment—for which the development compared with the BAU scenario is presented in Figure 4. As already indicated by the trade impacts in the previous section, France is developing better than Italy, and both countries show a positive change of GDP with +0.3% for France and +0.1% for Italy until 2020. The employment impacts are much smaller and follow mainly the construction process of the Lyon–Turin

TABLE 4 Percentage Change in Monetary Exports for Relevant Country Pairs Compared with BAU Scenario

Import To / Export From	Scenario	Austria	Belgium	Spain	France	Italy	Portugal
Austria	New rail only (RIO)	0.00	0.00	0.01	0.09	–0.06	0.01
	New rail plus road toll (RIPT)	0.00	0.00	0.00	0.05	–0.05	0.01
Belgium	New rail only (RIO)	0.01	0.00	0.00	–0.06	–0.35	0.02
	New rail plus road toll (RIPT)	0.00	0.00	0.00	–0.05	–0.47	0.01
Spain	New rail only (RIO)	0.01	0.00	0.00	–0.17	–0.06	0.00
	New rail plus road toll (RIPT)	0.00	0.00	0.00	–0.14	–0.07	0.00
France	New rail only (RIO)	0.11	0.23	0.03	0.00	0.54	0.06
	New rail plus road toll (RIPT)	0.07	0.20	0.02	0.00	0.12	0.05
Italy	New rail only (RIO)	0.04	0.07	0.26	0.12	0.00	0.09
	New rail plus road toll (RIPT)	0.03	0.03	0.21	–0.03	0.00	0.07
Portugal	New rail only (RIO)	0.09	–0.03	0.00	–0.58	–0.11	0.00
	New rail plus road toll (RIPT)	0.09	–0.02	0.00	–0.49	–0.10	0.00

SOURCE: ASTRA results in scenarios.

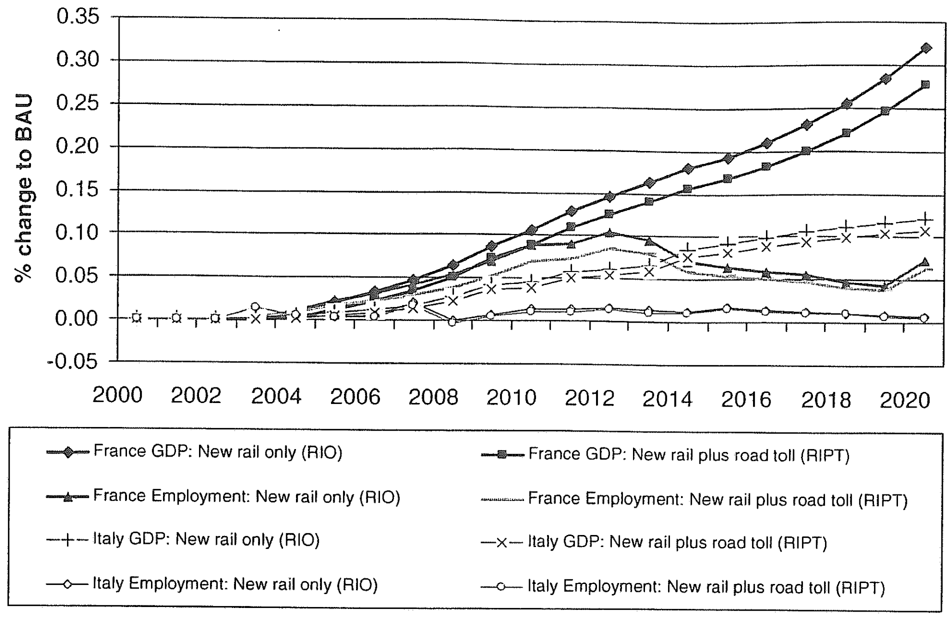

FIGURE 4 Changes of selected economic indicators for France and Italy.

link, though for France a slight increase of +0.05% remains in 2020. However, looking at the trend of GDP in 2020, it appears that a continuous increase of GDP after 2020 also can be expected.

A look at changes at the aggregate EU15 level in Figure 5 reveals small changes in relative terms. However, with the change accumulated over 15 years and a look at the totals, for example, the change of undiscounted GDP would reach €61 billion and the additional employment amounts to 275,000 person years.

More meaningful than absolute values in this case are the trends showing the time improvements for average rail transport time that go in line with each single step of completing the Lyon–Turin link. These average time improvements are calculated by the networkwide freight travel time and the total ton-kilometers being aggregated and the totals being divided such that it is a real networkwide figure that reveals the impact of one single corridor.

It has been shown that six major impact chains in ASTRA link transport impacts to the economy (*17, 8*) of which four impact chains prove to be more important if a transport policy measure changes expenditures for transport, while two other impact chains are more influential when a transport policy measure alters transport times. In principle, these two major impact chains in ASTRA could be decisive for the positive economic development through the Lyon–Turin corridor:

- Impact chain: new infrastructure → transport time↓ → accessibility↑ → exports↑ → GDP↑ or
- Impact chain: new infrastructure → freight time↓ → total factor productivity↑ → GDP↑ → imports↑ → exports↑.

For an analysis of the importance of each chain in ASTRA, selected impact chains can be switched off in the model and replaced

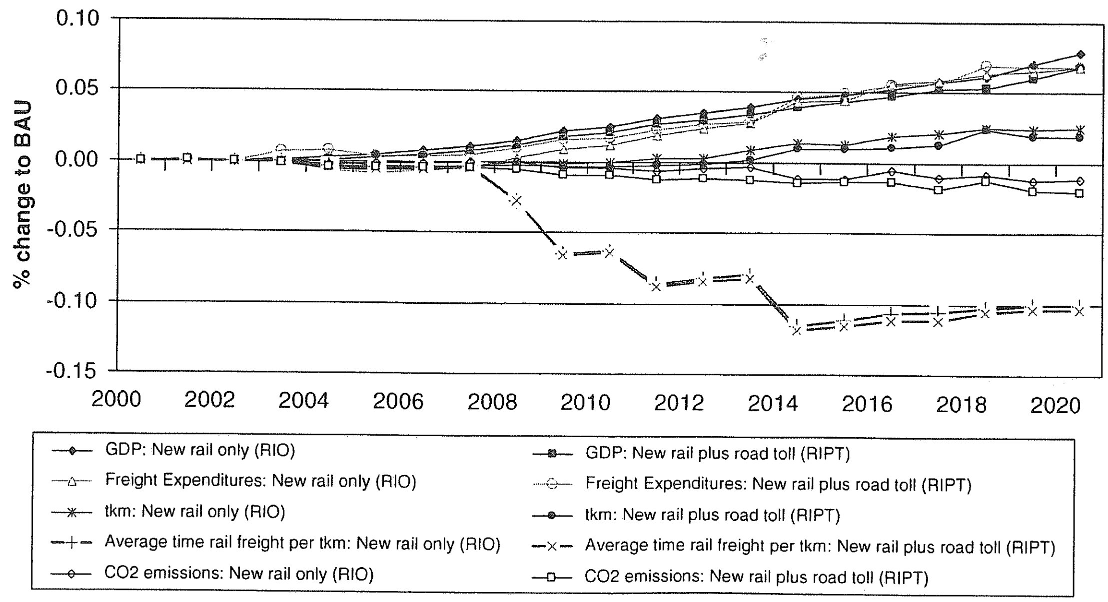

FIGURE 5 Changes to BAU at EU15 level for selected indicators.

by the BAU results. Applying this switch-off analysis to find out if the link accessibility to exports is more important or the link freight time to TFP, the conclusion can be drawn that the influence of the time improvements on productivity is about four times more relevant than the influence on exports.

CONCLUSIONS

Two questions have been the focus of this paper. The first is, with the aggregated O-D-matrix approach of ASTRA, can an assessment of single infrastructure projects of European significance can be performed? The second is, would there be measurable economic impacts identified by ASTRA? To answer these questions, the Lyon–Turin corridor was selected since one of the TEN-T projects runs through this corridor, which is a high-speed rail link that reduces passenger travel times on the link by 2.25 h and allows for a strong increase of capacity for rail freight.

Besides a business-as-usual scenario considering the major policy measures as defined in the White Paper on European transport policy (*1*), two policy scenarios were defined. The first includes only the implementation of the Lyon–Turin high-speed railway; the second imposes a road freight charge on this link to encourage modal shift toward rail by cost incentives.

The first question—if the analyzed policy packages cause significant transport changes that can be detected by ASTRA—can be positively answered. Modal shifts predicted by ASTRA reach levels up to −10% for road freight demand and +25% for rail freight demand compared with the BAU scenario, which is a significant change though still less optimistic than expectations raised in the official plans. Here, ASTRA could underestimate the impacts due to its aggregate approach.

The second question, which is the more interesting one for ASTRA, also can be answered positively, though it has to be taken into account that economic changes remain small such that the trend indications provide more relevant tools for analyses than the absolute values. On the country level, export changes compared with BAU can reach +0.6% in 2020 and GDP changes +0.3% in the case of France, which is the country benefiting most from this project. On the level of the EU15, a comparison between the investment cost of €13 billion and the aggregated increase of GDP over 15 years until 2020, which reaches €61 billion, appears to indicate a reasonable usage of public money, although no alternative uses are considered for comparison.

In consideration of the mechanisms causing this positive impact, it appears that the influence on the supply side caused by the freight time savings driving productivity, as freight transport is part of today's production chains, is more relevant than the influence on the demand side, which works via accessibility gains induced by the new infrastructure affecting the export flows.

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