European
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The impact of TEN-T completion on growth, jobs and the environment

METHODOLOGY AND RESULTS

Final Report

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About the project consortium

M-Five GmbH Mobility, Futures, Innovation, Economics (Karlsruhe) is a scientific consultancy providing systemic advice in the fields of mobility and economics. Their expertise covers the fields of emerging new mobility services and technologies, transport policy, economics and innovations. M-Five advises public and private entities, the former receiving sound policy advice and the latter strategic guidance for their business in the mobility domain and its deepening linkages with energy and ICT domains in a world of strong climate mitigation ambitions.

TRT Trasporti e Territorio srl (Milan) is an independent consultancy specialised in transport economics, transport planning and modelling. Established in 1992, TRT combines its expertise in research projects with professional studies supporting public and private players in the transport sector. TRT experts have a long record of experience in strategic planning, transport modelling, sustainable urban mobility, feasibility studies, project assessment, transport demand analysis and forecast, logistics and freight transport, planning and regulating of public transport, energy and environment.

Ricardo Energy & Environment is an energy and environmental consultancy with over 40 years' experience working with clients across the globe. Ricardo Energy & Environment is experienced in high-level strategic policy development and research for the European Commission and national governments, as well as analysis and modelling for major businesses, with their expertise covering a wide range of analytical tools and techniques. These skills and knowledge are used to provide strategic and specialist support to develop and evaluate transport policy both at home and internationally.

Report on behalf of the European Commission

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List of Abbreviations

AFID	Alternative Fuels Infrastructure Directive (2014/94/EU)
AP	Annual work programme of CEF
ATL	Atlantic core network corridor
BAC	Baltic-Adriatic core network corridor
Bn	Billion
Basel III	Third Basel Accord by the BIS
BIS	Bank for International Settlements
CBA	Cost-benefit analysis
CEF	Connecting Europe Facility
CGE	Computable general equilibrium model
CNC	Core network corridors on the TEN-T
CNoCNC	TEN-T core network not part of any CNC
CO_2	Carbon dioxide
EC	European Commission
EIB	European Investment Bank
EIOPA	European Insurance and Occupational Pensions Authority
EP	European Parliament
ERTMS	European rail traffic management system
EU	European Union
EU 13	Bulgaria, Croatia, Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovak Republic, Slovenia
EU 15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden, United Kingdom
FTE	Full-time equivalent employment
GHG	Greenhouse gas emissions

GDP	Gross domestic product
IO	Input-Output, may refer to IO-Tables or IO-Analysis
IWW	Inland Waterway transport
M	Million in relation to currencies
MAP	Multi annual work programme of CEF
MED	Mediterranean core network corridor
MoS	Motorways of the sea
MS	Member States
Mt	Megatonne, million tonnes
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne.
NEC	National emissions ceiling
NEDC	New European Driving Cycle – road vehicle test cycle
NSB	North-Sea-Baltic core network corridor
NSM	North-Sea-Mediterranean core network corridor
OEM	Orient-East-Med core network corridor
p.p.	Percentage points
PBI	Project bond initiative of the EIB
PHEV	Plug-in hybrid electric vehicle
Pkm	Passenger kilometre – 1 person transported over 1 km distance
PPP	Public-private-partnership
PSO	Public service obligations
RALP	Rhine-Alpine core network corridor
REF2016+	EU Reference Scenario 2016 (updated version)
RHD	Rhine-Danube core network corridor
SAM	Social accounting matrix
SCGE	Spatial computable general equilibrium model
SCM	Scandinavian-Mediterranean core network corridor

SCR	Solvency capital requirement
SDM	System dynamics model
Solvency II	Directive 2009/138/EC for the harmonisation of the EU insurance regulation
SPV	Special purpose vehicle
TEN-T	Trans-European-transport-network
Tkm	Tonne kilometre – 1 tonne of goods transported over 1 km
TFP	Total factor productivity
VaR	Value-at-risk
WEI	Wider economic impacts
WLTP	Worldwide harmonized Light-vehicles Test Procedure

1 Introduction

TEN-T policy is a major European Commission policy directed towards development of a Europe-wide multimodal transport network, which contributes to the three principal objectives of European policy-making: fostering growth, creating jobs and mitigating climate change. The TEN-T consists of a "core network" layer to be completed by 2030 and a "comprehensive network" layer to be completed by 2050. The comprehensive network covers all European regions, whereas the core network represents the most strategically important parts of the comprehensive network. A major instrument to facilitate and streamline the coordinated development of the core network is the "corridor approach", in which a set of nine core network corridors (CNC) have been identified.

The objective of this study is to assess the growth, jobs and climate impacts resulting from investments to be made between 2017 and 2030 to implement each CNC, as well as the TEN-T core network overall.

A second important element of EU transport policy concerns the funding of TEN-T projects. Therefore, a second objective of the study concerns an assessment of expected impacts of the Connecting European Facility (CEF) for 2021 - 2027, as proposed by the European Commission. This current report is only dedicated to the assessment of the implementation of the core TEN-T network. The assessment of the CEF funding will be documented separately.

Two modelling scenarios have been defined: The Baseline Scenario and the Reference Scenario. In the Baseline Scenario, it is assumed that the implementation of the core TEN-T network stops at the end of 2016 and no further investments are made. In the Reference Scenario, the core TEN-T network is assumed to be fully implemented by 2030, in line with the requirements of Regulation 1315/2013 on the development of the TEN-T. The Reference Scenario is consistent with an update of the EU 2016 Reference Scenario[1]. The TEN-T core network is defined in the present study by the infrastructure projects collected in the context of the CNC studies as of mid-2017, plus the sections of the core TEN-T network that will be implemented by 2030 but are not part of the CNCs. The difference between these two scenarios is equivalent to the impact of the TEN-T core network implementation between 2017 and 2030. The analysis is based on a modelling suite consisting of a European multi-modal transport network model, called TRUST, and an integrated transport-economy-environment assessment model, called ASTRA.

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[1] The updated EU Reference Scenario 2016 includes some updates in the technology costs assumptions (i.e. for light duty vehicles) and a few policy measures adopted after its cut-off date (end of 2014) such as the Directive on Weights and Dimensions, the 4th Railways Package, the NAIADES II Package, the Ports Package, the replacement of the New European Driving Cycle (NEDC) test cycle by the new Worldwide harmonised Light-vehicles Test Procedure (WLTP). It has been developed with the PRIMES-TREMOVE model (i.e. the same model used for the EU Reference Scenario 2016) by ICCS-E3MLab (Capros et al. 2016). A detailed description of this scenario is available in the Impact Assessment accompanying the Proposal for a Directive amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures, SWD (2017) 180

The report contains eleven sections, including this introduction. The section following this introduction provides a brief overview of the methodology for the assessment of impacts. The third section explains the economic terminology relevant for understanding the economic findings. The fourth section provides a literature review on economic impacts of transport infrastructure in general, as well as of the TEN-T network. The fifth section explains the design of the scenarios including the relevant input data. This is followed by a description of the Baseline Scenario, i.e. the scenario without further implementation of the TEN-T core network after 2016. The seventh section gives a comparison of the Reference Scenario in the models with the data of the external Reference Scenario. The eighth section describes the transport impacts and the economic impacts of the implementation of the whole TEN-T core network, while the ninth section provides an overview on the impacts of each single CNC. The tenth section presents the conclusions. These are followed by a section listing tables and figures and a final section on the references.

2 Overview of the project methodology

The analysis of impacts is based on the interaction between two models: TRUST and ASTRA, as explained below. Both models have been applied in several projects before, and linking them together aims to achieve two goals:

- The addition of economic and social dimensions to the analysis of impacts of transport policy measures, simulated in detail on a network basis.
- Evaluation in detail of the transport impacts of infrastructure projects on the network.

2.1 Overview of TRUST

The TRansport eUropean Simulation Tool (TRUST) is a transport network model allowing for the assignment of Origin-Destination matrices at the NUTS-III level for passenger and freight demand. The matrices are estimated from various sources, including Eurostat, national statistics and the European ETIS database. The model is calibrated to reproduce tonne-km and passenger-km by country consistent with the statistics reported in the Eurostat Transport in Figures pocketbook, apart from the intra-NUTS-III demand, which is not assigned to the network. Based on the transport demand on the network, TRUST deals with the assignment of road transport O-D matrices for both passenger (cars) and freight (trucks > 3.5t). The road network covers all relevant links between the NUTS3 regions, including motorways, primary roads, and roads of regional and sub-regional interest. Ferry connections (Ro-Ro services) between European regions and between Europe and North Africa are also explicitly modelled including travel time and fare. Road network links are separated in different classes, each with specific features in term of capacity, free-flow speed and tolling. The link types distinguish different road categories (e.g. motorways). Specific flags are used to identify links belonging to the Core TEN-T Network and to each corridor.

The passenger car matrix is segmented into three groups:

- Short distance (<100 km) commuting
- Short distance (<100 km) non-commuting
- Long distance (>100 km)

The road freight matrix is segmented into four groups:

- Domestic Short distance (<=50 km)
- Domestic average distance (50–150 km)
- Domestic Long distance (>=150 km)
- International

The segmentation allows dedicated parameters to be applied (such as different load factors, considering that short distance domestic transport usually uses lighter trucks than long distance international transport), and to measure the contribution of each segment to link loads. In addition, each demand group is further divided by the origin country (there are 242 flows in total) to allow the differentiation of fuel costs. Base year matrices, in terms of trips or tonnes in an average day (24 hours), are based on those estimated in the ETISplus project. Revisions have been applied to these matrices to update the base year from 2010 to match Eurostat statistics on road traffic for later years. For projections, future matrices are estimated by applying demand growth rates provided by the ASTRA model.

The car cost function reflects the variable operating costs (fuel and toll costs) relevant for route choice. Tolls are coded on relevant link types and are always expressed in terms of cost per kilometre. When the toll is applied on a different basis (for example an annual vignette) assumptions on the representative annual kilometres run on tolled roads are used to derive an average cost per kilometre. Operating costs are also coded as cost per kilometre and depend on the total distance irrespective of the specific route. Fuel costs are differentiated among countries and are based on the ASTRA model results.

For trucks, cost functions include tolls and variable costs. Again, tolls are transformed into a cost per kilometre if the system applied is based on fixed fares. Truck variable costs include fuel consumption and labour costs, both expressed in Euros per vehicle kilometre. Operating costs are different across freight demand segments to reflect that lighter vehicles are used for shorter distance journeys compared to heavy vehicles which are used more for longer distances. Both fuel costs and labour costs are differentiated among countries and are based on the ASTRA model results.

Value of travel time is used to transform travel time into a monetary equivalent. It is coded in terms of Euros per hour-trip or Euros per hour-tonne and varies according to country and demand segment.

The SUE (Stochastic User Equilibrium) assignment algorithm distributes demand for each origin/destination pair among available alternative routes according to their utility using a logit model. The utility of each route is measured in terms of generalised cost.

The rail model adopts a rail transport network based on the TRANS-TOOLS and ETISplus rail network with several integrations. The rail network includes different link types (conventional, high speed, border rail link - by demand segments where allowed). Rail supply includes intermodal terminals where loads are transferred between road and rail. Inland waterways and maritime are modelled as feeder modes.

Demand is segmented according to types of traffic that correspond to different train types in terms of occupancy of rail capacity. For passenger demand, three segments based on train type are used:

- Regional Trains
- Intercity Trains
- High Speed Trains (or similar, like the German ICE trains).

For freight trains, two different types are considered:

- intermodal trains,
- conventional trains (conventional block trains or single wagon load trains). Since UIC statistics suggest that average load of conventional trains is very different

across countries, this second type is further split according to the average train load (700, 1200 or 2900 tonnes).

Base year matrices are based on those estimated in the ETISplus project (ETISPlus 2010 data). The original matrix from the ETISplus project has been distributed among the segment demands of the TRUST model. Results have been compared with the Eurostat statistics on rail traffic (ton-km and pass-km) for later years. For projections, future matrices are estimated by applying demand growth rates provided by the ASTRA model. Matrices are given in terms of trips or tonnes in an average day (24 hours). Trips and tonnes are endogenously translated into trains loaded onto the rail network by means of average occupancy and load factors. TRUST rail assignment does not consider capacity limitations and is performed according to an AON (all or nothing) algorithm.

2.2 Overview of the ASTRA model

The Assessment of Transport Strategies (ASTRA) model is a System Dynamics model designed for the assessment of impacts of various transport policies and strategies (Fiorello et al. 2012, Schade et al. 2015). The model has also been applied for economic assessment of energy and climate policies (Schade et al. 2009a, Schade et al. 2009b). It is one of the few tools that integrates the full transport system. It comprises a transport demand model, a vehicle fleet model, an environmental model and a fully-fledged macro-economic model (including models of the national economies of all EU Member States as well as a trade model for Intra-EU trade and trade with other world regions). ASTRA is therefore able to model different levels of effects: (1) the direct effects of a transport policy taking place within the transport sector itself (e.g. changes of transport flows and modal-shift), (2) the direct effects of infrastructure policies in the economy (e.g. the impact of the investments on the construction sector) and (3) the indirect effects (or second-round effects) occurring anywhere in the economy usually with some delay after the initial impulse of the policy entered the transport and/or economic system (e.g. value-added in the metal industry, growth of GDP or jobs in service sectors).

The objective of ASTRA is to support strategic decision-making (i.e. to provide advice on policy choices that can make a difference in the medium to long-term (2025, 2030, 2050) and less on details of a policy for the short-term). Given the uncertainty that is associated with the analysis of such long-term time horizons, the ASTRA model is based on a System Dynamics simulation. It is able to run scenarios and sensitivity tests in a comparably low running time (minutes) compared with other methodologies that take hours or days. This comparatively high-speed of generating results is traded-off against a lower level of detail in which results are generated (i.e. ASTRA results can be provided at the level of NUTS-II zones (parts of the transport demand results and the population model) or at the level of countries (economic and trade results, vehicle fleet results)). The ASTRA model is calibrated to reproduce the development of selected variables for the period 1995 to 2016 with an emphasis on the second decade.

The focus of ASTRA application in this project is on: (1) the macro-economic module, (2) the proper representation of the TEN-T scenarios and (3) the linkages between the transport module and the macro-economic module, including the transport linkages that were fed from the TRUST model.

The macro-economic modelling from ASTRA relevant for this project can be roughly differentiated into four core elements:

- The **demand side** with private consumption of households, investments and the trade balance differentiated by 25 economic sectors (NACE-CLIO system) and government consumption.
- The **supply side** with capital stock, labour supply and total factor productivity (TFP).
- The **input-output tables** depicting the sectoral interactions and enabling to estimate sectoral gross-value-added (GVA) and sectoral employment.
- The **micro-macro-bridges** linking the bottom-up calculations of the transport system with the various elements of the macro-economic module.

At the core of the macro-economic modelling in ASTRA is the determination of GDP for each future year, which results from the interaction between the supply and demand side of the national economy of each Member State. The level of GDP and the taxation systems of the countries determine disposable income and subsequently the sectoral spending behaviour of households, which is also affected by spending for the transport sector that is determined by the results of the transport models. Sectoral final demand as well as energy and transport-related impacts affect the sectoral value-added through the input-output tables, which in turn constitutes a driver of sectoral employment. On the supply side, the most relevant variable is Total Factor Productivity (TFP), which is driven by sectoral labour productivity, type of investment goods demanded and nationally averaged freight transport time - linking TFP directly with an efficiency indicator of the transport sector.

The transport module in ASTRA follows the classical four-stage modelling approach with generation, distribution, modal split and assignment for both passenger and freight transport. The major difference compared to network-based models is that ASTRA models the assignment in a simplified way and without a map-based transport network.

In the passenger generation, the number of passenger trips is driven by the development of societal groups with similar travel and trip making patterns distinguished by income and age. The trip distribution splits trips of each zone into three distance bands within the zone and two crossing the zonal borders. Freight transport is driven by two mechanisms. Firstly, national transport depends on sectoral production value. The monetary output of the input-output table calculations are transferred into volume of tonnes by means of value-to-volume ratios. Secondly, international freight transport flows are generated from monetary Intra-European trade flows using the same approach.

Using transport cost and transport time matrices, the transport module calculates the modal-split for five passenger modes (car, bus, train, air, and walking and cycling) and four freight modes (truck, train, maritime, and inland waterways). The cost and time matrices depend on influencing factors like travel speeds, structure of vehicle fleets, transport charges, fuel price or fuel tax changes. Travel times for passenger and freight transport per Origin-Destination (O/D) relation change endogenously via speed-flow curves depending on the transport demand and the network capacity relevant for the specific mode. Hence, the ASTRA model does not cover a real transport network. The transport module calculates vehicle-km per mode and country based on passenger and freight transport performance in terms of passenger-km and ton-km, occupancy rates and load factors, respectively.

Major outputs of the Transport Module, which calculates vehicle-km travelled (VKT) per mode and distance band, are provided to the Environment Module (ENV) of the ASTRA model. These inputs and the information from the vehicle fleet model on the technical composition of the vehicle fleets are used by the environmental module to calculate the major greenhouse gas (GHG) and air pollutant emissions from transport, including CO_2, NO_x, CO, VOC and PM10.

2.3 Interaction between TRUST and the ASTRA model

Figure 1 presents the interactions between TRUST and the ASTRA model as well as the main inputs used in this study. Both models are calibrated to an update of the **EU Reference Scenario 2016**[2] in terms of demographics, economic growth, energy and transport sector developments. In the EU Reference Scenario 2016, it has been assumed that the TEN-T core network will be implemented by 2030 and the TEN-T comprehensive network by 2050. It employed a combined econometric and engineering approach for deriving transport activity by transport mode, drawing on inputs from the TENTec system for the expected length and/or upgrades of the TEN-T network. However, it did not consider concrete projects and did not investigate the transport network dimension. These details have been elaborated by the Corridor Studies of the nine CNC and have been collected and documented in the project list of each CNC. The project lists of all nine CNC by mid 2017 have been used for the purpose of this study. Eliminating double counting of projects, 2,931 projects have been identified that are needed to implement the CNC.

Assumptions on the implementation of the TEN-T core network over time constitute the major specific input to both the ASTRA model and TRUST. Assumptions are derived from

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[2] The updated EU Reference Scenario 2016 includes some updates in the technology costs assumptions (i.e. for light duty vehicles) and a few policy measures adopted after its cut-off date (end of 2014) such as the Directive on Weights and Dimensions, the 4th Railways Package, the NAIADES II Package, the Ports Package, the replacement of the New European Driving Cycle (NEDC) test cycle by the new Worldwide harmonised Light-vehicles Test Procedure (WLTP). It has been developed with the PRIMES-TREMOVE model (i.e. the same model used for the EU Reference Scenario 2016) by ICCS-E3MLab (Capros et al. 2016). A detailed description of this scenario is available in the Impact Assessment accompanying the Proposal for a Directive amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures, SWD (2017) 180

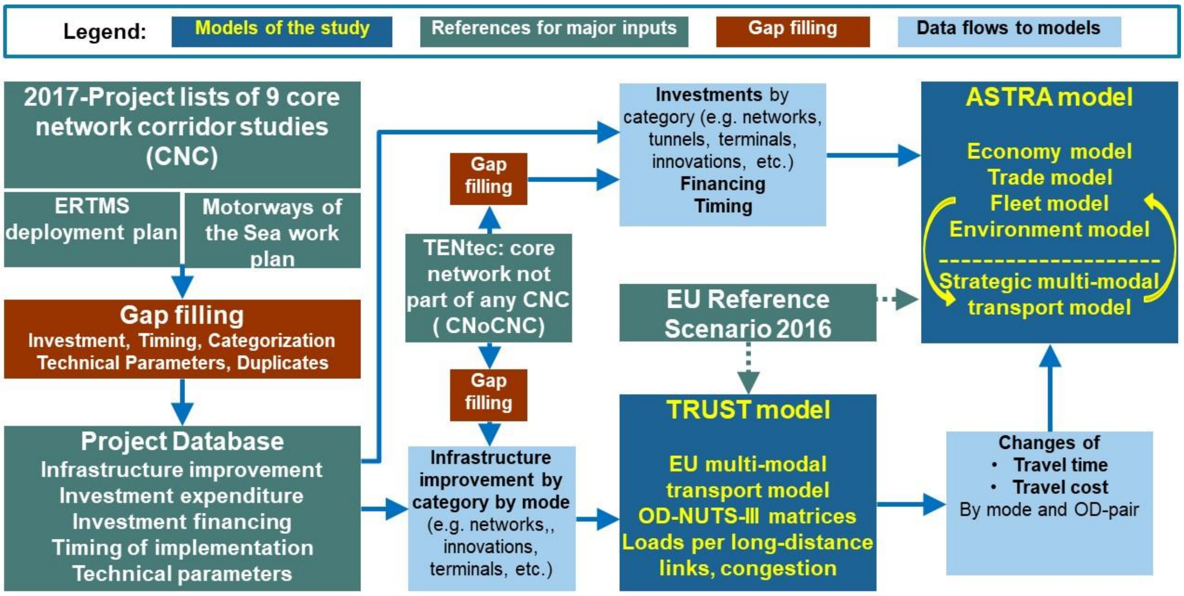
a **Project Database** specifically developed by the project team for the purpose of this assessment by building upon various sources: the project list of the nine CNC, the ERTMS deployment plan and the related list of investment, and the first work plan of Motorways of the Sea (see Figure 1).

The final project database contained 3,037 projects. Building on the project database, several process steps were needed to define the input as required by each of the models.

In addition, assumptions were needed on the development of the core network beyond the CNCs over time, estimating technical improvements and investments for the parts of the network that do not yet comply with TEN-T standards.

These inputs were used to develop the **Baseline Scenario** of the project, which assumes that no further core TEN-T network investments are implemented beyond 2016. Investment, financing and timing of investment directly alter the corresponding variables in ASTRA, which then generate new estimates for GDP, income, consumption, transport activity, etc. Assumptions on the evolution of the CNCs over time (e.g. new links and/or improvements of existing ones) are fed into the TRUST model (i.e. speed and number of tracks remain unchanged without investment) and changes of travel times and cost in the Reference Scenario are compared with the Baseline Scenario. Changes in travel times and costs are converted from the spatial concept of TRUST (link level) into the NUTS I level and fed into the ASTRA model in order to calculate the impacts on transport activity, GDP, income, consumption, etc. It should be noted that, as for any transport network model, the TRUST model is run for selected years only (i.e. 2016, 2020, 2025 and 2030), while ASTRA projects the impacts on a yearly basis.

After the projects of all nine CNC were added to the Baseline Scenario in ASTRA and TRUST, the models reflect the developments under the Reference Scenario.



Source: M-Five

Figure 1: **Major elements of the project methodology**

Figure 1 presents major linkages of the ASTRA economic modelling for the transport sector (i.e. infrastructure investment, travel time and cost). Further linkages exist between the vehicle purchase model, which feeds into sectoral investment in the same way as the infrastructure investment into TEN-T. Transport expenditures of households are considered in the household consumption models. Transport cost by mode affect the trade model, as an input to trade flow modelling, as well as the Input-Output model, as an input influencing the exchange of intermediate products between sectors. Transport demand and spending is a driver of value-added and thus employment by the different transport sectors.

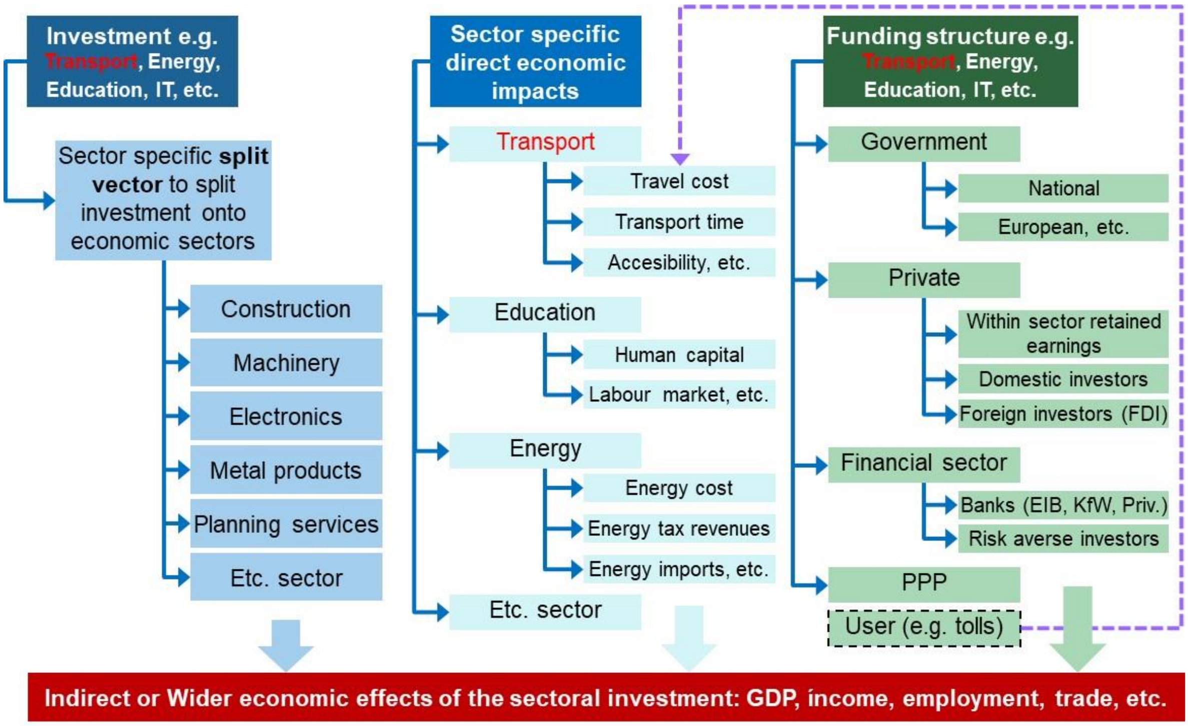
Finally, investment into TEN-T but also into other domestic transport infrastructure is considered as part of the government budget. The investments for cross-border projects for larger projects are split according to the involvement of the respective countries, where this information is available from the database. For smaller projects the split is evenly applied between the countries. In the context of this project, further funding mechanisms have been elaborated and implemented in ASTRA to reflect the new and innovative funding options foreseen by the European Commission and their advisors (e.g. Christophersen et al. 2015).

Combining the two models TRUST and ASTRA allows transport to be analysed at two levels: the network level covered by the TRUST model, which includes the links and nodes of the European transport system, and the strategic level by the ASTRA model, which includes intrazonal demand split into different distance bands and interzonal demand provided at the level of origin-destination pairs of transport between NUTS zones.

Figure 2 provides an overview of impacts generated by a transport investment divided into three pillars (1) direct investment impacts, (2) sector specific impacts, and (3) impacts of funding and of government interventions, as well as a comparison with impacts kicked-off if a similar investment would take place in selected other sectors (e.g. energy or education). The first pillar concerns the direct impact of investment. In transport, as in any other sector, the total investment would be split into a final demand vector assigning different shares of the investments to the sectors that produce the goods and services to implement the investment. For example, in case of a road, the largest share would go to the construction sector. In case of ERTMS, the largest shares would go to the electronics and computer sectors. In such cases, value-added and employment in these sectors and their supplier sectors would be fostered by the investment.

The second pillar comprises the sector-specific impacts. Transport interventions change transport cost, transport time and thus accessibility. These impacts differ for each sector. As ASTRA is specifically designed to model transport policies it includes the necessary sector specific models to assess transport policy impacts.

The third pillar concerns the funding of the investment, which in relation with transport networks largely stems from government funds. The impacts of the various funding options also need to be considered in the modelling, at least in cases in which the amount of investment is substantial in relation to the national GDP and the national amount of investment. Therefore, the modelling of funding impacts has been extended in the ASTRA model from the mere representation of crowding out private investment by debt funded government investment by considering further funding structures.



Source: M-Five

Figure 2: Impacts generated by transport infrastructure investments compared with investments in other sectors

3 Overview of economic terminology

A common terminology is needed to understand the meaning of the different approaches for measuring economic impacts. This section explains these different concepts.

3.1 Overview of economic impact measurement

Impact assessment projects aim to capture the economic impacts of policy interventions, such as infrastructure investments, pricing policies or government regulations. The classical approach to assess the welfare impact of single projects, in particular of transport infrastructure projects, is through a cost-benefit analysis (CBA). This section briefly explains the CBA approach and then discusses various extensions to a CBA. Extensions often involve designing an add-on to the classical CBA, or using a different modelling methodology compared to transport CBAs.

Conventional CBAs measure the change of consumer and producer surpluses stemming from public investment activities, and considers changes in environmental and safety costs. Applying this approach to a transport project shows the total economic impacts, assuming the economy is in perfect equilibrium (i.e. if all markets clear through equilibrium prices), and the equilibrium is only marginally affected through the investment activity. This general assumption requires a set of detailed hypotheses on preferences (rational choices) and technologies, such as decreasing returns to scale (or increasing marginal costs) of production. Since these rigid hypotheses do not correspond to the real-world observations, many suggestions can be found in the literature to extend the narrow CBA approach. These extensions have led to a rich list of technical terms:

Direct versus Indirect effects: Direct effects relate to the project and can either take place in the transport sector (e.g. changes of transport cost) or in the construction sector (e.g. due to infrastructure investment). Indirect effects are generated through feedback mechanisms with other markets (e.g. the supplier industries to the construction sector or the users of the infrastructure).

Induced effects: Induced effects are generated through mechanisms other than the dominating impacts (alternative terminology used: stemming from effects).

Second-round effects: While first-round effects are observed at the initial point in time of an impact mechanism, the second-round effects occur later and include other markets.

External effects: While internal effects are processed through the market mechanism (prices regulate supply and demand), external effects are processed outside the market (alternative terminology used: spillover effects).

Wider economic impacts: Wider economic impacts (WEI) comprise all economic effects which are not appropriately captured by a partial CBA. Alternative terminology used refer to: other economic impacts (OEI), wider economic benefits (WEB).

A typical add-on to a classical transport CBA includes the employment generated by a project or a policy/infrastructure programme, with the following associated terminology found in the literature:

Direct employment effects: These jobs are generated by the construction of the infrastructure (e.g. including the construction workers and the planners managing the work). We use the term ‘generated’ for these jobs, although the person on the job will have worked on other projects before and will continue to work on other projects after the construction under analysis is completed. In that sense it is not a new job. Nevertheless, the current job is sustained by the project under analysis.

Indirect employment effect: These jobs are generated by industries supplying inputs to the project (e.g. the concrete and steel industry delivers these materials to the construction sector that, in turn, undertakes the construction).

Induced employment effect: These jobs are generated in those sectors in which the employees/workers benefit from workers’ expenses spending their income from direct and indirect effects. The operation and use of the new infrastructure may also generate induced effects.

Second round employment effects: The implementation of the project has increased income and production potential of the economy in the first year of analysis. In subsequent years, the higher income is spent to generate additional new jobs creating again more income, and so on. Due to the circular nature of these impact chains they are called second round economic impacts and second round employment effects.

The European Investment Bank (EIB) differentiates the type of employment during the construction and the operation of new infrastructure. Jobs generated during construction are termed *temporary jobs,* as construction lasts a comparably short duration compared to the operation of the infrastructure. Jobs generated by the operation of the infrastructure are then called *permanent jobs* by the EIB. The EIB also concludes that additional indirect and induced jobs can be generated by the infrastructure project, and could be even more significant in number than the temporary and the permanent jobs (EIB 2016, p. 23).

As such, the objective of this study is to measure the temporary, permanent, indirect and induced jobs of the TEN-T implementation.

Extended impacts may occur as soon as the assumption of a perfect equilibrium on all markets of the economy does not apply. The identified deviations from the perfect equilibrium can be small or large, and the method of measurement depends on general economic approaches (welfare or GDP-based) and specific models applied.

Welfare approach: If one assumes that the deviations from the perfect equilibrium world occur only in one or a few markets then the welfare approach is preferred. This is applied in (spatial) general computed equilibrium models ((S) CGEs) as described by Venables (2007) or Bröcker (2011; CG Europe model). In these models only one market is assumed to show increasing returns to scale, while all other markets show decreasing returns and increasing marginal costs. This leads to agglomeration effects and increased economic productivity in central regions. Graham (2006) developed a simplified approach for the UK Department for Transport in which the agglomeration effects dominate the assessment.

GDP-based approaches: If major deviations from the general equilibrium environment are identified then the welfare approach is of a limited value. The agglomeration effects, which are at the core of the welfare measurement, are not always positive from the viewpoint of regional or urban development. They can lead to over-densification of cities or to neglect of regions with lower population density, as in the case of border areas. GDP-based assessment approaches can be appropriate to show long-term structural changes and development effects which support a more balanced and sustainable development of all regions of the economy. There is a rich variety of approaches that are used for measurement, which can be classified into comparative static and dynamic modelling branches.

Comparative static approaches: Examples are:

- Regional land-use and transport investment models (LUTI-models).
- Regional potential factor analysis (regional attributes which are indivisible, immobile, not substitutable and polyvalent).
- Keynesian macro-economic analysis (multiplier-accelerator analysis).
- Input-Output-Analysis and Social Account Matrix (SAM), aggregate and regional.

Dynamic approaches: Examples are:

- Romer’s model of endogenous growth (rate of technical progress explained by highly educated personnel in the R&D sector).
- Dynamic simulation models, possibly combined with CGE.
- System Dynamics models.

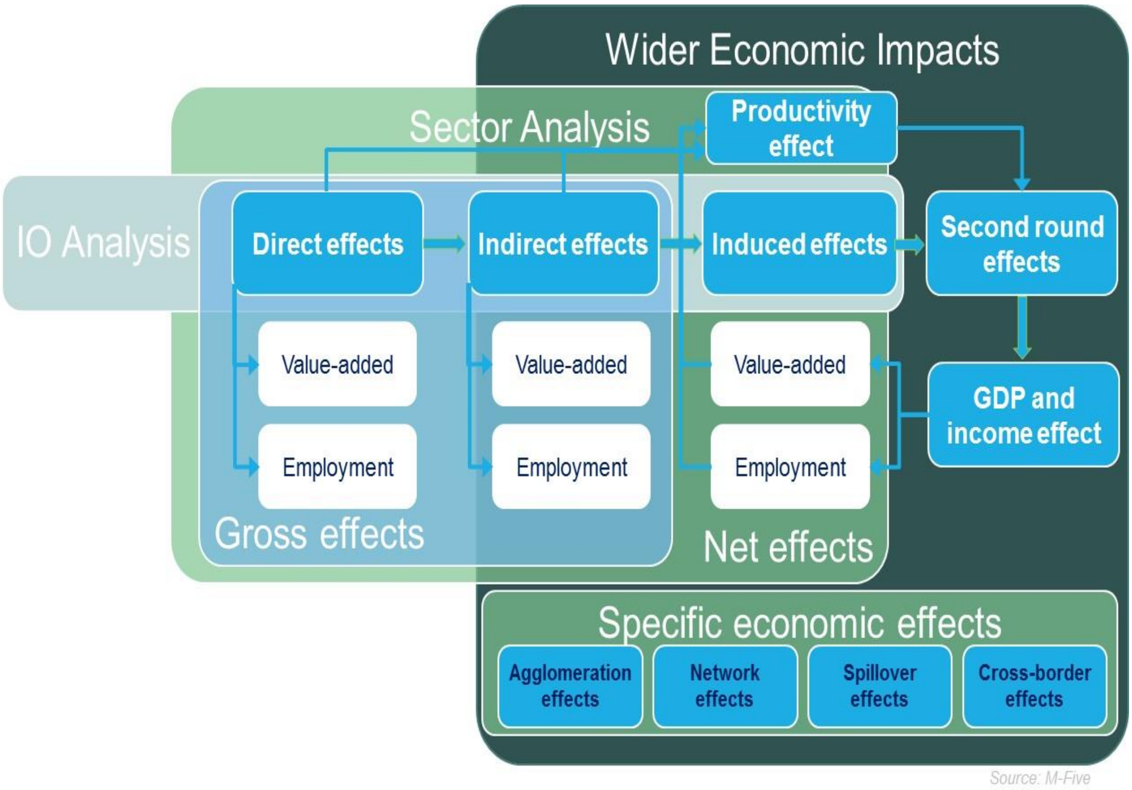
These models and their appropriateness for particular assessment tasks are explained in the literature (see Rothengatter, 2017).

3.2 Brief assessment of terminologies and approaches used for the quantification of impacts

Impacts can directly relate to a project or an action. If an economy showed a perfect equilibrium for all markets, then the measurement of direct impacts would also measure the total welfare effects. This is the implicit assumption of conventional cost-benefit analyses, which measure the change of project-related generalised costs, and environmental and accident costs as mandatory impacts. As soon as there are imperfect markets in the system, for instance showing increasing returns to scale of production (decreasing marginal costs), further impacts can occur. Their types and terminologies vary with the assumed scope of imperfections and the economic modelling approaches which are used for identification and measurement. Many different terms are used which can lead to confusion, such as ‘indirect’, ‘induced’, ‘stemming from’, ‘spillovers’, ‘external’, ‘second round’, ‘other’ or ‘wider’ economic impacts. Looking at the spatial dimension of impacts, ‘corridor’, ‘network’ or ‘cross-border’ effects are also mentioned.

Welfare theoretical approaches start from the general equilibrium baseline and assume that there are only a few markets that do not clear through the price mechanism, such as labour markets (e.g. EIB 2013, p.34). The developed SCGEs and their simplified versions measure in the first instance agglomeration effects (i.e. increasing returns to scale of production lead to spatial concentration and higher productivity in densely populated areas).

GDP-based regional and macroeconomic approaches may deviate from the perfect equilibrium paradigm and can identify a much wider scope of indirect impacts. Input-output models and their extension by social accounting matrices are widely used to measure sectoral and regional impacts of policy actions. In this context the terms ‘direct’, ‘indirect’ and ‘induced’ benefits are used to describe the first change after a stimulus, the impact on the industrial interchange, and finally the additional impact stemming from income effects in a second round of feedbacks. The following figure summarises the variety of technical terms.



Source: M-Five

Figure 3: **Variety of terms to denote economic impacts**

Figure 3 illustrates that it would bring some clarity to distinguish only between direct (project or action related) and wider economic impacts. The latter can be defined as narrow or wide depending on the assumed deviation from the general equilibrium paradigm and the model used for identification and measurement.

The models applied on the macroeconomic scale are input-output/social accounting, macroeconomic CGE or Keynesian, eventually combined with dynamic simulation and System Dynamics. All models have their strengths and weaknesses. IO/SAM are highly differentiated by industrial sectors (and eventually by regions) and able to model impacts on the inter-industrial and inter-organisational flows in high detail. However, they are not dynamic and use fixed coefficients and linear-limitational relationships between inputs and outputs. Macroeconomic CGEs model price changes and can accommodate several market imperfections, such as on the transport and labour markets. Perfect market mechanisms are assumed for the larger parts of the economy, which can conflict with observations and make model calibration difficult. Keynesian macroeconomic models include the multiplier/accelerator mechanism as an integral part and assume imperfections like involuntary unemployment as a permanent phenomenon. System Dynamics modelling can be constructed independently from economic philosophies to represent observed phenomena in a suitable way. They can integrate other economic models such as IO-modelling or endogenous growth and are able to model future trends.

Keynesian and System Dynamics models can integrate the widest scope of deviations from the general equilibrium paradigm. Therefore, one can expect that they generate higher WEI compared with CGEs and IO models. All GDP-based models for quantification of WEI share one property; they cannot be merged with the conventional CBA (i.e. it will not be possible to add WEI results to the CBA outcome), particularly as this would cause double counting (see also EIB 2013, p. 36). This implies that a CBA can be used for partial project evaluation while WEI measurement relates to the strategic evaluation of mega projects, corridor investments, network investments or policy action programmes. Using GDP as an indicator to measure economic impacts is justified in cases of large investments. In addition, measuring employment impacts provides for a suitable indicator of social impacts for such programmes.

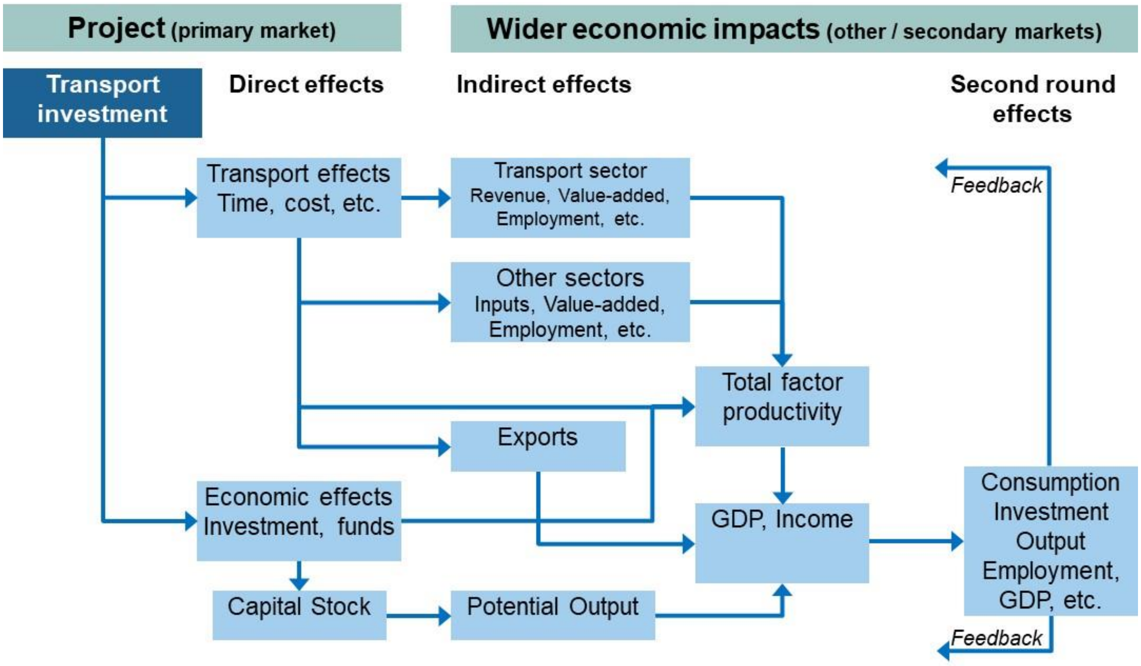
4 Literature review on economic impacts of transport infrastructure

The previous section explained the terminology used to understand the economic impacts as well as the theory and modelling methods to analyse and estimate such impacts. This section elaborates the empirical findings on growth and job impacts of transport infrastructure, and summarises those findings in relation to the TEN-T network.

4.1 Growth and jobs impacts of transport infrastructure

Investments in transport infrastructure result in two types of economic impacts: direct and indirect. The first captures direct transport impacts, such as changes in transport user costs and time or modal split, and the economic impacts arising from funds for investment into transport infrastructure or vehicles, and the required resources. Indirect impacts affect the overall economy, such as impacts on employment in the transport sector and other sectors, or changes in net exports and potential output (see Figure 4). Indirect impacts are often used synonymously with wider economic impacts, second-round effects or induced effects in the literature.

As highlighted in Figure 4, transport investment triggers a chain of effects. Firstly, direct effects of the project or infrastructure program influence transport by lowering the travel time and stimulate the economy due to additional investment and funds. Secondly, indirect effects cause changes in sectors involved in the project (e.g. the transport sector) and other sectors, changes in net exports due to better infrastructure, and changes in the potential output – and, thereby, the gross domestic product. The indirect effects (especially the changes in the gross domestic product or income) foster second-round effects such as changes in consumption, investment, output, and employment. It is more suitable to use the term loop instead of chain as there are multiple feedback loops present.



Source: own extensions from Schade et al. 2015

Figure 4: Chain or loop of effects of transport investments in the transport and economic systems structured into direct, indirect and second round impacts

Impacts from infrastructure investment go beyond an improvement in user-benefits which are often studied in a CBA. Transport improvements could act as a catalyst for growth of the local and national economy, job creation and private sector investment (Venables, 2016). According to Venables (2016), benefits from transport improvements are larger than conventionally measured user-benefits. These wider economic benefits are created through three main mechanisms. Firstly, transport improvements promote the interaction of economic activities that raises productivity by connecting areas. Secondly, infrastructure investments make concerned areas more attractive and therefore increase the level and location of private investment. Thirdly, transport impacts the labour market by improving accessibility to jobs (Venables, 2016).

One challenge of studying wider economic impacts is to include not only the expansion of regional economic activity due to transport improvement, but also to analyse the impact where economic activities are displaced due to the investment. This reallocation mechanism tends to be often excluded in a simple CBA.

4.2 Assessing the impacts on jobs

Employment is a key economic concern for governments and policy-makers and is significantly influenced by large transport investments. The EIB states that labour markets are also a major reason to consider wider economic impacts in transport impact assessments[3]. Several effects arising from the additional investment in the economy alter the labour market. The investment encourages new employment in the construction sector (a direct effect), as well as stimulating other sectors via time or costs savings (an indirect effect). Lower commuting costs and better accessibility of jobs change the number of hours worked and the labour force participation rate. Furthermore, improved transportation can result in labour relocating to more productive sectors (Wangsness et al. 2017).

Firms in rural areas can have power over workers due to a thin labour market (Wangsness et al. 2017). If marginal productivity is higher than marginal costs, such firms might still have little incentive to hire new workers as they would have to increase the wages for all workers. Infrastructure investment can reduce the job searching costs as well as the commuting cost and foster education, making workers less susceptible to monopsonies as they can work as specialists for other companies (Wangsness et al. 2017).

In the literature, CBAs are often used as a tool to model the impact of transport investment. Bröcker et al. (2010) state that this standard approach can be justified as long as two assumptions hold. The first assumption is that all benefits and drawbacks of the investment have to be at least approximately included in the transport subsystem itself (Bröcker et al. 2010). If prices correctly represent marginal costs the assumption holds. However, there are multiple factors causing price distortions, for example non-clearance of the labour market, and taxes or subsidies. In case of price distortions, the wider economic effects have to be included on top of the effects within the transport system. The second assumption is that distributional aspects are not significant (Bröcker et al. 2010). The transport investment should equally affect individuals without regional impacts. As both these assumptions are unlikely to hold on an international level, the CBA can produce misleading results.

The CBA is a necessary assessment to analyse economic impacts at project level, but not sufficient to cover wider economic impacts (Metsäranta et al. 2013). If markets are imperfect or if distributional impacts are important, computable general equilibrium (CGE) analysis is often the appropriate tool (Bröcker et al. 2010). While the CBA focuses on price changes in the transport system, CGE analysis focuses more on the impact on households' utility (Bröcker et al. 2010). Hence, using a CGE analysis gives the opportunity to study the impact of transport investment on the affected households. However, the use of CGE models is rather expensive and specific knowledge and skills are required (Metsäranta et al. 2013), as also acknowledged by the EIB (2013, p. 33).

Most studies focus on the short-term impact of infrastructure investment on the economy. This is due to the complexity of modelling long-term effects and Metsäranta et al. (2013) argue that the long-term effects are low compared to the short-run impacts. In the long run, predicting the impact of transport investment on the overall labour demand is impossible

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[3] EIB (2013, p. 34): "*Recall that the theory suggests it is valid to include wider impacts if secondary markets are distorted. This is generally the case with labour markets, not least given the presence of taxes.*"

as it depends strongly on the overall level of economic activity (Bivens. 2014). However, the composition of employment due to the additional investment can be projected (Bivens 2014).

One of the most common models used in current literature is the input-output model (IO), that analyses the flow of industry’s income and calculates the impact of changes in one industry on the growth of the rest of the economy (Metsäranta et al. 2013). The key outputs of IO models are changes in GDP, income and employment and are typically reported during the construction period. As only the output effects are denoted, and the price effects are not accounted for, the IO results can be seen as short-run effects (Metsäranta et al. 2013). In IO models, employment changes are often distinguished in three types – direct, indirect and induced effects.

Another common type is a simulation-based land-use and transportation interaction (LUTI) model, which is used to predict the response of markets to changes in land-use and transport accessibility. LUTIs evaluate changes in land use patterns which will influence transportation costs and predict the resulting redistribution of employment. As these models often take the region’s economic and demographic projections as fixed input, the models are useful for understanding the dynamics of regional economic impacts but do not consider the impacts on economic growth (Metsäranta et al. 2013).

An important term related to employment is job-years or person-years of employment, where one job-year means one job providing employment for one year for one person in a full-time position. Part-time jobs may also be converted into a smaller number of full-time equivalent jobs (e.g. two half-time jobs would account for one full-time equivalent job (FTE)).

There are many reports modelling the short-run impact of transport investment on employment, especially in the United States. Heintz et al. (2009) found that in the United States an additional $1 billion of investment in infrastructure will create approximately 18,000 jobs including direct, indirect and induced jobs. The authors also estimate that each $1 billion infrastructure investment will generate between 9,819 and 17,784 jobs considering only direct and indirect effects, and between 14,515 and 23,784 jobs including induced effects (Heintz et al. 2009). Depending on the category of the infrastructure investment project, the size of job creation differs. According to Heintz et al. (2009), the highest direct and indirect employment impacts are related to investment in mass transit systems while low job creation can be found for investment in electricity production, transmission and distribution infrastructure.

Table 1 presents the breakdown of jobs in terms of direct, indirect and induced effects, generated by an additional $1 billion of public transportation investments. The total effect due to an additional investment in capital spending in public transportation (which includes purchases of vehicles and equipment, and the development of infrastructure and supporting facilities) is about 13,900-15,900 additional jobs (Weisbrod et al. 2014). The total effect on employment for operations spending (including management, operations and maintenance of vehicles and facilities) accounts for 21,000-24,000 new jobs

(Weisbrod et al. 2014). Indirect effects lead to a smaller job creation than direct and induced effects. For operations spending, the direct effects predominate the operations effects, while for capital spending they are about the same size.

Table 1: Jobs Generated in the US per Billion US Dollars of Spending on Public Transportation

Job Generation per $ Billion of Spending	Capital Spending	Operations Spending	National Average
Direct Effect	5,063 – 5,822	11,364 – 13,069	9,551 – 10,984
Indirect Effect	3,679 – 4,231	1,863 – 2,142	2,385 – 2,743
Induced Effect	5,117 – 5,885	7,826 – 9,000	7,047 – 8,104
Total Effect	13,859 – 15,938	21,053 – 24,211	18,983 – 21,830

Source: Weisbrod et al. 2014

Besides looking at total job creation, it is of interest to analyse the sectoral job creation. The construction sector benefits directly from the additional infrastructure, while the increase in employment in other sectors arises through indirect and induced effects. Heintz et al. (2009) found that the highest employment increase was in the construction sector with 56.4% of total job creation, including direct and indirect effects, followed by the service sector with 31.9%. Manufacturing (10.7%) and agriculture show limited effects. Comparatively, Weisbrod et al. (2014) noted that $1 billion of public transportation capital investment has the largest impact on job creation in construction (30%), manufacturing (16%), retail trade (7%) and professional, scientific and tech services (7%).

While there are limited studies on this topic in Europe, the CECA (2013) found that in the UK, infrastructure investment which directly creates 1,000 jobs in the construction sector, creates 1,329 jobs due to indirect impacts. Additional spending by employees in the economy generates another 724 jobs (induced effects). As shown in Table 2, the total impact on employment is highest in the construction sector, followed by wholesale and retail trade, administrative and support services, and manufacturing.

Table 2: Employment impacts from a 1,000 job increase in the construction sector arising from infrastructure investment, thousands of jobs

Sector	Direct Impact	Indirect Impact	Induced Impact	Total Impact
Construction	1.000	0.412	0.024	1.436
Wholesale and retail trade	-	0.099	0.181	0.280
Administrative and support services	-	0.220	0.049	0.269
Manufacturing	-	0.202	0.049	0.251
Professional and scientific activities	-	0.149	0.049	0.198
Finance and insurance	-	0.029	0.040	0.069
Mining and quarrying	-	0.030	0.008	0.038
Other	-	0.188	0.323	0.511
Total	1.000	1.329	0.724	3.053

Source: CECA 2013

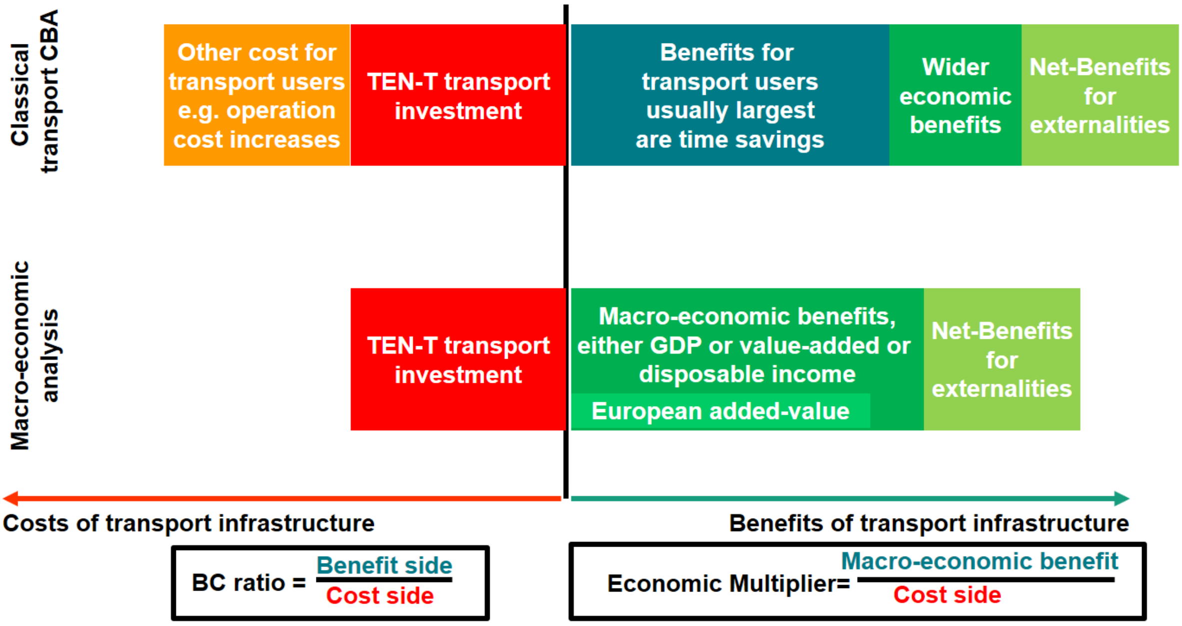
Besides splitting the impact of investments in infrastructure on economic sectoral level, Haider et al. (2013) also focus their analysis on occupations. The job creation resulting from $12 billion investments in Ontario (Canada) is largest for clerical occupations (22,014 jobs), followed by middle and other management occupations (21,072 jobs) and intermediate sales and service operations (20,196 jobs) (Haider et al. 2013).

4.3 European added value and cross-border spillovers

For international infrastructure projects (i.e. cross-border projects affecting at least two neighbouring countries) investment might be insufficient as the financing country does not benefit from it enough to cover the costs. Despite having benefits greater than the costs across all countries involved, the project may appear unattractive to the investing country from a national perspective and suffer from insufficient financing.

Countries have often given priority to projects of interest only for their national network and underinvested in border projects due to low benefits for the financing country (Gutiérrez et al. 2011). In the EU context, improving cross-border connections constitutes a political priority which requires EU funding for such projects. The concept of European added value refers to the extent to which an infrastructure project stimulates cross-border spillover, multi-modal connecting points, and fully connected networks (Doll et al. 2015). Doll et al. (2015) conclude that the reduction of bottlenecks at border crossings is an effective instrument to generate European added value. From a European perspective, the removal of bottlenecks at border crossings can generate wider economic impacts that are higher than average per unit of investment (Doll et al. 2015).

In the study by Schade et al. (2015) an economic multiplier is used to measure the ratio of macro-economic benefits to cost of transport infrastructure. As illustrated in Figure 5, this multiplier is structured in a similar way to that of the benefit to cost ratio of the classical transport CBA. On the cost side, both ratios include the investment cost of the TEN-T investment while in the macro-economic analysis other costs for transport users are excluded. On the benefits side, net-benefits arising from (largely environmental) externalities are considered in both ratios. However, in the CBA benefits for users and wider economic benefits are separately calculated and may under certain conditions (see also EIB 2013) be added to the overall benefits. For the macro-economic analysis benefits are typically the change in GDP, value added or disposable income including the European added value.



Source: Schade et al. 2015

Figure 5: **Understanding wider economic benefits**

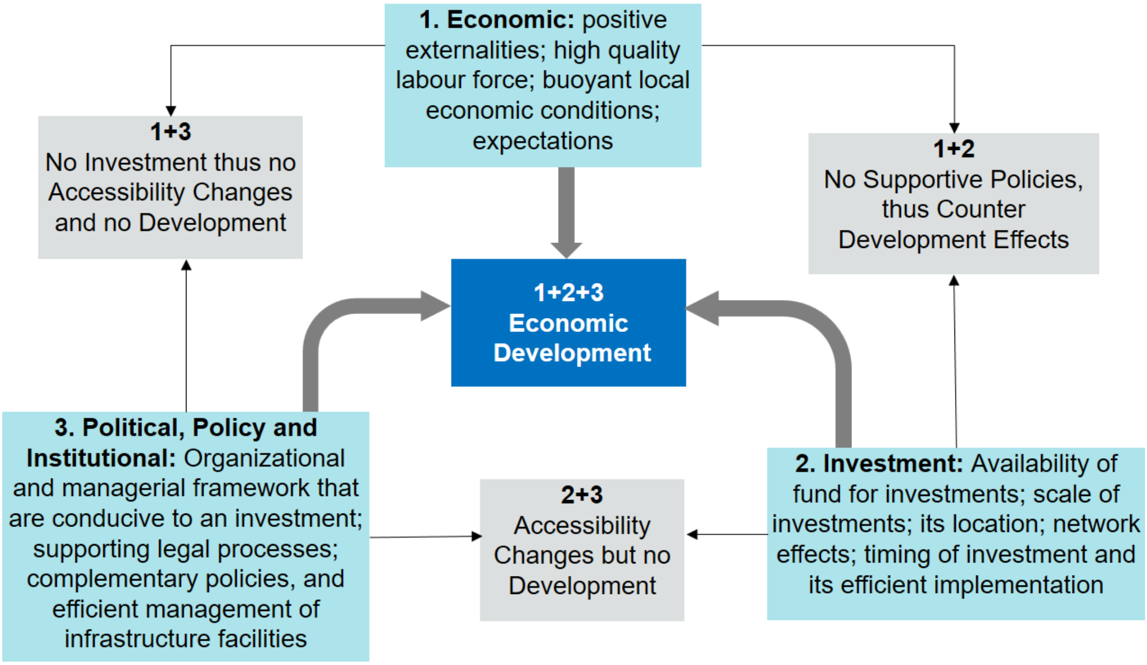
4.4 Agglomeration effects and network effect

Agglomeration effects provide benefits for firms and workers that work in close proximity of larger cities. They might arise through different mechanisms. Firms have the possibility to share suppliers and learn from the experience and innovation of other companies (Combes et al. 2012). Furthermore, larger labour markets facilitate matching and firm-level shocks are ironed out (Combes et al. 2012).

Another benefit from infrastructure investments are network effects. These are positive externalities resulting from the improved quality of transport networks, which increase the effective density of a region. Businesses and workers become better connected leading to increasing productivity and improving economic outcome (Wangsness et al. 2017). With improved infrastructure, agglomeration and network effects arise and foster economic growth.

It is well known that firms and workers are on average more productive in larger cities. Combes et al. (2012) investigated the causes for this productivity advantage. One explanation is firm selection, whereby higher competition means that only the strongest firms sustain in the market and agglomeration economies. Analysing French data Combes et al. (2012) find that spatial productivity differences cannot be explained by firm selection, and that '[…] agglomeration effects are behind most of the shift in the log productivity distribution between less dense and denser areas […]' (Combes et al. 2012).

Banister and Berechman (2001) state that in developed countries with an already well-connected transport infrastructure network, investment in infrastructure will not on its own result in economic growth. Transport infrastructure investment is complementary to other more important economic conditions and acts as a supporting role (Banister and Berechman 2001).



Source: after Banister and Berechman (2001)

Figure 6: **Illustration of necessary sets of conditions**

Besides infrastructure investments, there are three other necessary conditions for economic growth to arise (Banister and Berechman, 2001). According to Banister and Berechman (2001) economic externalities that relate to agglomerations, labour market economies or buoyant local economic conditions have to be present. Further, investment factors such as the availability of funds for the investment, the timing of investment, the network effects, and the scale and location of the investment are of great importance. Political factors relating to the broader policy environment must be in place to achieve economic development. A favourable political environment with supporting legal, organisational and institutional policies as well as a sufficient level of investment have to be present for transport investment to have a positive impact on economic growth

(Banister and Berechman, 2001). As illustrated in Figure 6, all these conditions have to be fulfilled for transport investment to have an effective and positive impact on economic development.

4.5 Growth and jobs impacts of TEN-T

While the literature on job creation in the United States is rather extensive, the literature in European markets is still limited. Most of the studies discuss job creation on a national level. The international impact of infrastructure investment on employment is still narrowly understood and studied. The previously mentioned study on the cost of non-completion of TEN-T by Schade et al. (2015) already fills some of the gaps.

The objective of the TEN-T is to strengthen the social, economic and territorial cohesion of the European Union and thereby to create an efficient and sustainable transport area (European Parliament & Council of the European Union, 2013). According to the EU (European Parliament and Council of the European Union, 2013), the network increases user benefits and fosters growth. Gutierrez et al. (2011) study the European added value of the motorway TEN-T project 25, which crosses Poland, Czech Republic, Slovakia and Austria. Intuitively as well as empirically, the border regions generate less internal benefits and more spillovers than internal regions (Gutierrez 2011). The authors suggest that as sections of the same cross-border project have different EVA, they should also receive different funding. This is in line with the European TEN-T projects who focus on missing links and especially cross-border sections (Gutierrez et al 2011).

Di Cataldo and Rodriguez-Pose (2017) study the impact of human capital, innovation, infrastructure and the quality of the government on employment growth and the reduction of long-term unemployment in some EU countries. They find that transport infrastructure is negatively and marginally significantly correlated with job generation. By including regional factors, regions with more developed infrastructure have a negative effect on high-skilled employment growth, which is, though not in all regressions, statistically significant (Cataldo & Rodriguez-Pose, 2017). For low-skilled job generation transport infrastructure is unrelated. Further, according to Cataldo and Rodriguez-Pose (2017) long-term unemployment and social exclusion are unaffected by the quality of regional transport networks. Overall, investment in infrastructure seems to have a rather small and negative impact on job generation in this study.

According to Exel et al. (2002) large infrastructure projects, such as the TEN-T projects, are likely to have direct or indirect network effects at a supra-national level. Even if at a national level investment assessments are negative, the network effects may justify the construction project. Exel et al. (2002) highlight the importance of an international body such as the EU to stimulate the project and summarise the results of three European infrastructure projects. They find that for the high-speed rail link between Amsterdam and Paris, the projects on their own are not all feasible, but including European added value, the project as a whole is feasible. The rail link between Antwerp and Roosendaal is another example of large cross-border benefits. The impacts in the Netherlands alone would lead to misleading results as with the inclusion of the effects in Belgium the total effects due to the investment increase by about 50%. The expansion of the harbour in Rotterdam is another example of supporting infrastructure projects at a supra-national level. While the national benefits cannot balance out the costs on a Dutch level, including European added value in the analysis results in positive revenue (Exel et al 2002).

Bröcker at al. (2010) studied the economic effects of 22 TEN-T projects with a spatial CGE analysis, and found that only 12 projects had a yearly rate of return of more than 5%. According to Bröcker et al. the other projects are unprofitable. Five or six projects had large enough spillover effects to justify EU support. However, the analysis lacked the inclusion of some externalities, such as noise and air pollution. Furthermore, benefits to local transport, pricing, and financing are excluded in their analysis as well the impact of congestion is limited included.

Sichelschmidt (1999) states that most TEN-T projects only involve two or three neighbouring countries, and therefore cross-border infrastructure could be solved with bilateral or trilateral negotiations of the Member States. The author suggests that besides providing investment for infrastructure, appropriate legal frameworks are needed which encourage investment by the affected countries. Sichelschmidt (1999) also highlights the importance of continuing the current programmes, but suggests that the TEN-T in the form of the Essen projects should not be extended in the future. Thus it can be argued that the EU guidelines from 2013 (1315/2013) have taken-up the criticism of Sichelschmidt by (1) the concept of core network corridors extending beyond 2-3 neighbouring countries only and enabling long-distance EU-wide transport, and (2) by defining improved programmes with clear funding priorities, differentiated funding rates and the two layers of a core and a comprehensive network. Spiekerman and Wegener (1996) analysed the impact of the TEN-T high-speed rail network investments. The authors found that the high-speed network has a larger influence on central regions than on peripheral regions and therefore does not promote a reduction of interregional economic and social disparities (Spiekerman and Wegener, 1996). This effect was also found for other transport infrastructure investments e.g. roads connecting regions to central metropoles (e.g. the A20 connection to Hamburg), which rather enabled long-distance commute than stronger economic growth in the regions. Thus such observations of infrastructure impacts have to be understood and interpreted in the individual context of the concerned regions.

Schade et al. (2015) studied the impact of non-completion of the TEN-T with an emphasis on economic growth and job creation until 2030. The approach applies an integrated assessment model, ASTRA-EC, which simulates the systems of economy, demography, transport and environment. The Reference Scenario involved the full implementation of the TEN-T core network by 2030. Stopping the implementation of the TEN-T core network after 2015 would generate a loss of GDP accumulated from 2015 until 2030 of about €$_{2005}$ 3,000 billion and would cause that more than 10 million potential job-years would not be created between 2015 and 2030.

5 Design of scenarios

This section explains the design of the scenarios and the inputs used from the CNC studies and the TENtec system. It also explains how the part of TEN-T core network which is not part of CNCs has been considered.

5.1 Baseline and Reference scenarios

The Baseline Scenario assumes that no further TEN-T core network projects beyond 2016 are implemented, while the Reference Scenario assumes the core TEN-T network is fully implemented by 2030. The modelling exercise has been designed in such a way that the Reference Scenario in this study is consistent with the update of the EU Reference Scenario 2016[4], which also assumes the completion of the core TEN-T network by 2030. However, though in principle following the same scenario logic, the **Reference Scenario** used by the models in this study and the **EU Reference Scenario 2016** elaborated by PRIMES-TREMOVE should be clearly differentiated. The EU Reference Scenario 2016 provides the blueprint for the Reference Scenario, but it does not contain a detailed modelling of the TEN-T network or cover detailed investment and funding data at a project level. The detailed project data is part of the Reference Scenario quantified with the TRUST and ASTRA models. In terms of EU level GDP, transport demand, vehicle fleets, and energy price projections, the Reference Scenario and the EU Reference Scenario 2016 are consistent. More detailed explanations are provided below.

Comparing the Reference Scenario with the Baseline Scenario will show the impacts of the implementation of the full TEN-T core network.

Figure 7 presents different illustrative pathways on how the share of completed TEN-T core network increases over time. The starting point of completed share of TEN-T and the linear trajectory representing the continuous TEN-T implementation in the Reference Scenario until 2030 are both theoretical. In 2030, the Reference Scenario assumes that 100% of the TEN-T core network will be implemented (blue line). In contrast, the Baseline (yellow line) foresees no further implementation of TEN-T core network after 2016 (the share completed remains constant between 2017 and 2030). Furthermore, two examples of possible CNC implementation scenarios (named ABC and XYZ) are provided in Figure 7. Completion of each CNC will increase the share of implemented core network but

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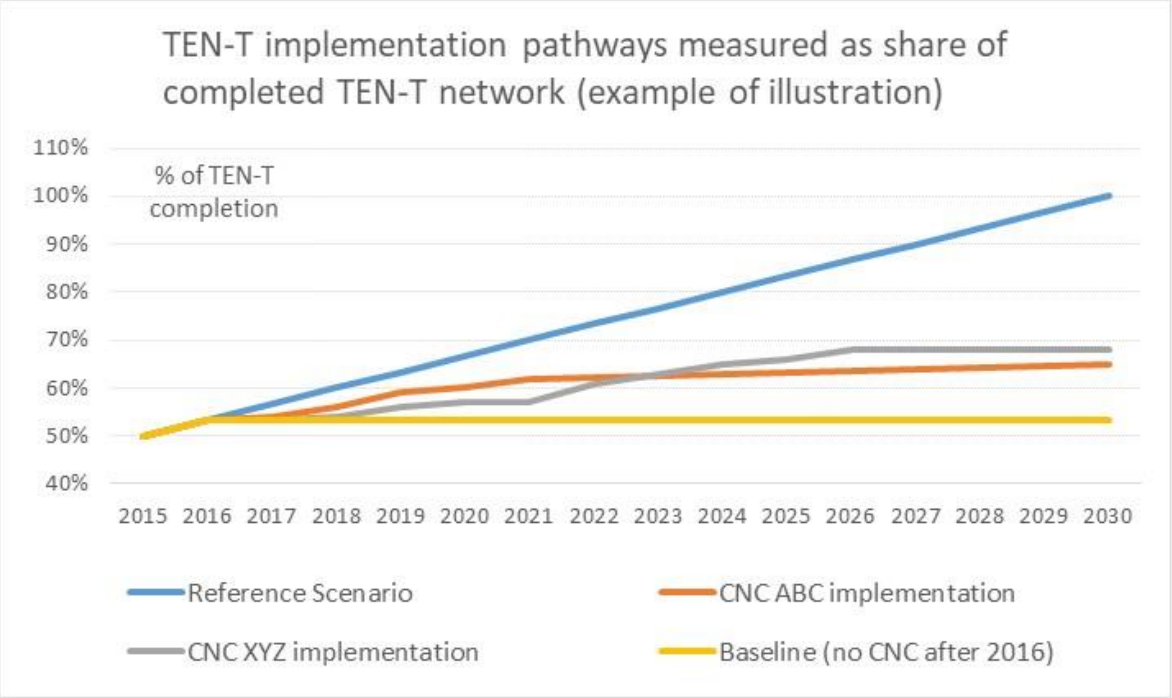
[4] The updated EU Reference Scenario 2016 includes some updates in the technology costs assumptions (i.e. for light duty vehicles) and a few policy measures adopted after its cut-off date (end of 2014) like the Directive on Weights and Dimensions, the 4th Railways Package, the NAIADES II Package, the Ports Package, the replacement of the New European Driving Cycle (NEDC) test cycle by the new Worldwide harmonized Light-vehicles Test Procedure (WLTP). It has been developed with the PRIMES-TREMOVE model (i.e. the same model used for the EU Reference Scenario 2016) by ICCS-E3MLab (Capros et al. 2016). A detailed description of this scenario is available in the Impact Assessment accompanying the Proposal for a Directive amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures, SWD (2017) 180.

following their individual profile as defined by the project list of the corridors' studies and extended by the gap filling in our project database.



Source: M-Five

Figure 7: **Baseline and TEN-T implementation pathways**

The impact on the transport sector of implementing the TEN-T infrastructure by 2030 in the Reference Scenario is straightforward, resulting in higher speeds and lower levels of congestion than in the Baseline Scenario.

5.2 Methodological approach for the development of the Reference Scenario

The European Commission regularly develops projections under current trends and policies adopted until a certain cut-off date. Such projections include policies such as the CO_2 standards for new cars for 2021 or the implementation of the TEN-T core network by 2030 (i.e. policies that will have an effect in the future). The latest version of such projections is reflected in an update of the so-called EU Reference Scenario 2016[5].

One of the requirements of this study was to ensure consistency with the updated EU Reference Scenario 2016. Additional complexity arises when the impact of policies to be tested are already part of the EU Reference Scenario 2016, which is the case of implementation of the core TEN-T network. In the EU Reference Scenario 2016 this has been reflected by applying a combined econometric and engineering approach for deriving transport activity by transport mode, drawing on inputs from the TENTec system for the expected length and/or upgrades of the TEN-T network. Thus, the EU Reference Scenario 2016 did reflect the TEN-T core network at an aggregate top-down level, while in this study the TEN-T core network has been analysed by considering the individual CNCs projects and the CNoCNC sections that altogether form the TEN-T core network.

As a first step of developing the Reference Scenario in ASTRA and TRUST, both models have been adapted to fit to the EU Reference Scenario 2016. In a second step, the core network (i.e. CNCs and the CNoCNC part of the network) has been subtracted. At this point a first draft of the Baseline Scenario representing the situation of the TEN-T core network development until the end of the year 2016 has been achieved. This specific set-up of the Baseline and Reference Scenarios also meant that any updates in the assumptions led to the revision of both of them with the latter needing to comply with the EU Reference Scenario 2016.

5.3 Implementation of the core network corridors (CNC)

The impacts of the implementation of each CNC has been assessed separately in relation to the Baseline Scenario (see also Figure 8):

- Atlantic core network corridor (ATL).
- Baltic-Adriatic core network corridor (BAC).
- Mediterranean core network corridor (MED).

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[5] The updated EU Reference Scenario 2016 includes some updates in the technology costs assumptions (i.e. for light duty vehicles) and few policy measures adopted after its cut-off date (end of 2014) like the Directive on Weights and Dimensions, the 4th Railways Package, the NAIADES II Package, the Ports Package, the replacement of the New European Driving Cycle (NEDC) test cycle by the new Worldwide harmonized Light-vehicles Test Procedure (WLTP). It has been developed with the PRIMES-TREMOVE model (i.e. the same model used for the EU Reference Scenario 2016) by ICCS-E3MLab (Capros et al. 2016). A detailed description of this scenario is available in the Impact Assessment accompanying the Proposal for a Directive amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures, SWD (2017) 180.

- North-Sea-Baltic core network corridor (NSB).
- North-Sea-Mediterranean core network corridor (NSM).
- Orient-East-Med core network corridor (OEM).
- Rhine-Alpine core network corridor (RALP).
- Rhine-Danube core network corridor (RHD).
- Scandinavian-Mediterranean core network corridor (SCM).

These nine CNCs account for roughly 75% of the TEN-T core network. The remaining 25% of the core network is not part of any CNC and it is not shown on this map. We refer to the remaining part of the network as CNoCNC.

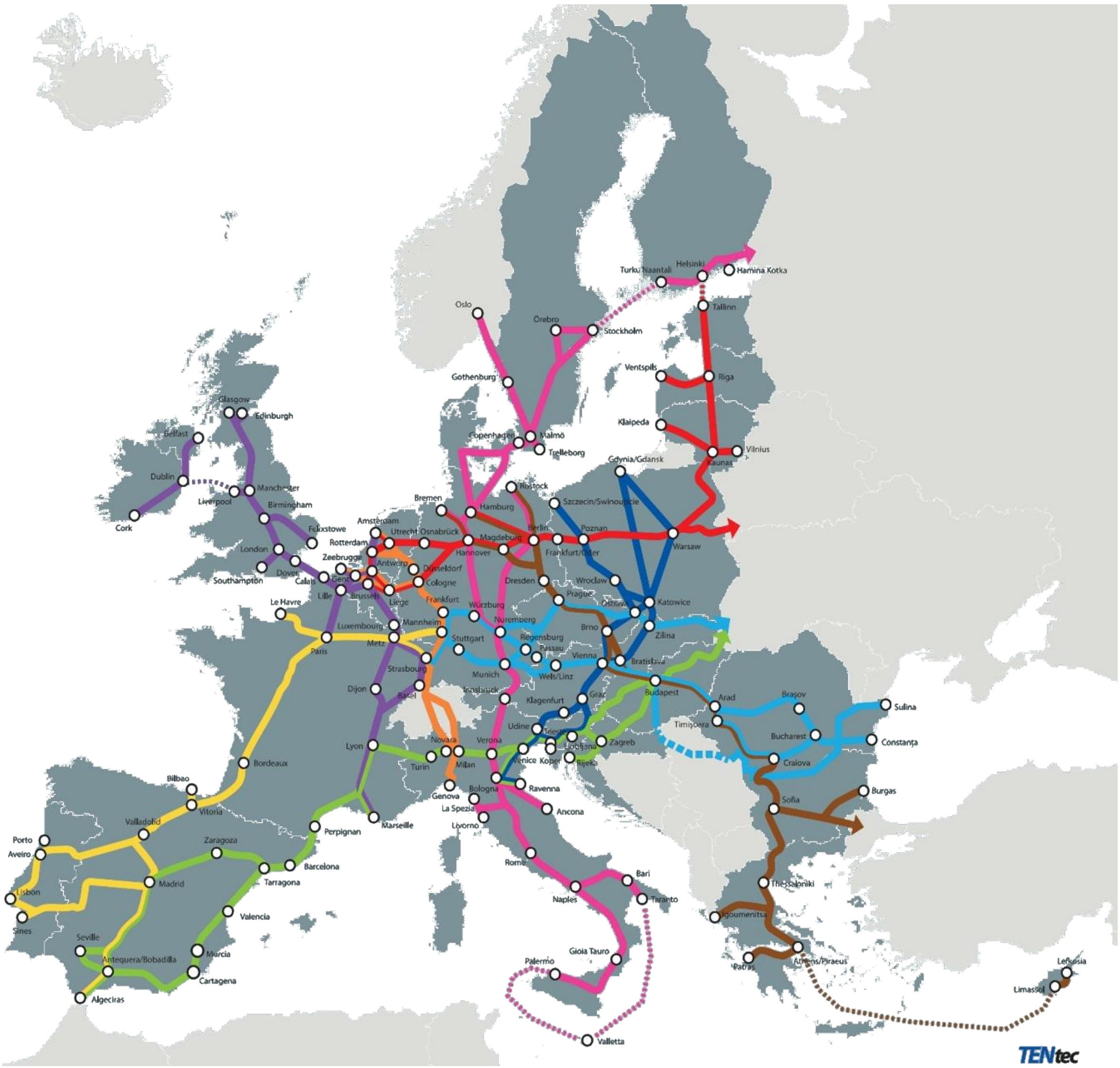


Figure 8: **Map of the nine CNC**

5.4 TEN-T core network not part of any CNC (CnoCNC)

The TEN-T core network is composed by the nine TEN-T CNCs, amounting to about 75% of the whole core network length, and by other sections not belonging to any corridor.

Building on TENtec data, 284 planned and ongoing sections contributing to the overall core TEN-T network but not located on the CNCs have been identified. Geographically they are spread across 23 EU Member States and Norway.

A time line was defined for each section dependent on their size and status. Sections with the status ‘planned’ were set to start in 2021 and sections with the status ‘ongoing’ were set to have started in 2018.

5.5 Preparation of the TRUST model

5.5.1 Implementation of CNC corridors

The analysis of investment projects on the CNCs was supported by the development of the project database intended to collect and systematise technical and financial information on the projects of all CNC.

The development of the project database was based on different sources made available by the Commission. The main information source was the CNCs projects’ list developed in the context of the Corridor studies. Other information sources to support the development of the database were (i) MoS projects list; (ii) ERTMS investments from the EY/INECO study.

The analysis of the information included in the CNC’s projects’ list revealed several data gaps, covering financial and technical aspects. To fill in the data gaps, a multi-step approach was followed. For the first step, the project team derived technical information for the project’s description. The second step required the involvement of the experts of all nine CNCs who were asked to fill in the remaining technical and financial data gaps. Nonetheless, several data gaps on technical parameters still applied. For missing technical parameters, it was agreed to follow as much as possible the indications included in the TEN-T guidelines concerning the minimum technical standards.

Another fundamental part of the work was the mapping of all projects into a GIS system to allow for their quick identification along the CNCs.

Once all projects were mapped, the information included into the database was joined with the GIS information. This allowed for an identification of projects to be completed within different time horizons (i.e. 2020, 2025 and 2030) together with their technical characteristics.

The modelling of the CNCs within the TRUST model required implementing changes in the network in terms of: adding new links to simulate new constructions, improving the existing network parameters to simulate network improvements and rehabilitations, and reducing operational costs to simulate the impact of ERTMS deployment. When more than one project exists on the same mode’s link, assumptions on the average impact of the projects on that link were implemented.

Changes in rail operational costs along the CNCs take into account the ERTMS deployment over time. In particular, it was assumed that the full deployment by 2030 would reduce rail operational costs by 9% along all the CNCs. For 2020 and 2025 a reduction of operational costs respectively of 5% and 7% was implemented only on those parts of the rail network presenting a certain continuity in ERTMS deployment.

TRUST model outputs are related to road and rail costs and time savings following the implementation of the TEN-T core network. In TRUST, inland waterways and maritime are considered as feeders to road and rail modes. Since the aggregation of TRUST NUTS-III output into aggregated NUTS-I input for the ASTRA model would entail a smoothing of the improvements on inland waterways and maritime transport, complementary assumptions on these modes are implemented in ASTRA (see next page).

5.5.2 Implementation of Core-non-CNCs network (CNoCNC)

Lacking specific information on the nature and exact location of the projects description, the implementation of core network not part of any CNC (CNoCNC) has been implemented through a general improvement of those sections of the CNoCNC network having infrastructure characteristics below the TEN-T minimum technical standards. The modelling in the TRUST network consisted therefore in an upgrading of part of the Core-non-CNCs network in terms of increased speed and upgraded link type for road and rail modes, and in the deployment of ERTMS.

Following the implementation of the TEN-T minimum technical standards, the average change of travel time on those parts of the network that were not complying with the TEN-T standards is shown in the following table

Table 3: Average changes in travel time on the upgraded part of the CNoCNCs road and rail networks in 2030 (% change to the Baseline)

MODE	TRAVEL TIME %CHANGE	
	PASSENGERS	FREIGHT
ROAD	-33%	-23%
RAIL	-20%	-26%

Source: TRUST model, IWW not relevant on CNoCNC part of network

5.6 Preparation of the ASTRA model

5.6.1 Modelling the impact on transport

This study focuses on modelling the impact of the completion of the TEN-T core network as a result of the implementation of the interventions included in the CNCs projects' database.

The TRUST model was run for the time horizons 2016 (Base Year), 2020, 2025 and 2030. Each of these model runs included different developments for the road and rail networks, reflecting the TEN-T core network evolution over the time.

The TRUST model output in terms of changes in OD costs, and time by road and rail modes were then used as input for the ASTRA model to compute changes in modal shares determined by infrastructure improvement.

Besides the input deriving from TRUST, the modelling of transport impacts within ASTRA required additional assumptions concerning transport modes not covered by TRUST. For air transport, the projects related to airports included in the CNCs projects' database were located at NUTS1 level. Assumptions in terms of changes in access travel time to the airports have been implemented. For maritime transport, reduction in transport time for loading, unloading and access to ports have been implemented for the countries affected by all CNCs projects in the database. For inland waterways, the countries involved in the projects included in the CNCs projects' database have been identified. For the international origin-destination relations and the domestic transport illustrated in Table 4, assumptions on reduction of transport costs (-3% for unitised, bulk and general cargo commodities) and of travel time (-15%) have been implemented.

Table 4: Transport relations considered for the implementation of assumptions on inland waterways

International relations		Domestic
Origin country	**Destination countries**	**Country**
AT	DE, BG, RO, HR	AT
BE	FR, NL	BE
FR	BE, DE, NL, CH	FR
DE	AT, FR, NL, BG, CH, CZ, HU, RO, SK	DE
NL	BE, FR, DE	NL
BG	AT, DE, HU, RO, SK, HR	BG
CH	FR, DE	CH
CZ	DE	CZ
HU	DE, BG, RO, SK, HR	HU
RO	AT, DE, BG, HU, SK, HR	RO
SK	DE, BG, HU, RO, HR	SK
HR	AT, BG, HU, RO, SK	HR

Projects related to intermodal terminals included in the CNCs projects' database have been identified and located at country level. Assumptions on the reduction of transport time for loading, unloading and access to railways, taking into account the impacts on national and international demand, have been implemented.

Assumptions on the uptake of alternative fuels and higher electrification of rail, reflecting the projects included in the TEN-T projects' list, have also been reflected. For example, higher use of electric and alternative fuels vehicles is assumed in the Reference Scenario in comparison with the Baseline, based on the availability of refuelling infrastructure which is enabled by the completion of the core TEN-T network. More specifically, the refuelling/recharging infrastructure for alternative fuels and electromobility is assumed to have an impact on the vehicle fleet composition. The impact is especially visible for passenger cars, where the share of battery electric vehicles in 2030 at the EU28 level is assumed to increase from 1.4% in the Baseline Scenario to about 2% in the Reference Scenario. Similarly, the share of fuel cell cars is assumed to go up from 0.1% in the Baseline to 0.3% in the Reference Scenario. Similar increases are assumed for light commercial vehicles, while for heavy goods vehicles assumptions concern the uptake of LNG vehicles (their share going up from 2.1% in the Baseline to 2.6% in the Reference Scenario). As a result, the average fuel efficiency per vehicle-km and the related CO_2 emissions are also affected.

The completion of TEN-T projects related to the electrification of railways for passenger and/or freight is assumed to directly impact on the share of train-km with electric traction, affecting the related CO_2 emissions in the Reference Scenario. In a similar way, several TEN-T projects aiming at the deployment of LNG in inland waterways are considered in the Reference Scenario.

Results on total transport activity and GHG emissions are provided by the ASTRA model. Since ASTRA is not a network model, results for individual CNC scenarios are provided at NUTS1 level (the lowest level of detail available in the model) and not at corridor level.

5.6.2 Modelling the economic impact

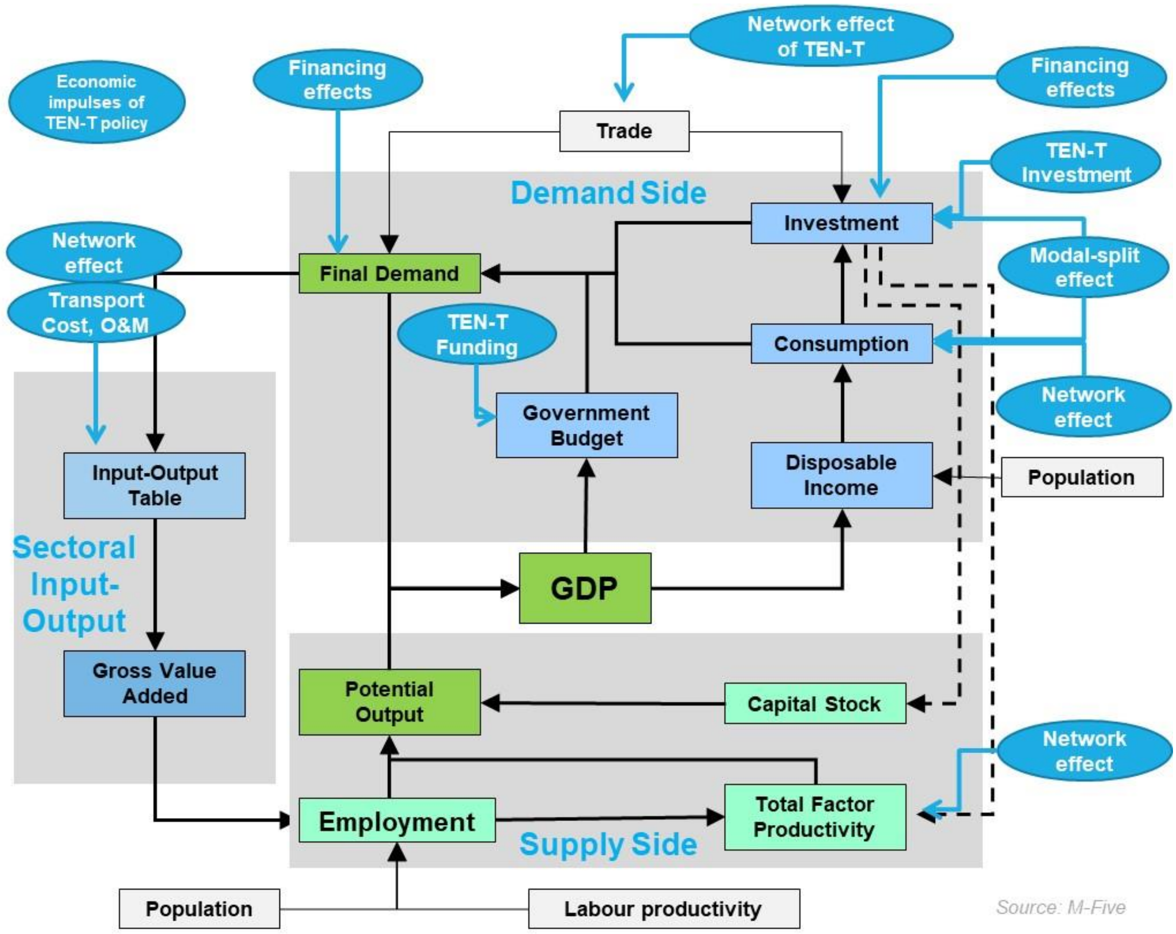
As a first step in the preparation of the economic modelling in ASTRA, the Reference Scenario in ASTRA-EC was calibrated against the aggregated economic projections of the updated EU Reference Scenario 2016. Employment and population projections are derived from the 2015 Ageing Report (European Commission, 2015). GDP in the EU28 is projected to grow by 1.2% per year in the period 2010-2020 and by 1.4% in the period 2020 to 2030. Part of the calibration procedure in ASTRA-EC requires the determination of investment for the evaluation of the capital stock and the total factor productivity. Both investments and capital stock, together with employment, form the basis of the long-term growth development for each EU country.

The three major building blocks of the economic module in ASTRA, and the economic impulses of the TEN-T projects and their linkages to the macroeconomy are shown in Figure 9. The three building blocks constitute:

1. The demand side with the major demand aggregates (i.e. consumption, investment and trade modelled at sectoral level, and government consumption) that together generate the final demand.
2. The supply side with employment, total factor productivity (TFP) and the capital stock determining the potential output.
3. The sectoral interlinkages building on the 30 input-output tables of the modelled countries. The final demand (demand side) and potential output (supply side) generate the national GDP and influence investments.

The economic impulses generated by the TEN-T policy enter the model via several impact chains indicated by the elliptic bubbles. Infrastructural investments change Final Demand

and the intermediate deliveries via the Input-Output tables. Network effects are represented in ASTRA by increasing the factor productivity and by lowering the travel costs for the consumers and for businesses. Financing these investments may lead to crowding out effects. Operation and maintenance together with transport cost impact the technical coefficients in the Input-Output table. Furthermore, there are effects from the transport modules whose exact effects are not shown in Figure 9; modifying infrastructure changes the relative attractiveness of the modes and this leads to modal changes. These modal changes have further impacts on investments and consumption.



Source: M-Five

Figure 9: **Overview of the TEN-T impulses and the macroeconomic core of ASTRA**

5.6.3 Implementation of the core network corridors

According to the most recent database all nine CNCs include 3,037 projects and reveal an overall investment sum of €603 billion[6]. Of these investments, €438 billion are planned to be spent in the period 2017 to 2030 (see Table 5). In the same period the TEN-T core

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[6] Currencies are if not else classified converted in Euro 2005 using a GDP deflator

network investments (i.e. the investments on the nine CNCs and the CNoCNC network) account for €556 billion.

In the database 1,363 projects resulting in an investment sum of €169 billion lie on more than one corridor. When analysing each corridor, such projects are double counted as they are considered for each CNC. Hence, in Table 5 the sum over all nine individual CNC investments is bigger than the overall sum of all CNC projects combined. However, for the analysis of impacts of all CNC each project must only be counted once.

Table 5: Investments per CNC for the EU28 plus Norway and Switzerland [million EUR$_{2005}$]

CNC	2017-2030
Atlantic	31,037
Baltic Adriatic	46,265
Orient-East Med	47,375
Rhine Alpine	61,910
Rhine Danube	63,554
North Sea Mediterranean	59,186
North Sea Baltic	62,552
Mediterranean	90,208
Scandinavian Mediterranean	118,546
Total CNC investments	***437,767***
Total investment in TEN-T core network (CNC and core non CNC)	***556,101***

Source: EC, M-Five

The share of TEN-T investments to GDP differs over time and between EU13 and EU15 (see Table 6). In the EU28, the TEN-T core network investments (nine CNCs and the CNoCNC network) account for 0.2% of the total GDP in the period 2017 until 2030. The share of TEN-T core network investments in EU15 is 0.2%, and 0.6% in EU13. In the period 2017 to 2020 the shares are higher relative to the next periods both for EU13 and EU15.

Table 6: Share of TEN-T investments in relation to GDP

Share TEN-T investment of GDP	2017-2020	2021-2025	2026-2030	2017-2030
EU15	0.2%	0.2%	0.1%	0.2%
EU13	1.1%	0.7%	0.2%	0.6%
EU28	0.3%	0.3%	0.1%	0.2%

Source: EC, M-Five

Detailed country assumptions for the share of TEN-T investments in relation to the country's GDP level are summarised in Table 7. The largest TEN-T investments relative to the country's GDP are made in Bulgaria (1.4%) and Latvia (2.0%) for the period 2017 to

2030, followed by Slovakia (1.0%) and Estonia (1.2%). As explained above, the share of TEN-T investment to GDP is higher in the period 2017 to 2020 and decreases over time.

Table 7: Share of TEN-T investments in relation to GDP on country level

Share TEN-T investment of GDP	2017-2020	2021-2025	2026-2030	2017-2030
AT	0.4%	0.2%	0.0%	0.2%
BE	0.3%	0.2%	0.0%	0.2%
DK	0.3%	0.2%	0.0%	0.2%
ES	0.2%	0.1%	0.1%	0.1%
FI	0.2%	0.3%	0.2%	0.2%
FR	0.1%	0.3%	0.1%	0.2%
UK	0.0%	0.0%	0.0%	0.0%
DE	0.3%	0.2%	0.1%	0.2%
EL	0.2%	0.1%	0.1%	0.1%
IE	0.2%	0.3%	0.1%	0.2%
IT	0.5%	0.5%	0.3%	0.4%
NL	0.3%	0.2%	0.0%	0.2%
PT	0.4%	0.2%	0.1%	0.2%
SE	0.4%	0.4%	0.0%	0.3%
BG	1.9%	1.9%	0.6%	1.4%
CY	0.5%	0.2%	0.2%	0.2%
CZ	0.8%	0.8%	0.4%	0.6%
EE	2.7%	1.3%	0.1%	1.2%
HU	0.6%	0.3%	0.1%	0.3%
LV	3.0%	2.4%	0.8%	2.0%
LT	1.6%	0.8%	0.0%	0.7%
MT	1.1%	0.1%	0.2%	0.4%
PL	1.0%	0.4%	0.1%	0.4%
RO	1.3%	1.2%	0.2%	0.8%
SI	1.1%	0.6%	0.3%	0.6%
SK	2.4%	1.1%	0.2%	1.0%
LU	0.5%	0.3%	0.0%	0.2%
HR	0.9%	0.3%	0.0%	0.4%

Source: EC, M-Five

Looking at the different types of projects on the corridors shows that the highest investments are made in the construction projects (€144 billion for 2017 to 2020, and €203 billion for 2021 to 2026). ERTMS projects account for €20 billion between 2017 and 2030 with the largest share invested in the first three years[7]. ERTMS projects are divided into on board ERTMS projects and ERTMS track side projects. Overall, ERTMS track side projects are smaller than on board projects. The investments for the other project types *Study*, *Rolling Stock* and *Clean Fuel* are summarised in Table 8.

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[7] The analysis refers to the ERTMS data contained in the CNC project list. For the modelling exercise, the values have been adapted to be consistent with the ERTMS deployment plan and to remain linked with the projects on the corridors.

Table 8: **TEN-T investments in the CNC by project type in million Euro$_{2005}$**

Investment type	2017-2020	2021-2026	2027-2030	2017-2030
ERTMS on board	8,853	7,023	1,388	17,263
ERTMS track side	1,499	1,190	235	2,924
Study	4,106	2,230	310	6,646
Construction	143,510	203,400	61,970	408,880
Rolling Stock	12	198	0	210
Clean Fuel	1,318	492	34	1,844[8]
Total CNC	159,298	214,533	63,937	437,767

Source: EC, M-Five

For each type of project there is a different sectoral split assumed to differentiate the TEN-T investment for all nine CNCs on a sectoral level. The multiplier differs depending on the sector where the investment is made, resulting in different growth rates on a sectoral level and different growth rates for total factor productivity. For example, the investment type ‘construction’ allocates the majority of investment in the construction sector with only moderate growth and spillover impacts, but a relatively high multiplier, depending on the input-output-structure of the respective Member State. The investment type ‘ERTMS’ allocates a substantial share to electronics and computers, both of which have stronger growth impacts and sectoral spillover effects on total factor productivity. Hence the cumulative growth effects may be higher, even though the multiplier effects could be lower than in the construction sector. Details on the difference between the indirect effects and the wider economic impacts are explained in the discussion on the economic terminology and the literature (see sections 3 and 4).

The information on the investments for each type and the assumptions on the sectoral split for each investment type gives the sectoral investments made by each country over the period 2017-2030. The results of this split indicate that the largest share of investments are made in the construction sector. Small parts are invested in the computer, electronics, as well as in other market services, vehicles, metals and other sectors. Also in other investment types like ‘study’ there are some parts going to the construction sector. Investments in ERTMS have a high share in the electronics sector and influence the computers sector and construction. Rolling stock largely impacts the vehicles sector.

The project size on the CNC differs significantly. The distribution of project size is shown in Figure 10. On the CNC there are 20 projects with a budget of more than €5 billion, and 126 with a budget between €1 billion and €5 billion. 1,181 projects, and thereby the largest number of projects, show investments of €10 million to €100 million. The biggest projects may even have a significant impact on the national economy, whereas the smaller projects

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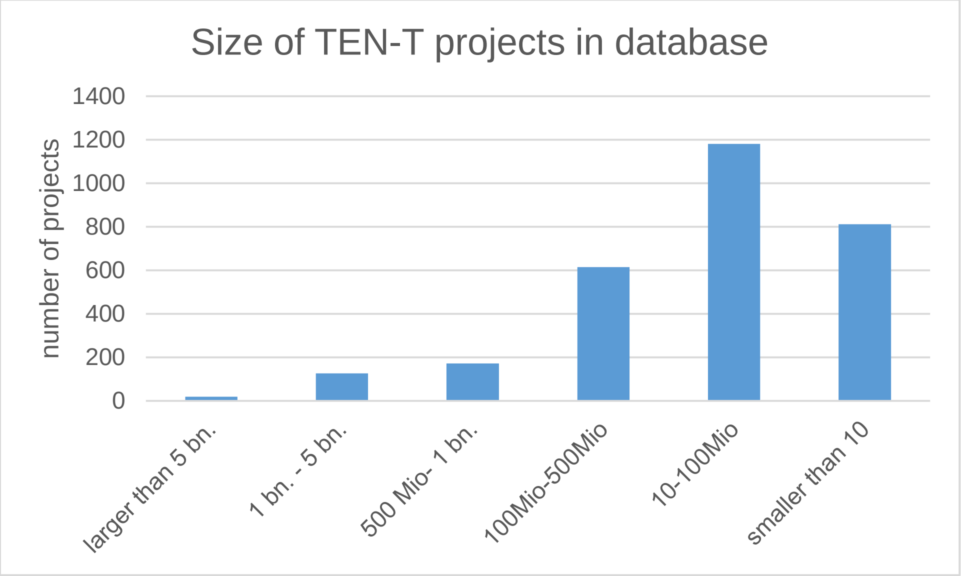
[8] This includes only the projects which have been identified so far in the core network corridor analysis. Further projects concerning e-mobility and alternative fuel infrastructure should be identified in the next phases of the corridor work so as to ensure continuity and full equipment in line with Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure.

can only be measured in macroeconomic terms in aggregate. Hence, especially for the larger projects it seems highly advisable to include wider economic impacts in the assessment of the projects.



Source: EC, M-Five

Figure 10: Distribution of investment volumes of TEN-T CNC projects in the project database in Euro$_{2005}$

Table 9 gives a detailed overview of the distribution of TEN-T investments per EU28 country. The highest share of investments goes to Italy with 21% of total TEN-T core network investments, followed by Germany with 16%, France with 12%, Poland with 6%, and Spain with 5%. TEN-T investments in the EU15 are oftentimes not strongly supported by EU funds (e.g. the Cohesion Fund does not apply to these countries) and thus the bulk of the TEN-T investments in these countries needs to be borne by national governments. As a result, additional checks for such countries on the level of debt and fiscal leeway in government expenditures needs to be carefully considered for modelling purposes, even if the share of TEN-T investments compared to overall investments in these countries seems non-critical.

Table 9: Distribution of TEN-T Investment by Country in million Euros$_{2005}$ and shares in total TEN-T investments

Country	2017-2020	2021-2025	2026-2030	2017-2030	Share of total
AT	4,416	3,649	499	8,564	2%
BE	3,826	4,028	510	8,364	2%
BG	2,336	3,242	1,087	6,666	2%
CH	2,368	19,705	816	22,889	5%
CY	278	175	145	599	0%
CZ	4,172	6,093	3,176	13,440	3%
DE	29,923	25,808	16,459	72,190	16%
DK	2,724	2,462	483	5,669	1%
EE	1,440	897	74	2,411	1%
EL	1,372	1,326	1,002	3,700	1%
ES	8,686	8,310	6,440	23,436	5%
FI	1,651	2,845	1,562	6,059	1%
FR	8,006	30,164	16,230	54,399	12%
HR	1,380	691	93	2,163	0%
HU	2,296	1,435	863	4,594	1%
IE	1,467	2,890	1,719	6,077	1%
IT	30,168	36,070	26,457	92,696	21%
LT	1,733	1,191	0	2,924	1%
LU	697	616	5	1,318	0%
LV	2,054	2,280	844	5,178	1%
MT	280	53	70	403	0%
NL	6,327	6,207	1,164	13,698	3%
NO	1,891	1,576	664	4,131	1%
PL	15,934	8,746	1,337	26,016	6%
PT	2,931	1,859	575	5,365	1%
RO	5,487	7,090	1,253	13,830	3%
SE	6,080	8,148	772	15,000	3%
SI	1,426	1,193	511	3,130	1%
SK	5,762	3,667	613	10,042	2%
UK	2,186	628	0	2,815	1%

Source: EC, M-Five

Around 75% of the length of the TEN-T core network is formed by nine CNCs. The TENtec system reports data on the remaining part of the TEN-T core network. Building on an analysis of TENtec data, 284 sections (known as CNoCNC sections) with planned or ongoing works on the networks have been identified. CNoCNC sections will contribute to the overall core network efficiency improvement but are not located on any of the 9 CNCs.

To assess the investment costs for CNoCNC sections cost benchmarks are used, building on the CNC project database. The existing project database is used to identify and cluster similar projects and match them with the categories of CNoCNC sections. The clustering is based on project characteristics, including technical parameters, infrastructure type, measure type, and information delivered in the project descriptions.

Some of the values may not match cost benchmarks in the literature but reflect the TEN-T core network cost structures. In particular, this is true for the cost benchmarks for HSR new construction, which was estimated to be in proportion to the cost benchmark for conventional railways. In complex landscapes requiring larger numbers of tunnels and bridges, the cost per kilometre of new construction of HSR can be substantially higher.

According to the available information on CNoCNC sections, they can be differentiated into twelve categories, 6 for road projects and 6 for rail projects. The categories distinguish between the measure types ‘new construction’, ‘rehabilitation’, and ‘upgrade’. Furthermore, a distinction is made between the infrastructure types ‘motorway’ and ‘rural or urban road’ for roads, and ‘conventional’ rail and ‘high-speed’ rail for railways. Technical information (e.g. lanes/tracks, speed and electrification status) was not explicitly available. Therefore, only rough average cost benchmarks are determined from the project database for those categories. The resulting cost benchmarks are presented in Table 10.

Table 10: Cost benchmarks to assess investment for CNoCNC sections

Transport mode	Type	Measure Type	EU15 [million € per km]	EU13 [million € per km]
Road	Motorway	New construction	14.4	12.7
	Motorway	Rehabilitation	9	5.2
	Motorway	Upgrade	10.5	7.25
	Rural or urban road	New construction	2.3	1.9
	Rural or urban road	Rehabilitation	1.6	1.01
	Rural or urban road	Upgrade	1.6	1.01
Rail	Conventional rail	New construction	12.45	10.15
	Conventional rail	Rehabilitation	2.7	2.41
	Conventional rail	Upgrade	2.51	2.2
	High-speed rail	New construction	17	15
	High-speed rail	Rehabilitation	6.8	5.9
	High-speed rail	Upgrade	6.7	5.8

Source: EC, M-Five analysis

The cost benchmarks were distinguished between EU15 (+Norway) and EU13 projects, considering that infrastructure projects within EU13 can be implemented at lower costs.

Applying the cost benchmarks to the identified sections, the overall investment costs of CNoCNC amount to €136,299 million, of which 82% are dedicated for railway projects and 18% for road infrastructure (also shown in Table 11).

Table 11: Aggregation of investment costs of the CNoCNC sections by mode type

Transport mode	Number of sections		Estimated investment costs [million €$_{2015}$] and [%]	
Road	139	49%	24,303	18%
Rail	145	51%	111,996	82%
Total	**284**	**100%**	**136,299**	**100%**

Source: EC, M-Five

Furthermore, a time line is defined for each section dependent on their size and status. Projects with the TENtec status ‘planned’ are set to start in 2021 and projects with the status ‘ongoing’ are set to have started in 2018.

5.6.4 Modelling of impacts on financial markets

The projects in the database are categorised into different investment types. In ASTRA, the information from the database regarding the financing status of the projects has been considered. The five categories considered are:

1. Investments financed by the government of the Member State: Generally, infrastructure investments are made either by national or regional (or local) government bodies. The infrastructure considered in the TEN-T networks are for the most part investments exceeding the jurisdiction of local or regional governments and thus the assumption is made that those investments which are not specified in detail are executed by the national governments of the Member State. Government spending in ASTRA is assumed to have a Keynesian multiplier effect. In the Reference Scenario government expenditures are higher than in the Baseline.
2. EU funds: The effects are similar to those of the ‘pure’ Member State financing as described in point 1. However, in the Reference Scenario a certain level of ‘crowding out’ is assumed relative to the Baseline.
3. Private funding: In the Reference Scenario, some crowding-out-effects are assumed and reflected in modelling (similar to the case described in point (2)).
4. EIB funds: EIB funds are assumed to result in risk reduction for institutional investors in ASTRA in the Reference Scenario relative to the Baseline.
5. Toll revenues: These revenues are paid in the Reference Scenario and hence subtracted from income, whereas in the Baseline Scenario these payments are used for other consumption purposes.

These categories have different effects in the model. The investments which are funded by the respective government of the Member State increase the government expenditures. This results in higher budget deficits. However, this possibility might not be feasible for every Member State. For simplicity, we assume that there are no distorting effects on national budgets in the Reference Scenario.

Table 12 gives an overview of the funding and financing of the TEN-T projects in the project database, which take place in the period from 2017 until 2021. The largest burden of TEN-T investments is borne by national governments who invest according to the project database, totalling around €143 billion. Another large part of funding comes from other EU funds such as the Cohesion Fund, and account to more than €25 billion of investment in the period 2017 to 2021. Also, the CEF fund contributes significantly, with more than €16 billion invested in the same period. Private funds account for another €10 billion and EIB funds for €8 billion. In the period 2022 until 2030, funding is extrapolated on the basis of the funding structure of the previous years with the underlying assumption that the funding structure of projects will not change significantly in the upcoming period.

Table 12: Cumulated EU funding and Financing from CNC Project Database in Mio Euro$_{2005}$

Funding Types	2017-2021
CEF	16,344
Other EU Funds	25,145
Private Funds	9,883
EIB	8,210
Toll Revenues	2,265
National Government Funding	143,178

Source: EC, M-Five

The funding each MS receives for the projects by the EU or by extended loans of the EIB influence the risk premium for the investment. Loans or guarantees of the EIB cannot be easily differentiated regarding the vehicle of operations for the project, meaning that projects falling under the realm of PPPs are like regular government bonds for the respective Member State with regards to risk. Hence, the funding received from the EU and EIB reduces the interest rate for government bonds and subsequently the payments of the national governments. This is in line with the respective formulation (e.g. in Rhomolo, (Mercenier et al., 2016)); the supply of government bonds is determined by the budget constraint, but there are no forward-looking expectations that would result in an optimal financing strategy. Thus, the funding that leads to a lowering of the risk premium is not anticipated by the markets.

The modelling of the government sector in ASTRA is provided below:

$$INC^{Gov} = Tx^{VAT} + Tx^{Fuel} + Tx^{Prod} + Inc^{EU} + Inc^{Sc} * Emp$$

Where

INC^{Gov} = Government revenues

Tx^{VAT} = Value-Added Tax

Tx^{Fuel} = Fuel Taxes

Tx^{Prod} = Production and other taxes

Inc^{EU} = EU funds (e.g. Cohesion Fund and CEF)

Inc^{Sc} = Income from Social Contributions

Emp = Employment

The tax incomes are dependent on consumption (or GDP development). EU funds have been revised in the context of this study to match the project data and the relevant funding categories.

$$Exp^{Gov} = Inv^{Gov} + Inv^{Networks} + Transf^{Gov\to F} + Transf^{Gov\to HH} + (1-\lambda) * i_r^{Gov} * B^{Gov} + \lambda * (i_{Inf}^{Gov} * B_{Inf}^{Gov}) + Con^{Gov}$$

Where

Exp^{Gov} = Government Expenditures

Con^{Gov} = Government Consumption

Inv^{Gov} = Government Investments

$Inv^{Networks}$ = Investments transport infrastructure

$Transf^{Gov\to F}$ = Transfer from Governments to private firms (e.g. subsidies)

$Transf^{Gov\to HH}$ = Transfer from Governments to households (e.g. social benefits)

i_r^{Gov} = Real interest rate for government bonds

B^{Gov} = Government bonds

B_{Inf}^{Gov} = Infrastructure government bonds

λ = Share of expenditures in infrastructure bonds

i_{Inf}^{Gov} = Interest rate for infrastructure government bonds

Higher investments lead to higher government expenditures. The transfer payments to households are dependent on the level of employment.

$$B^{Gov} = Exp^{Gov} - Inc^{Gov}$$

Government bonds are issued to cover government deficit. There is no forward-looking behaviour in the model and expected changes in government debts do not change the consumption behaviour of private households.

$$i_{inf}^{Gov} = i_l^{Gov} + r_i * \frac{Inv^{Networks}}{Inv^{Gov}} * \left(1 - m_i^{FM} * \frac{Inc^{EU^{TEN}} + Inc^{EIB^{TEN}}}{Inv^{Gov} + Inv^{Networks}}\right)$$

Where

i_l^{Gov} = Long-term interest rate for Government bonds

m_i^{FM} = Financial market multiplier for EU funding for interest rate.

r_i = Infrastructure risk premium

$Inc^{EU^{TEN}}$ = Income from TEN-T funds

$Inc^{EIB^{TEN}}$ = Income from EIB financial instruments

The long-term interest rate for each country is dependent on the long-term outlook regarding growth expectations and convergence of government debt. Since private investors on capital markets do not differentiate between different kinds of government bonds, the risk reduction of funding from the EU or the EIB changes the interest payment for the government bonds as a whole. Issuers can also be local or regional governments in the case of transport investments, or special entities where the government serves as a backup insurer for the private investor.

The impact on private investments in the model according to changes in TEN-T projects are implemented as follows:

$$\Delta Inv^F = \left(i_r^F - \frac{i_l^{Gov} - i_r^{Gov}}{m_i^{FM}}\right)\left[\Delta Exp + \Delta Con - \Delta B^{Gov} + \Delta \frac{FD}{PO}\right]$$

Where

ΔInv^F = Changes in investment of private firms (per sector)

i_r^F = Real interest rate for firms

ΔExp = Changes in export demand

ΔCon = Changes in consumption

FD = Final Demand

PO = Potential Output

Export demand changes according to the transport times and costs (due to the network effects) as well as due to changes in GDP. Higher government borrowing results in crowding out of private investments to a certain extent. On the other hand, if Final Demand increases faster than Potential Output, this stimulates private investments.

$$\Delta Con = \Delta Con^{HH} - Inc^{EU}$$

Changes in the transport network (besides changes in modal shares and exports via transport time and cost changes) also trigger changes in total factor productivity, alongside changes in investment in research and development.

$$\Delta TFP = \Delta LabProd + \Delta FreightTime + \omega^{Inv} Inv^F$$

Where

ΔTFP = Changes in Total Factor Productivity

$\Delta LabProd$ = Changes in Labour Productivity at sectoral level

$\Delta FreightTime$ = Changes in Freight Transport Times at network level

ω^{Inv} = Weighting Factor for Investments in Innovation (Spillover Effects)

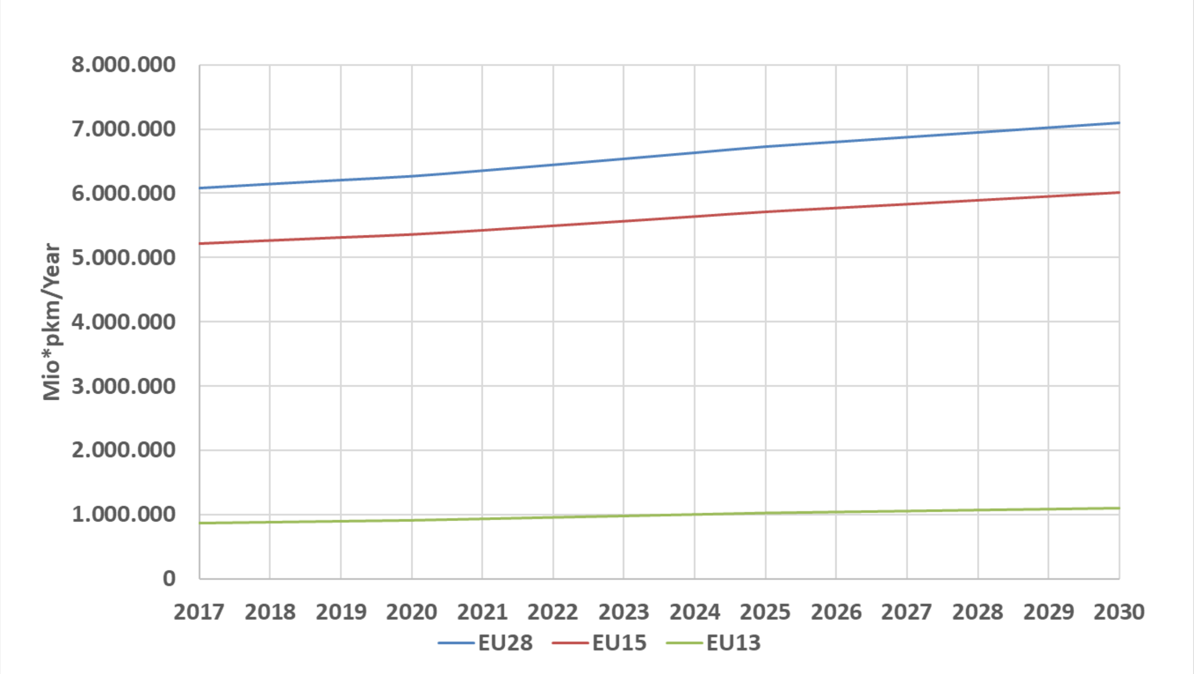
6 Baseline Scenario results

The Baseline Scenario results are described in this section. The impact of the core network and the CNCs implementation is measured against the Baseline Scenario. The ASTRA model Baseline provides yearly values in the period 2017- 2030, while the TRUST model Baseline provides values for the Base Year (2016) and for the different time thresholds of 2020, 2025, 2030 through model runs performed with the network of the base year and demand matrices for 2020, 2025 and 2030.

6.1 Transport activity projections

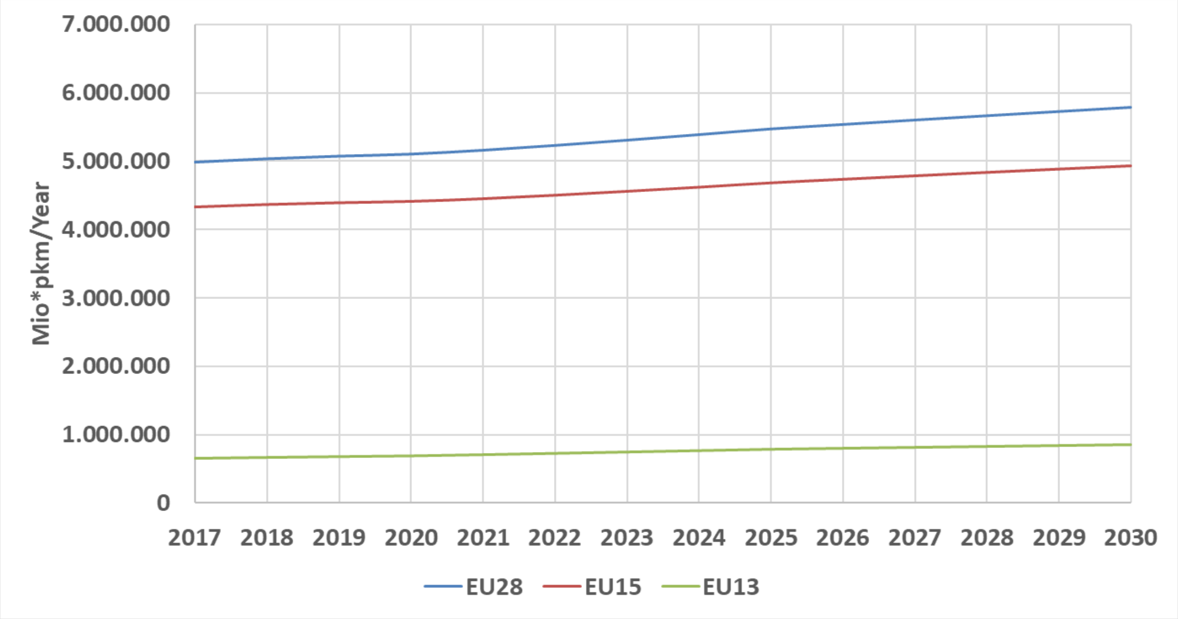
The ASTRA model key transport activity results for the Baseline Scenario for passengers and freight are given in the following figures. Total passenger transport activity (car, bus and rail) in the Baseline Scenario is projected to increase by 17% between 2017 and 2030 at the EU28 level (15% for EU15 Member States and 28% for EU13).

Similar results are shown for the transport activity by car (see Figure 12), which is expected to increase by 16% at the EU28 level (+14% in EU15; +30% in EU13). The figures are representing the transport activity on the territory of the Member States including pure domestic transport, transport originating or ending in a Member State as well as transit transport passing through a Member State only (territoriality approach). Air and maritime transport are excluded by the territoriality approach.



Source: ASTRA model

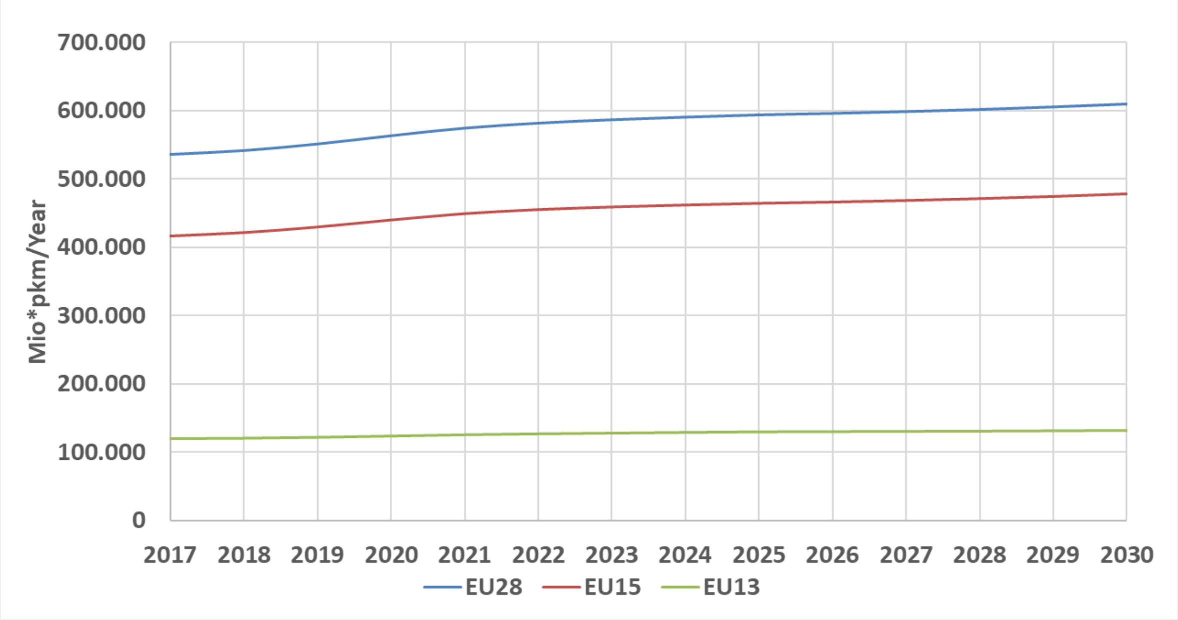
Figure 11: **Total passenger transport activity (territoriality approach) in the Baseline Scenario**



Source: ASTRA model

Figure 12: **Passenger cars transport activity (territoriality approach) in the Baseline Scenario**

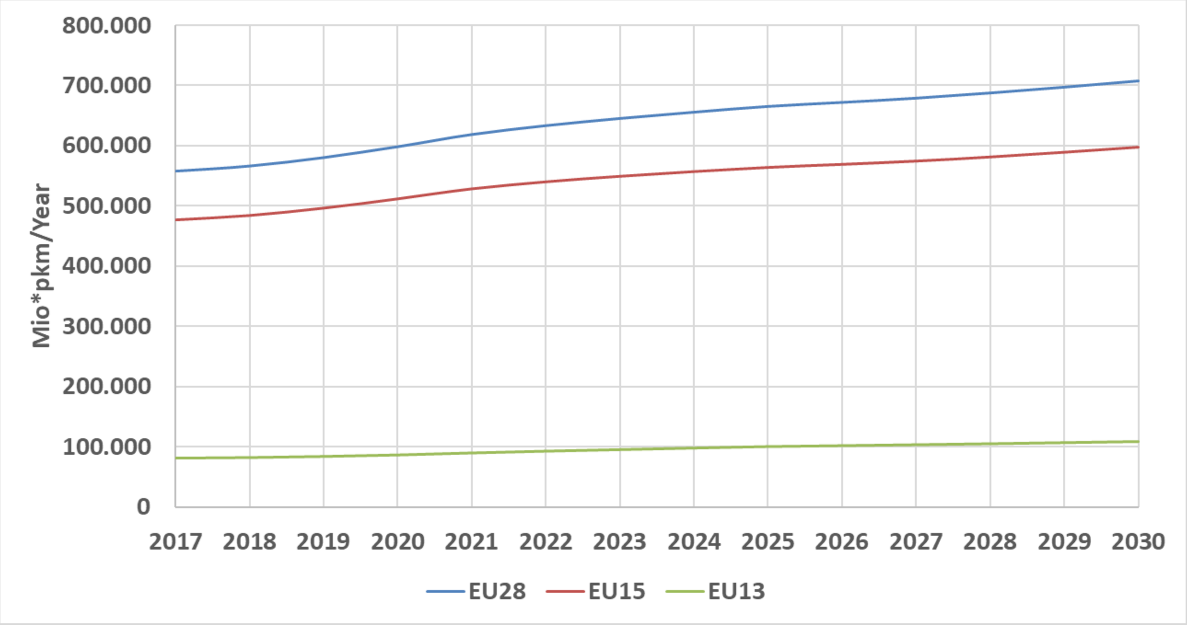
Transport activity by buses and coaches in the period 2017-2030 is projected to go up by 10% at EU level (+15% for EU15 and +10% for EU13 countries) as shown in Figure 13.



Source: ASTRA model

Figure 13: **Buses and coaches transport activity (territoriality approach) in the Baseline Scenario**

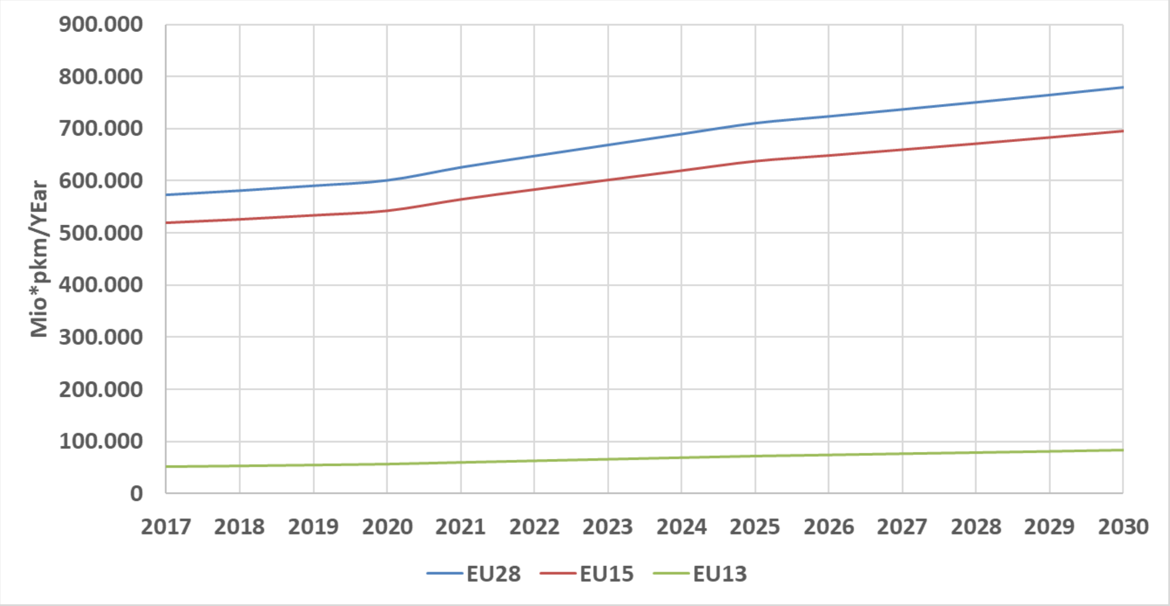
Rail passenger transport activity in the Baseline Scenario is expected to grow at higher rate than road, increasing by 27% between 2017 and 2030 at the EU28 level (+25% for EU15 Member States and +34% for EU13).



Source: ASTRA model

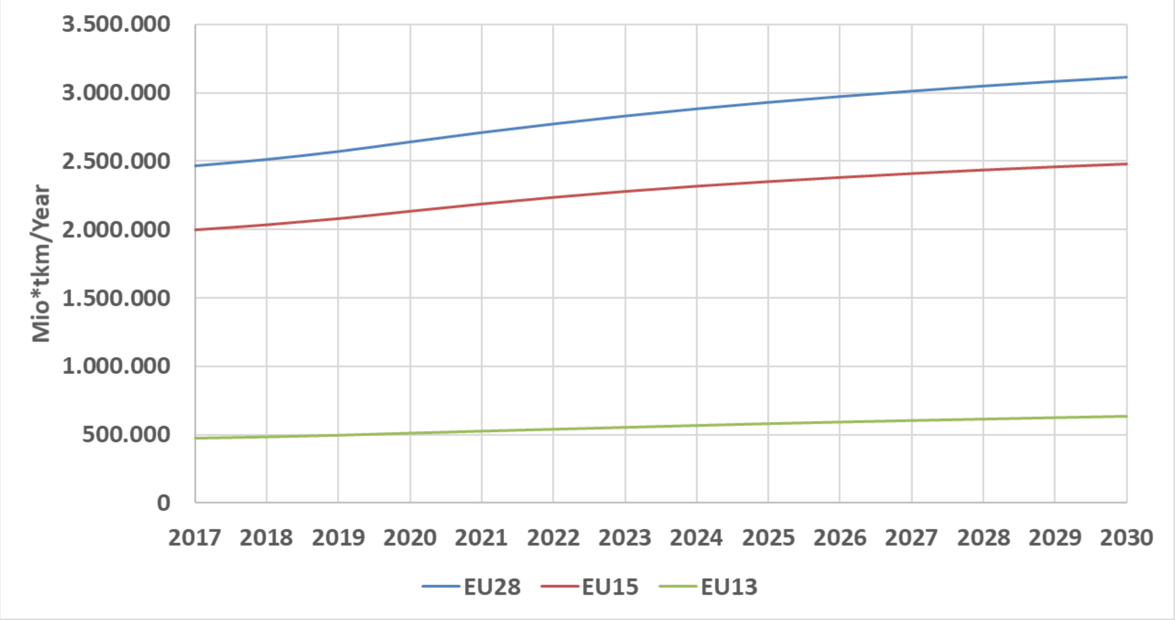
Figure 14: **Passenger rail transport activity (territoriality approach) in the Baseline Scenario**

Air transport activity in the period 2017-2030, illustrated in Figure 15, shows an overall increase of 36% at the EU28 level (+36% for EU15 and +60% for EU13 countries).



Source: ASTRA model

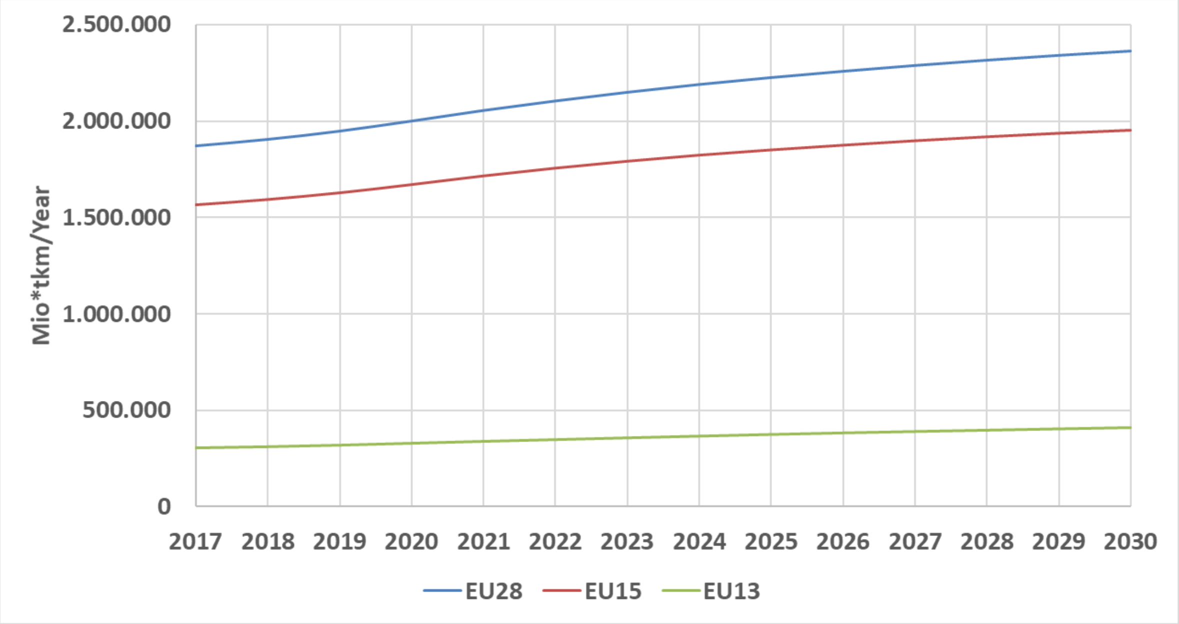
Figure 15: **Air passenger transport activity in the Baseline Scenario**



Source: ASTRA model

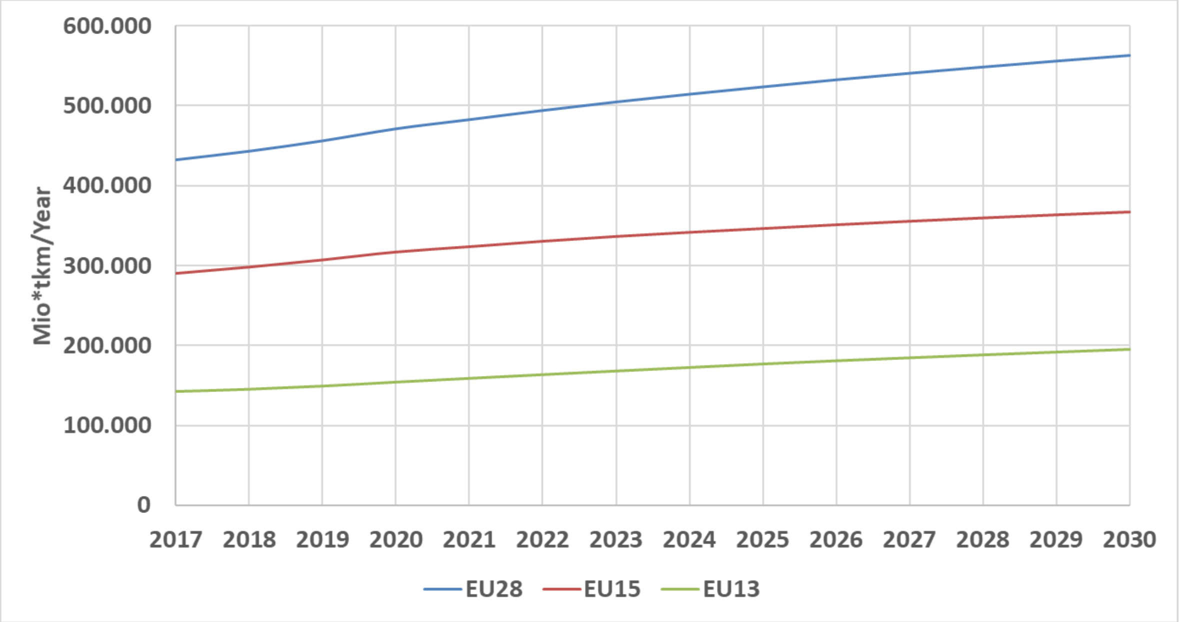
Figure 16: **Total freight transport activity (territoriality approach) in the Baseline Scenario**

Total freight transport activity (road, rail and inland waterways) is expected to increase by 26% at the EU28 level in the period 2017-2030 (+24% for EU15 and +35% for EU13). This growth is mainly driven by the road transport activity which shows very similar trends (i.e. +26% at the EU28 level, +25% at the EU15 level and +34% at the EU13 level).



Source: ASTRA model

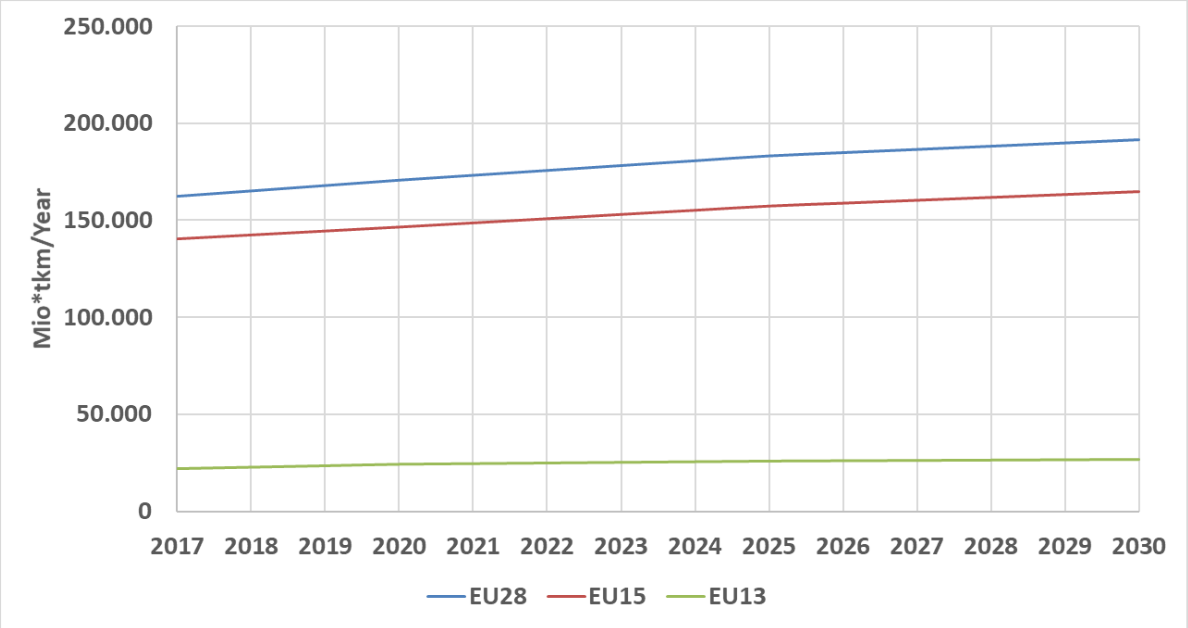
Figure 17: **Road freight transport activity (territoriality approach) in the Baseline Scenario**



Source: ASTRA model

Figure 18: **Rail freight transport activity (territoriality approach) in the Baseline Scenario**

The increase in rail freight activity for the period 2017-2030 ranges from 27% for EU15 to 38% for EU13 countries, with an overall increase of 30% at the EU28 level (see Figure 18). Somewhat lower growth is projected for transport activity by inland waterways in the Baseline Scenario (see Figure 19) which shows an overall increase of 18% at the EU28 level (+17% for EU15 and +20% for EU13 countries).

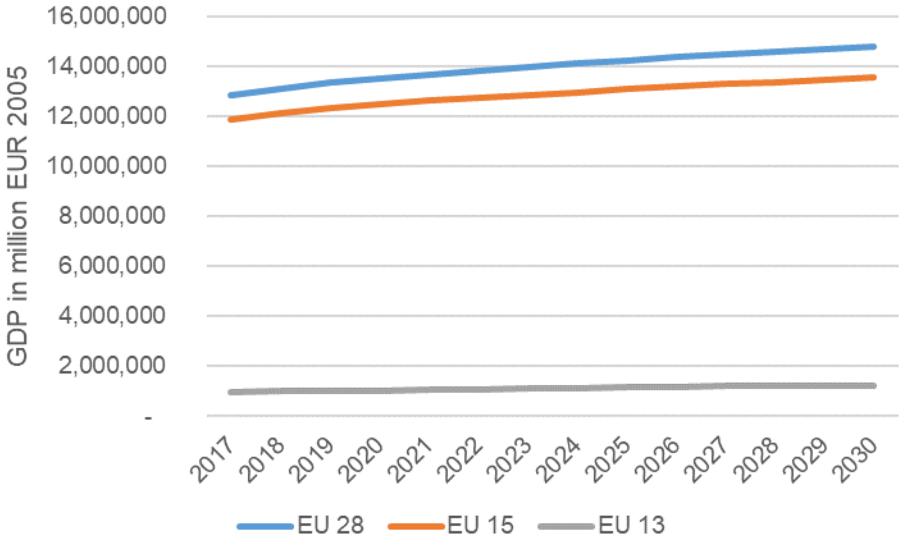


Source: ASTRA model

Figure 19: **Inland waterways freight transport activity (territoriality approach) in the Baseline Scenario**

6.2 Macro-economic projections

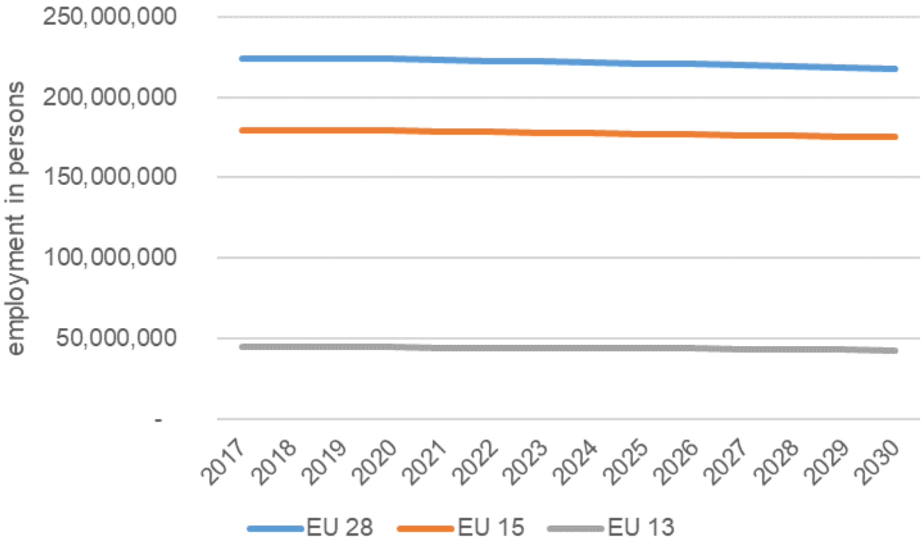
Figure 20 illustrates the GDP developments in the Baseline Scenario, without the impact of TEN-T investments beyond 2016. GDP is projected to grow by 1.1% per year from 2017 to 2030 (1.0% per year for EU15 and 1.9% per year for EU13).



Source: ASTRA model

Figure 20: **GDP projections in the Baseline Scenario**

Figure 21 shows the projected employment levels in the Baseline Scenario for the period 2017 to 2030 for the EU28, EU15 and EU13.



Source: ASTRA model

Figure 21: **Trend of employment in Baseline Scenario**

7 Alignment between the ASTRA-TRUST Reference and the update of the EU Reference Scenario 2016

A major task of the project was to ensure consistency with the ASTRA-TRUST models and the updated EU Reference Scenario 2016 (Capros et al. 2016). This section presents the fit of the Reference Scenario of the two models (TRUST and ASTRA) with the projections of the EU Reference Scenario 2016. The two models had to go through a second calibration process, after their parameters of the model equations have been calibrated to fit historic data, to also fit to the projections of the update of the EU Reference Scenario 2016. Transport results for the Reference Scenario are provided at the network level from the TRUST model and at an aggregate level from the ASTRA model.

7.1 Transport calibration

TRUST model is calibrated to reproduce tonnes-km and passengers-km by country consistent to the statistics reported in the Eurostat Transport in Figures pocketbook (net of intra-NUTS3 demand, which is not assigned to the network). At Member State level, the trend of road transport activity has been aligned to the trend of road transport demand in the ASTRA model.

ASTRA is calibrated to reproduce major indicators such as transport performance, fuel consumption, CO_2 emissions according to the main European reference sources such as Eurostat until 2015 and the PRIMES-TREMOVE EU Reference Scenario 2016 for future years. Table 13, Table 14 and Table 15 provide the comparison between transport performance in ASTRA Reference Scenario and PRIMES-TREMOVE EU Reference Scenario 2016 by mode. The comparison for CO_2 emissions is provided in Table 16.

Table 13: Comparison between the ASTRA model Reference Scenario and the update of the EU Reference Scenario 2016 (REF2016+) for passenger transport activity by car and rail (territoriality approach) - million pkm

	CAR			RAIL		
	EU Reference 2016	ASTRA Reference	% difference	EU Reference 2016	ASTRA Reference	% difference
2015						
EU15	4,368,238	4,188,643	**-4.1%**	464,287	480,228	**3.4%**
EU13	632,667	631,523	**-0.2%**	75,650	82,420	**8.9%**
EU28	5,000,905	4,820,166	**-3.6%**	539,937	562,648	**4.2%**
2020						
EU15	4,551,303	4,390,116	**-3.5%**	504,086	513,399	**1.8%**
EU13	699,135	704,477	**0.8%**	90,229	88,724	**-1.7%**
EU28	5,250,438	5,094,593	**-3.0%**	594,315	602,123	**1.3%**
2030						
EU15	4,873,078	4,870,033	**-0.1%**	601,273	645,586	**7.4%**
EU13	805,351	870,154	**8.0%**	118,211	119,585	**1.2%**
EU28	5,678,428	5,740,187	**1.1%**	719,485	765,170	**6.3%**

Source: ASTRA model

Table 14: Comparison between the ASTRA model Reference Scenario and the update of the EU Reference Scenario 2016 for passenger transport activity by bus and air (territoriality approach) – million pkm

	BUS			AIR		
	EU Reference 2016	ASTRA Reference	% difference	EU Reference 2016	ASTRA Reference	% difference
2015						
EU15	422,753	419,406	**-0.8%**	551,117	522,089	**-5.3%**
EU13	123,170	121,779	**-1.1%**	56,608	50,895	**-10.1%**
EU28	545,922	541,184	**-0.9%**	607,725	572,983	**-5.7%**
2020						
EU15	438,912	436,856	**-0.5%**	624,004	543,321	**-12.9%**
EU13	130,031	125,227	**-3.7%**	68,688	57,537	**-16.2%**
EU28	568,943	562,083	**-1.2%**	692,692	600,859	**-13.3%**
2030						
EU15	458,924	473,298	**3.1%**	759,732	691,278	**-9.0%**
EU13	140,892	134,264	**-4.7%**	99,057	118,211	**19.3%**
EU28	599,816	607,562	**1.3%**	858,789	775,498	**-9.7%**

Source: ASTRA model

Table 15: Comparison between the ASTRA model Reference Scenario and the update of the EU Reference Scenario 2016 for freight transport activity by road and rail (territoriality approach) - million tkm

	ROAD			RAIL		
	EU Reference 2016	ASTRA Reference	% difference	EU Reference 2016	ASTRA Reference	% difference
2015						
EU15	1,632,141	1,545,646	**-5.3%**	278,422	274,524	**-1.4%**
EU13	282,926	299,680	**5.9%**	149,089	137,605	**-7.7%**
EU28	1,915,066	1,845,326	**-3.6%**	427,511	412,128	**-3.6%**
2020						
EU15	1,790,217	1,691,687	**-5.5%**	308,398	321,513	**4.3%**
EU13	316,544	331,718	**4.8%**	174,139	154,583	**-11.2%**
EU28	2,106,760	2,023,405	**-4.0%**	482,537	476,095	**-1.3%**
2030						
EU15	2,048,395	1,970,231	**-3.8%**	371,050	390,263	**5.2%**
EU13	385,220	412,542	**7.1%**	222,435	200,802	**-9.7%**
EU28	2,433,615	2,382,772	**-2.1%**	593,485	591,065	**-0.4%**

Source: ASTRA model

Table 16: Comparison between the ASTRA model Reference Scenario and the update of the EU Reference Scenario 2016 for CO_2 emissions from total transport sector – 1 000 t/year

	TOTAL TRANSPORT SECTOR		
	EU Reference 2016	ASTRA Reference	% difference
2015			
EU15	894,179	832,496	-6.9%
EU13	134,288	135,690	1.0%
EU28	1,028,467	968,186	-5.9%
2020			
EU15	867,381	803,474	-7.4%
EU13	136,327	134,748	-1.2%
EU28	1,003,708	938,222	-6.5%
2030			
EU15	798,934	749,775	-6.2%
EU13	138,850	139,336	0.4%
EU28	937,784	889,111	-5.2%

Source: ASTRA model

7.2 Economic calibration

The economic modules were matched as closely as possible to the EU Reference Scenario 2016 (Capros et al., 2016) and the Ageing Report (EC, 2015). While it is easier to calibrate overall GDP, it is not straightforward to calibrate gross value added. Sectoral decomposition differs between the models and the indirect effects from the Input-Output-tables makes it nearly impossible to achieve the same growth trajectory for all sectors in the ASTRA model as in the EU Reference Scenario. Furthermore, the EU Reference Scenario does not report investment figures, and since the investment effects are deeply entangled with the growth trajectory in the ASTRA model, it is not possible to obtain a perfect match for GDP figures for all countries for every year. Table 17 shows the calibration results for EU13, EU15 and EU28 countries for the GDP deviations from the Reference Scenario. Table 18 illustrates the deviation of employment for EU13, EU15 and EU28 countries to the Ageing Report 2015.

Table 17: Deviation of ASTRA-EC with EU Reference Scenario

Difference GDP in ASTRA to EU Reference	% difference	
	2015	2030
EU15	-0.1%	-0.6%
EU13	-1.2%	2.6%
EU28	-0.1%	-0.3%

Source: ASTRA model, EU Reference Scenario

Table 18: Deviation of ASTRA-EC with Ageing Report 2015

Difference Employment in ASTRA to Ageing Report 2015	% difference	
	2015	2030
EU15	1.5%	-0.2%
EU13	-1.3%	2.8%
EU28	1.0%	0.6%

Source: ASTRA model, Ageing Report 2015l

8 Impacts of TEN-T implementation during 2017-2030

While in the Baseline Scenario no TEN-T core network projects are assumed to be implemented beyond 2016, the implementation of the core network continues in the Reference Scenario until 2030. In 2030 the TEN-T core network will then be fully implemented and operational. Thus, the impact of the implementation of the TEN-T core network over the period 2017-2030 is assessed by comparing the Reference Scenario with the Baseline Scenario.

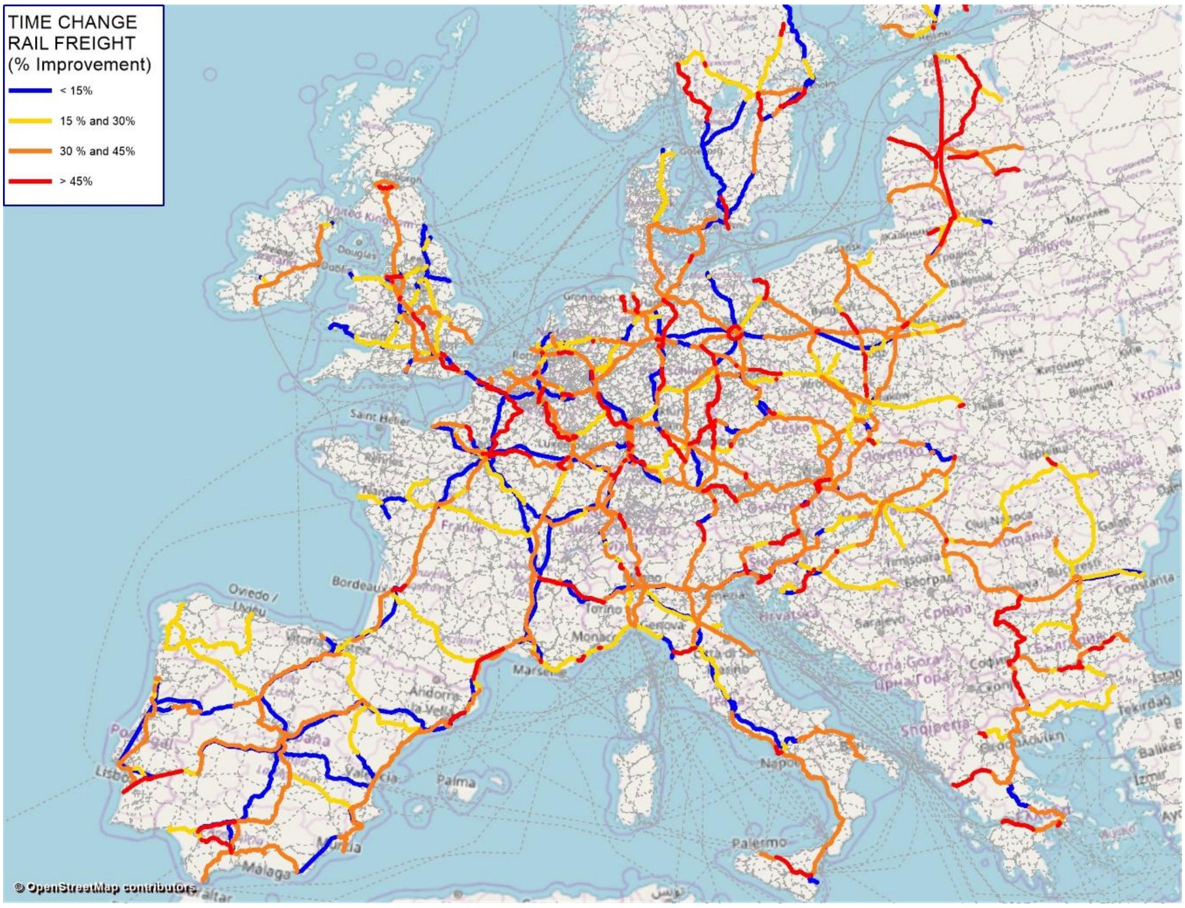
8.1 TEN-T impact at the network level

Network level results from TRUST are provided in terms of maps showing the changes in travel time along the core network in 2030. More detailed results in terms of changes in travel time and costs along the CNCs are provided in section 9.1.

Maps in Figure 22 and Figure 23 show the change in travel time for the TEN-T core rail network, respectively for freight and passenger, in the Reference Scenario relative to Baseline in 2030.

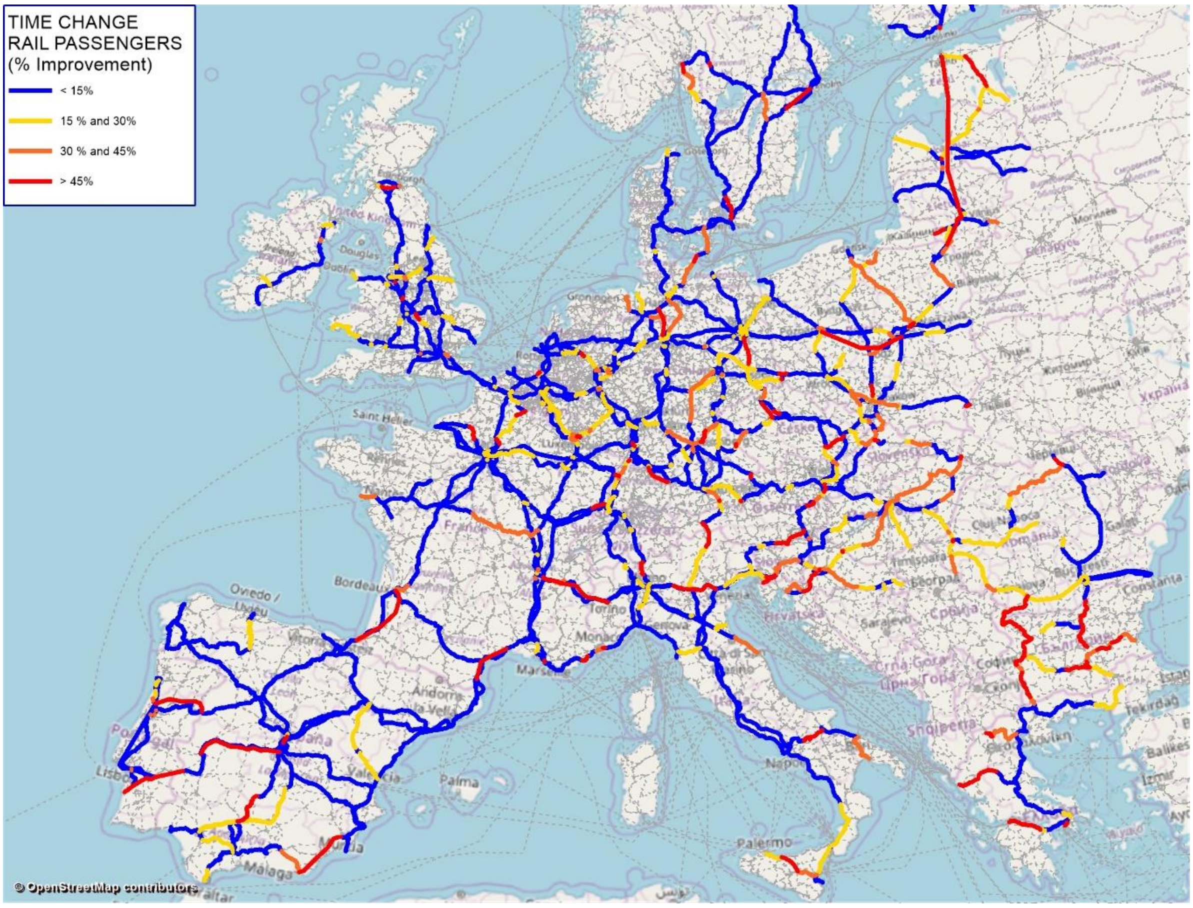
Comparing the maps for passenger and freight clearly shows that the investments planned on the core network are expected to benefit freight rail performance more than passenger rail. Figure 22 shows a high proportion of the freight network is expected to see travel time gains of over 30%, compared to Figure 23 which shows that a high proportion of the passenger network will see gains lower than 15%. This result reflects that most of the investments in the rail sector aim to increase rail freight performance where several improvements are still possible, while the performance of the rail passenger network is already of high level.

The reduction of travel time for rail freight is the outcome of two factors. First, the impact of infrastructure investment will allow for higher operational speeds on the corridors. Second, the impact from general improvement of the efficiency of the freight rail system through the removal of barriers to freight train circulation, including increased time slots for freight trains, better integration with passenger trains traffic, reduction/elimination of bottlenecks, technical and operational improvements in cross-border transit.



Source: TRUST model

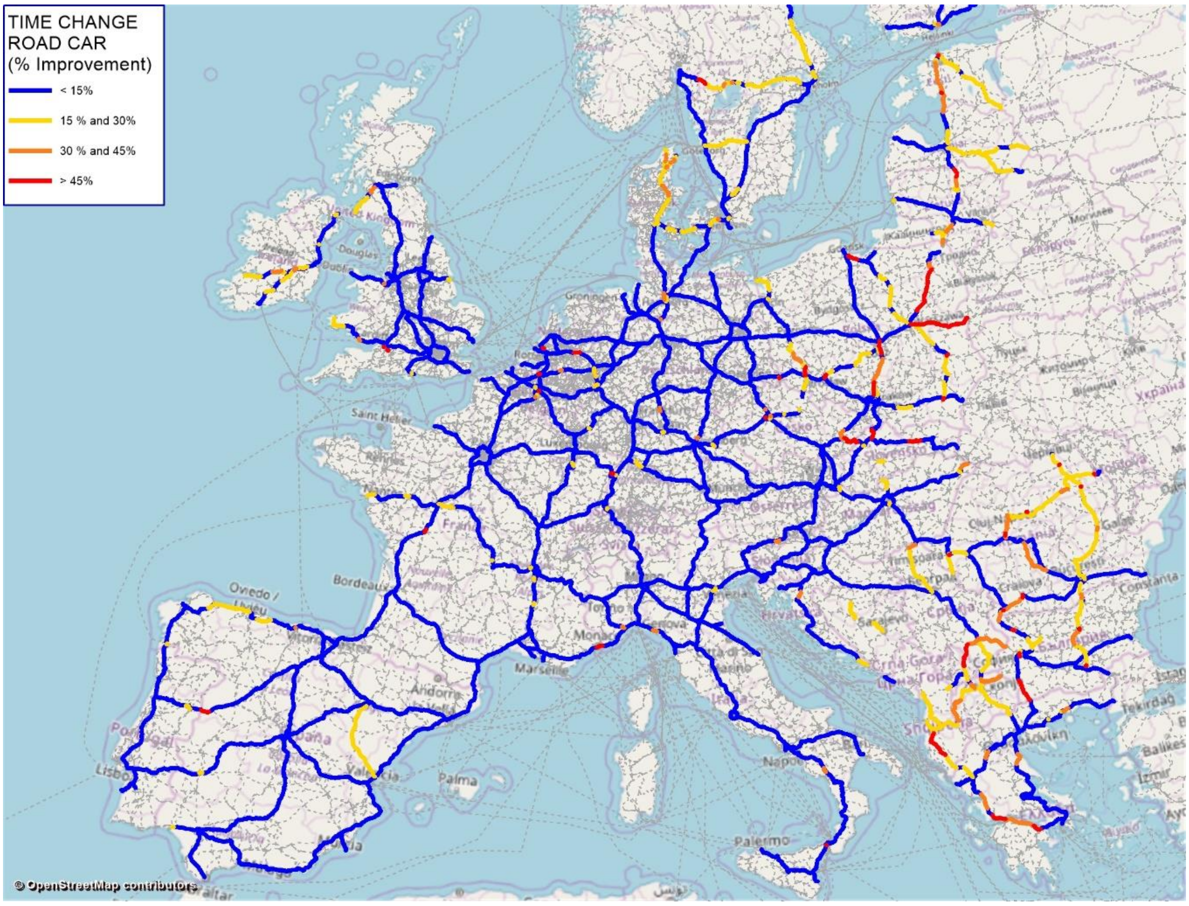
Figure 22: Changes in travel time for freight rail in the Reference Scenario relative to the Baseline in 2030 (% change)



Source: TRUST model

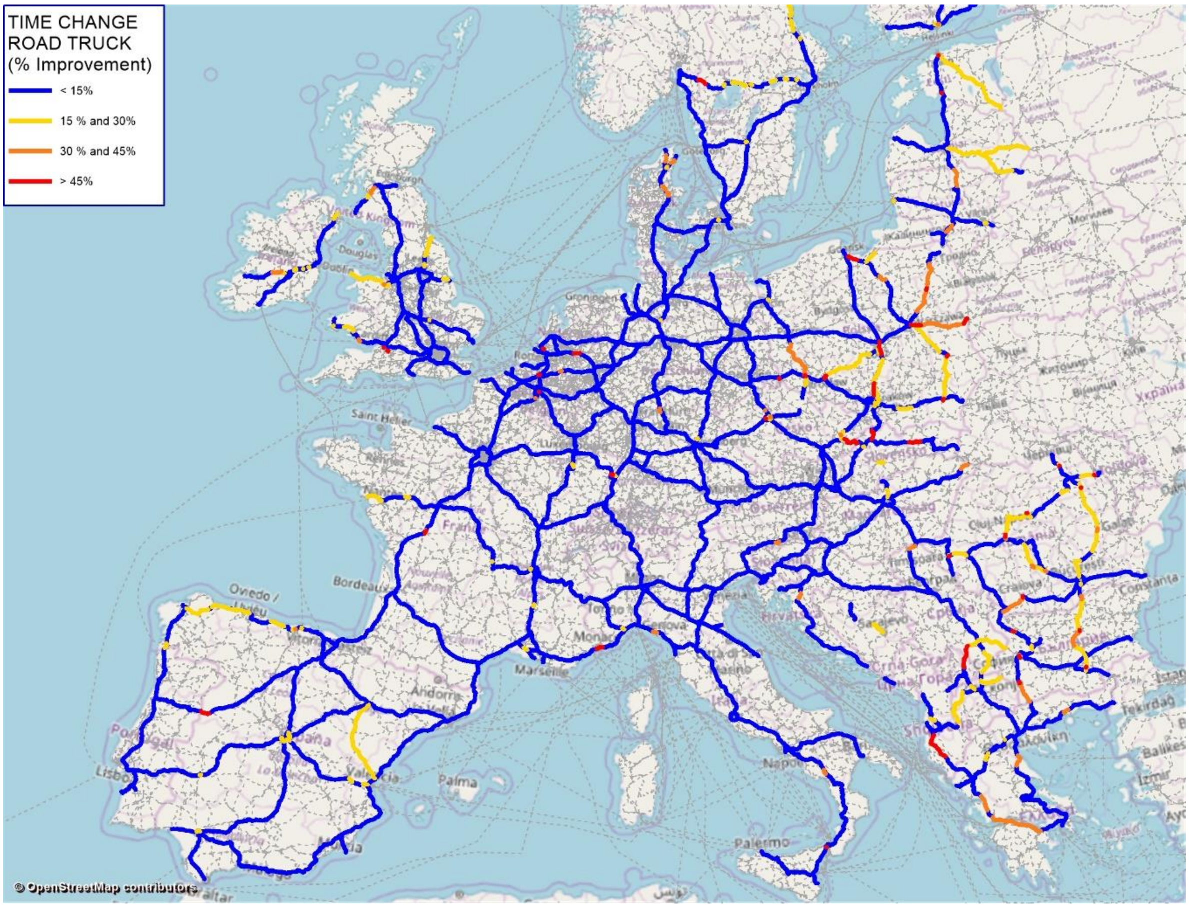
Figure 23: Changes in travel time for passenger rail in the Reference Scenario relative to the Baseline in 2030 (% change)

Figure 24 and Figure 25 show the changes in travel time by road for the Reference Scenario relative to Baseline in 2030, for cars and trucks respectively. Not surprisingly, the changes are lower than those observed for the rail network, reflecting the implementation of the rail network development projects in the EU TEN-T. Indeed, on most of the network, time gains are below 15%. More detailed results for corridor level, reported in section 8, show that the time gains on the road CNCs are mostly below 7%, partially due to the already high performance of the road network.



Source: TRUST model

Figure 24: Changes in travel time by road for passengers in the Reference Scenario relative to Baseline in 2030 (% change)



Source: TRUST model

Figure 25: Changes in travel time by road for freight in the Reference Scenario relative to Baseline in 2030 (% change)

8.2 TEN-T impact on transport demand

Transport impacts at aggregate level are provided by the ASTRA model[9]. Passenger (car, bus, rail) and freight (road, rail and inland waterways) transport activity is computed according to the territoriality approach[10] and cover distance bands (i.e. including short distance demand). The territoriality approach considers all the traffic on the territory of a country. Results for air transport are provided in Table 22. The maritime sector is covered only in so far as projects in ports as well as impacts on ports' hinterland connections are concerned. A detailed analysis on the growth potential of inland waterways and maritime transport is undertaken in the forthcoming "Study on support measures for the implementation of the TEN-T core network related to sea ports, inland ports and inland waterway transport" by EY et al.

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[9] ASTRA is not a network model and, at most detailed level, it works with a NUTS1 zoning system. It deals therefore with transport demand at NUTS 1 level and not at corridor level.

[10] The territoriality approach (e.g. also used in the Transport in Figures statistical pocket book) considers all the traffic on the territory of a country, regardless of its origin and destination.

8.2.1 Passenger demand

By 2030 the overall passenger transport activity slightly increases (0.2%) in the Reference Scenario relative to the Baseline (see Table 19). Passenger activity by transport modes shows an increase of rail activity by 8.4% at the EU28 level (+8.9% at the EU15 level and 6.0% at the EU13 level). Road transport activity decreases by 0.7% at the EU28 level.

Table 19: Changes in passenger transport activity (territoriality approach) for the Reference Scenario relative to Baseline in 2030 (difference in million passenger-kilometres and % changes)

	CAR		BUS		RAIL		TOTAL	
	Delta	% Change	Delta	% Change	Delta	% Change	Delta	% Change
EU15	-37,095	**-0.8%**	-1,061	**-0.2%**	53,168	**8.9%**	15,012	**0.2%**
EU13	-3,390	**-0.4%**	-498	**-0.4%**	6,561	**6.0%**	2,673	**0.2%**
EU28	-40,485	**-0.7%**	-1,559	**-0.3%**	59,729	**8.4%**	17,685	**0.2%**

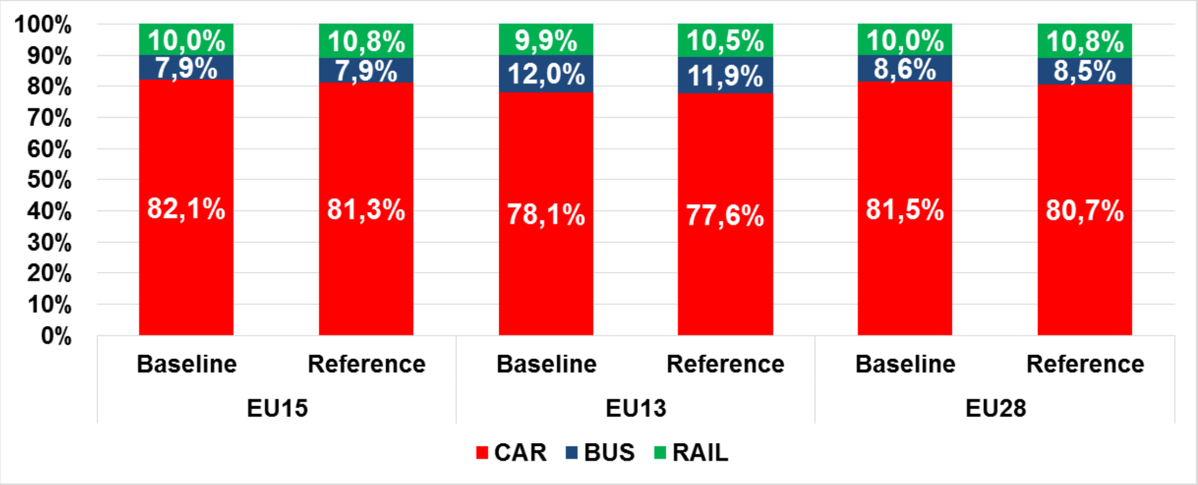
Source: ASTRA model; Note: Delta stands for the difference in tonne-kilometre per year while % change stands for the % difference between the Reference Scenario and the Baseline Scenario.

Passenger modal split in the Reference and Baseline Scenarios in 2030 is shown in Table 20 and Figure 26. The modal share of rail is projected to increase by 0.8 percentage points (p.p.) in the Reference Scenario in comparison with the Baseline at the EU28 level.

Table 20: Passenger Modal Split (territoriality approach) in the Reference Scenario, and difference relative to the Baseline in 2030

	Passenger Modal Split			
	Scenario	CAR	BUS	RAIL
EU15	**Baseline**	82.1%	7.9%	10.0%
	Reference	81.3%	7.9%	10.8%
	Variation	**-0.8%**	**0.0%**	**0.9%**
EU13	**Baseline**	78.1%	12.0%	9.9%
	Reference	77.6%	11.9%	10.5%
	Variation	**-0.5%**	**-0.1%**	**0.6%**
EU28	**Baseline**	81.5%	8.6%	10.0%
	Reference	80.7%	8.5%	10.8%
	Variation	**-0.8%**	**0.1%**	**0.8%**

Source: ASTRA model



Source: ASTRA model

Figure 26: Passenger modal split (territoriality approach) in the Reference and the Baseline Scenarios at 2030

More relevant changes can be observed for modal split of long distance passenger demand[11] as reported in Table 21 and Figure 27. In this case rail modal share increases by 1.5 p.p. in the Reference Scenario in comparison with the Baseline at the EU28 level.

Table 21: Long distance passenger Modal Split (territoriality approach) in the Reference Scenario relative to Baseline in 2030

	Passenger Modal Split			
	Scenario	**CAR**	**BUS**	**RAIL**
EU15	**Baseline**	84.0%	1.6%	14.4%
	Reference	82.4%	1.6%	16.0%
	Variation	**-1.6%**	**0.0%**	**1.6%**
EU13	**Baseline**	85.1%	4.9%	10.0%
	Reference	84.1%	4.8%	11.1%
	Variation	**-1.0%**	**-0.1%**	**1.1%**
EU28	**Baseline**	84.2%	2.2%	13.6%
	Reference	82.7%	2.2%	15.1%
	Variation	**-1.5%**	**0.0%**	**1.5%**

Source: ASTRA model

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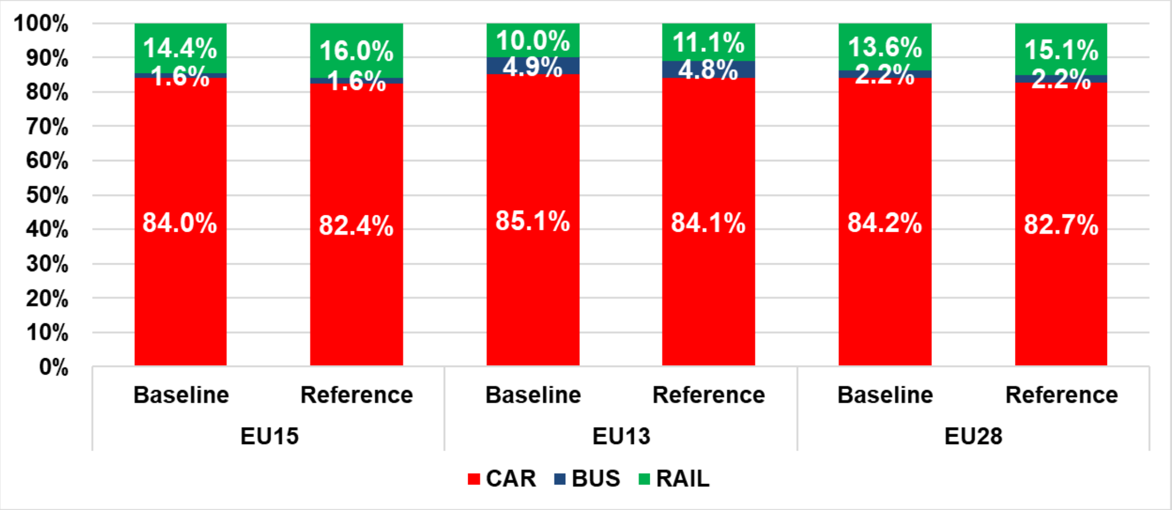
[11] Long distance transport activity refers to international and long-distance national transport, defined as traffic with destination outside the NUTS2 zone of origin.



Source: ASTRA model

Figure 27: Long distance passenger modal split (territoriality approach) in the Reference and the Baseline Scenarios at 2030

The changes in air passenger transport activity for the Reference Scenario relative to Baseline in 2030 are given in Table 22. At EU15 level a slight reduction of 0.5% is observed as consequence of the increased rail performance. A different trend is shown at the EU13 level, where a slight increase of 0.2% is observed. Overall the impact at the EU28 level is a slight reduction of 0.4%.

Table 22: Changes in air passenger transport activity for the Reference Scenario relative to Baseline in 2030

	AIR	
	Delta	**% Change**
EU15	-3,514	**-0.5%**
EU13	151	**0.2%**
EU28	-3,363	**-0.4%**

Source: ASTRA model; Note: Delta stands for the difference in million pkm/year while % change stands for the % difference between the Reference Scenario and the Baseline Scenario

8.2.1 Freight demand

Freight performance projections are shown in Table 23 and Figure 28. Total freight activity increases by about 0.6% at the EU28 level in the Reference Scenario relative to Baseline in 2030. Looking at the changes by mode it can be noted that freight activity by rail increases by 4.7% at the EU28 level, with an increase of 2.7% for EU13 countries and of 5.8% for EU15. Road freight transport decreases in EU15 countries by about 0.4% and by 0.3% in EU13 countries. Activity by inland waterways shows an increase of 0.6% at the EU28 level. These changes result in shifts towards more sustainable transport modes like rail and inland waterways - as shown respectively in Table 24 and Figure 28 for total transport activity and in Table 25 and Figure 29 for long distance traffic[12]. Overall, rail

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[12] Long distance transport activity refers to international and long-distance national transport, defined as traffic with destination outside the NUTS2 zone of origin.

freight activity increases its share by 0.7 p.p. at EU level. For long distance traffic, this means increasing the rail modal share by 0.9 p.p.

Table 23: Changes in freight transport activity (territoriality approach) for the Reference Scenario relative to Baseline in 2030

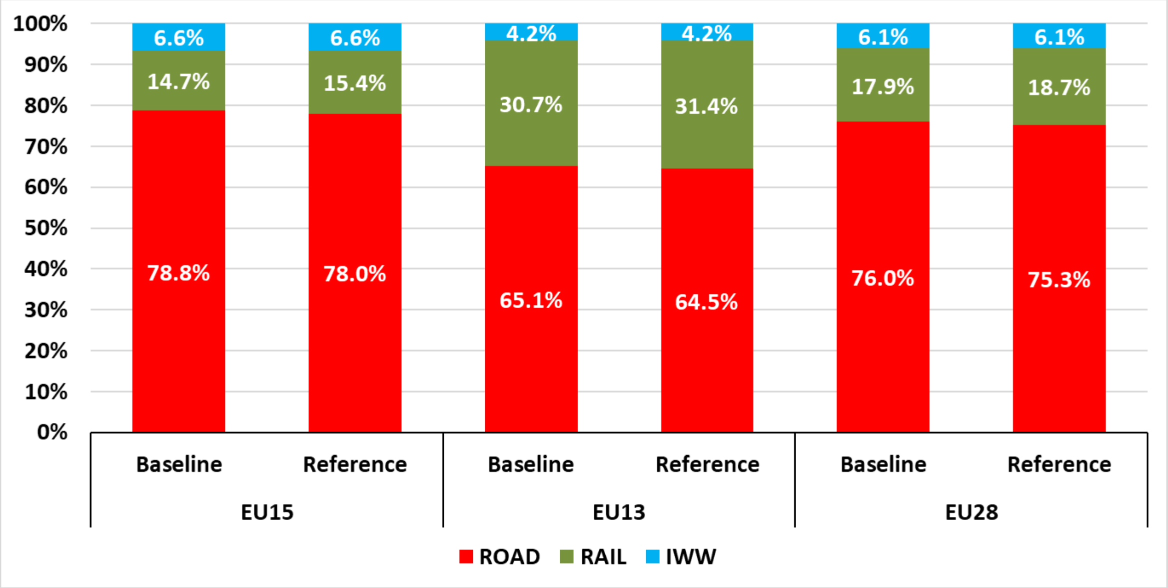
	ROAD		RAIL		IWW		TOTAL	
	Delta	% Change	Delta	% Change	Delta	% Change	Delta	% Change
EU15	-7,903	**-0.4%**	21,311	**5.8%**	1,108	**0.7%**	14,517	**0.6%**
EU13	-1,388	**-0.3%**	5,344	**2.7%**	70	**0.3%**	4,026	**0.6%**
EU28	-9,291	**-0.4%**	26,655	**4.7%**	1,178	**0.6%**	18,543	**0.6%**

Source: ASTRA model; Note: Delta stands for the difference in tonne-kilometre per year while % change stands for the % difference between the Reference Scenario and the Baseline Scenario.

Table 24: Change of freight modal split of total demand (territoriality approach) in the Reference Scenario relative to Baseline in 2030

	Scenario	ROAD	RAIL	IWW
EU15	**Baseline**	78.8%	14.7%	6.6%
	Reference	78.0%	15.5%	6.5%
	Variation	**-0.7%**	**0.8%**	**0.1%**
EU13	**Baseline**	65.1%	30.7%	4.2%
	Reference	64.5%	31.4%	4.2%
	Variation	**-0.6%**	**0.6%**	**0.0%**
EU28	**Baseline**	76.0%	17.9%	6.1%
	Reference	75.3%	18.7%	6.1%
	Variation	**-0.7%**	**0.7%**	**0.0%**

Source: ASTRA model



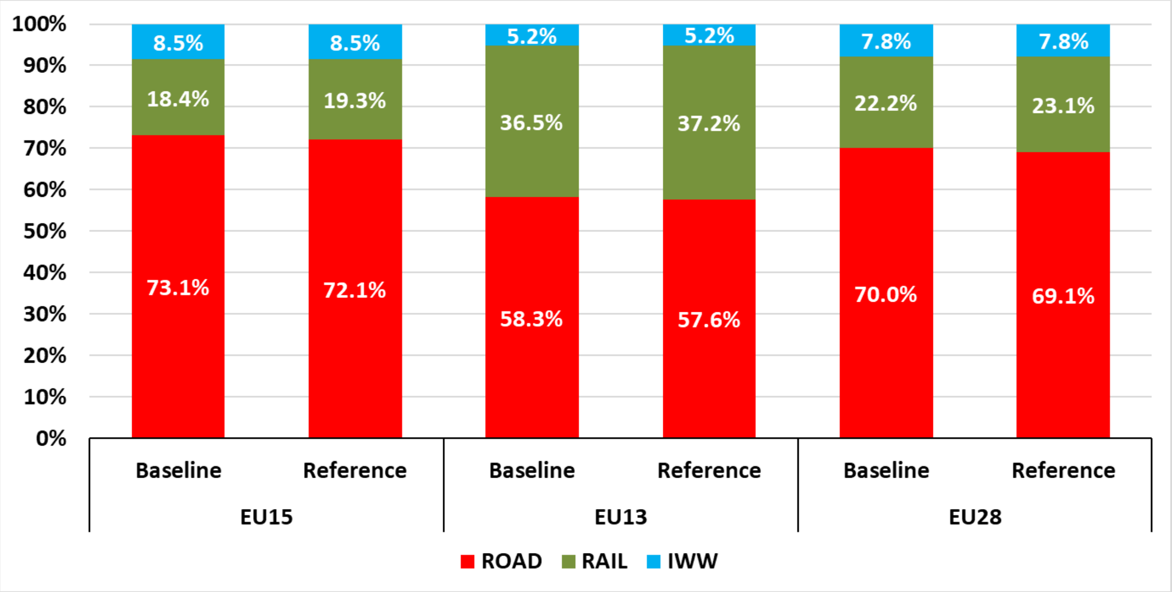
Source: ASTRA model

Figure 28: Freight modal split of total activity in tkm in the Reference and Baseline Scenarios in 2030

Table 25: Change of freight modal split of long distance demand (territoriality approach) in the Reference Scenario relative to Baseline in 2030

	Freight Modal Split			
	Scenario	**ROAD**	**RAIL**	**IWW**
EU15	**Baseline**	73.1%	18.4%	8.5%
	Reference	72.1%	19.3%	8.5%
	Variation	**-1.0%**	**1.0%**	**0.0%**
EU13	**Baseline**	58.3%	36.5%	5.2%
	Reference	57.6%	37.2%	5.2%
	Variation	**-0.7%**	**0.8%**	**0.0%**
EU28	**Baseline**	70.0%	22.2%	7.8%
	Reference	69.1%	23.1%	7.8%
	Variation	**-0.9%**	**0.9%**	**0.0%**

Source: ASTRA model



Source: ASTRA model

Figure 29: Freight modal split of long distance traffic in the Reference and the Baseline Scenarios in 2030

8.2.1 CO_2 emissions, transport external costs and time savings

The impacts on CO_2 emissions in the Reference Scenario relative to the Baseline in 2030 are given in Table 26. Overall EU CO_2 emissions are expected to decrease by about 12.5 million tonnes in 2030 (1.4% decrease) relative to the Baseline. This impact is driven both by (i) shifts from road to more sustainable transport modes (i.e. rail and inland waterways) (ii) changes in the vehicle fleet composition in the Reference Scenario in comparison with the Baseline Scenario enabled by the refuelling/recharging infrastructure for alternative fuels and electro-mobility as described in section 5.6.

Table 26: Change of CO_2 emissions from total transport sector in the Reference Scenario relative to Baseline at 2030

	CO_2	
	Delta	**% Change**
EU15	-10,797	**-1.4%**
EU13	-1,756	**-1.2%**
EU28	-12,553	**-1.4%**

Source: ASTRA model. Note: Delta stands for the difference in 1000 t/year while % change stands for the % difference between the Reference Scenario and the Baseline Scenario

This is expected to lead to a cumulative reduction of CO_2 emissions from the transport sector of about 72 million tonnes between 2017 and 2030, out of which 26 million tonnes are due to the TEN-T core network completion and the rest from measures to promote cleaner vehicle technologies enabled by the refuelling/recharging infrastructure for alternative fuels and electro-mobility. CO_2 external transport costs given in Table 27 show a reduction of about 436 million euro in 2030 (-1.4%) in the Reference Scenario relative to Baseline in 2030. Changes of CO, NOx, VOC and PM yearly emissions from the total transport sector in the Reference Scenario relative to Baseline in 2030 are given in Table 28.

The Reference Scenario does not take into account the policies recently adopted at the EU level for 2030 (i.e. the recast of the Renewables Energy Directive, the revision of the Energy Efficiency Directive and the Effort Sharing Regulation), and those recently proposed by the Commission (i.e. the first "Europe on the Move" package in May 2017, the second Mobility Package in November 2017 and the third "Europe on the Move" package in May 2018). Also, the National Emissions Ceilings (NEC) Directive (2016/2284/EU) is not part of the Reference Scenario. Taking these policies into account would lead to much higher CO2 emissions savings on the core TEN-T network.

Table 27: Changes of CO_2 external transport costs from total transport sector in the Reference Scenario relative to Baseline in 2030

	Delta	**% Change**
EU15	-375.6	**-1.4%**
EU13	-60.7	**-1.2%**
EU28	-436.3	**-1.4%**

Source: ASTRA model; Note: Delta stands for the difference in 1000 t/year while % change stands for the % difference between the Reference Scenario and the Baseline Scenario

Table 28: Changes of CO, NOx, VOC and PM from total transport sector in the Reference Scenario relative to Baseline in 2030

	CO		**NOx**		**VOC**		**PM**	
	Delta	**% Change**	**Delta**	**% Change**	**Delta**	**% Change**	**Delta**	**% Change**
EU15	-18.3	**-0.2%**	-9.3	**-0.7%**	-11.2	**-0.2%**	-0.4	**-0.7%**
EU13	4.2	**0.3%**	-1.7	**-0.7%**	1.8	**0.2%**	-0.1	**-0.5%**
EU28	-14.1	**-0.1%**	-10.9	**-0.7%**	-9.4	**-0.2%**	-0.5	**-0.7%**

Source: ASTRA model; Note: Delta stands for the difference in 1000 t/year while % change stands for the % difference between the Reference Scenario and the Baseline Scenario

Changes of external costs of noise from inter-urban road traffic are given in Table 29. Reduction of external costs is due to both the upgrading of roads along the core TEN-T road network (roads with higher technical standard have lower cost for noise) and to the shift of traffic from other secondary roads to the core TEN-T roads. Table 30 shows the changes of external costs of congestion from inter-urban road traffic at 2030. Benefits from reduced inter-urban congestion are expected to be higher in EU13 (-9.3%) than in EU15 (-4.7%). Overall, EU28 congestion costs are expected to be reduced by 5.3%.

Table 29: Changes of external costs of noise from inter-urban road traffic in the Reference Scenario relative to Baseline in 2030

	CARS		TRUCKS		TOTAL (CARS + TRUCKS)	
	Delta	% Change	Delta	% Change	Delta	% Change
EU15	-40	**-2.0%**	-56	**-4.5%**	-96	**-3.0%**
EU13	-32	**-6.9%**	-42	**-9.8%**	-75	**-8.2%**
EU28	-72	**-2.9%**	-98	**-5.8%**	-170	**-4.1%**

Source: TRUST model; Note: Delta stands for the difference in million Euro/year while % change stands for the % difference between the Reference Scenario and the Baseline Scenario

Table 30: Changes of external costs of congestion from inter-urban road traffic in the Reference Scenario relative to Baseline in 2030

	CARS		TRUCKS		TOTAL (CARS + TRUCKS)	
	Delta	% Change	Delta	% Change	Delta	% Change
EU15	-2,280	**-4.7%**	-504	**-4.6%**	-2,784	**-4.7%**
EU13	-595	**-8.4%**	-223	**-13.1%**	-818	**-9.3%**
EU28	-2,875	**-5.2%**	-727	**-5.7%**	-3,602	**-5.3%**

Source: TRUST model; Note: Delta stands for the difference in million Euro/year while % change stands for the % difference between the Reference Scenario and the Baseline Scenario

Table 31: Changes of total travel time by land transport in the Reference Scenario relative to Baseline in 2030

	Passengers		Freight	
	Delta	% Change	Delta	% Change
EU15	-11	**0.0%**	-39	**0.0%**
EU13	-307	**-0.6%**	-828	**-1.5%**
EU28	-317	**-0.1%**	-867	**-0.4%**

Source: ASTRA model; Note: Delta stands for the difference in million Hours/year while % change stands for the % difference between the Reference Scenario and the Baseline Scenario

Table 31 shows the changes in total travel time by land transport for both passengers (road and rail transport modes) and freight (road, rail and inland waterways) following the implementation of the core TEN-T network. Figures refer to yearly time savings in terms of million hours at 2030. It can be noted that, despite the increase in total demand, the completion of the core network will allow for savings of 317 million hours per year for the

EU 28 passenger sector and of 867 million hours per year for the freight sector with higher time gains occurring in EU13 countries.

8.3 TEN-T growth and jobs impacts

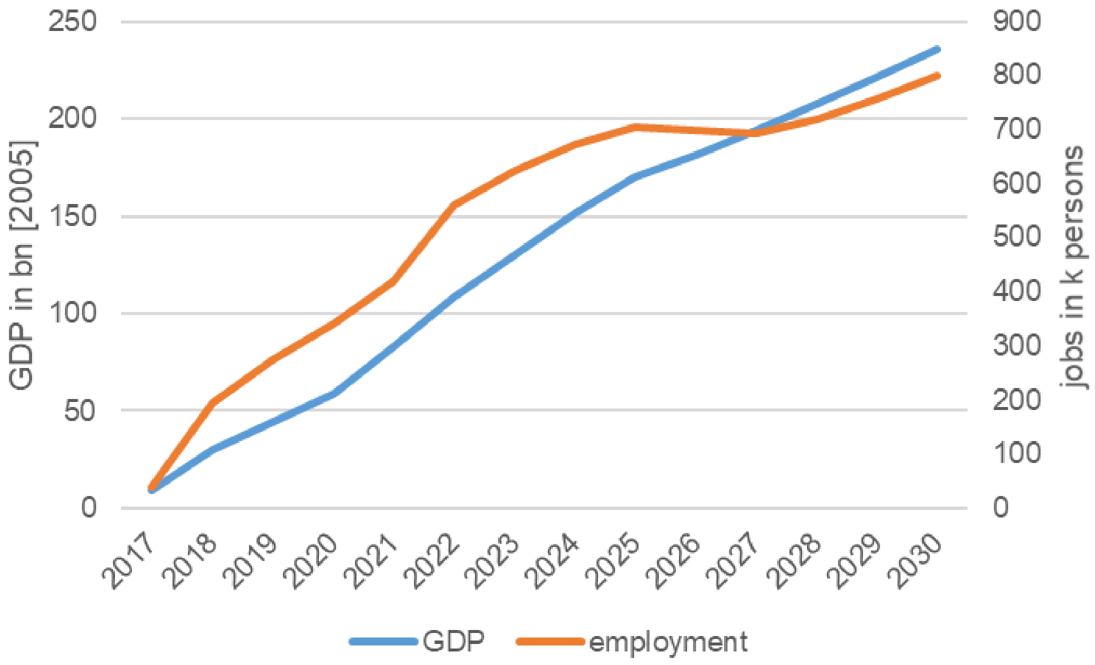
The economic impact of the completion of the TEN-T core network is explained by the interaction of the factors shown in Figure 9 above. On the one hand, the ASTRA model shows the transport network effects (time and cost improvements) as well as changes in operations and maintenance, trade, intermediate inputs, total factor productivity, among others. On the other hand, there are additional ‘pure’ economic impacts from the completion of the network represented in ASTRA (i.e. investments from the project database and the various financing options, which have been discussed in section 5.6.3).

One can distinguish three types of impacts arising from the various economic and transport impulses:

1. A transitional growth impact due to the demand shock associated with the direct demand impulses (additional investment in infrastructure), including the changes in demand by other sectors. Considering the discussion on terminology in section 3, this would represent the direct and indirect effects of the TEN-T investment.
2. A permanent increase in the level of GDP. This arises from the increase in the capital stock and the improved technology via higher levels of investment. This is part of the second-round effects fostered by productivity increase (see section 3).
3. A permanent impact on the rate of growth of GDP. This effect results from the gains in total factor productivity as well as induced effects from the changes in consumption and business outlook from the two impacts above. Changes in consumption also occur from increased income as an element of the second-round effects.

The time path of these three types of impacts is different. The bulk of the transitional growth impact due to the demand shock associated with the direct demand impulses occur primarily until 2025, but such impacts also take place post-2025. The second and third types of impacts occur gradually, at a later stage. The permanent impact on the rate of growth of GDP mainly takes place post-2025 and continues to have an impact after 2030. Hence, it is not possible to split the impacts according to the three categories, but it is usually possible to provide an indication on the main source of effects.

The completion of the TEN-T core network has positive economic impacts at EU28 level. Figure 30 displays the changes in GDP and employment in the Reference Scenario relative to the Baseline Scenario. While the difference in GDP between the Reference and Baseline Scenarios is steadily rising from 2017 to 2030, employment shows more significant transition growth impacts.



Source: ASTRA model

Figure 30: Impact of TEN-T core network implementation on GDP and employment between 2017 and 2030

Although GDP grows steadily in Figure 30, the annual increase of GDP compared with the Baseline is higher during 2017-2025 relative to 2026-2030.

Table 32 shows the difference in GDP and employment between the Reference and Baseline Scenarios for the years 2020 and 2030, split by EU15, EU13 and EU28 countries.

In 2020, GDP for the EU13 countries is 1.9% higher in the Reference Scenario than in the Baseline Scenario. For the EU15 countries, this difference is only 0.3%, and 0.4% for the whole EU28, as can be seen from Table 32.

The difference in employment in absolute numbers is reversed in 2020. As Table 32 shows, EU13 countries have approximately 155,000 more full-time equivalent jobs in the Reference Scenario compared to the Baseline Scenario. This difference, however, translates to 0.4% more employment for EU13 countries in 2020.

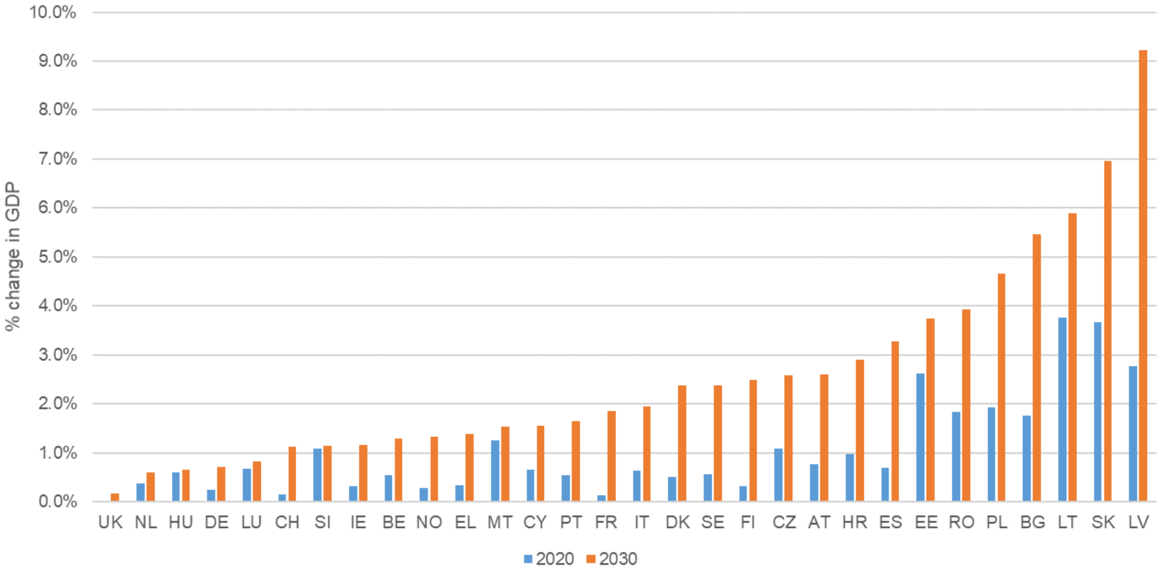
EU15 countries have approximately 185,000 more full-time equivalent jobs in 2020 in the Reference Scenario than in the Baseline Scenario. In relative terms, this means 0.1% more employment for EU15 countries in the Reference Scenario in 2020.

Table 32: Changes in the Reference Scenario relative to the Baseline Scenario for employment and GDP for EU15, EU13 and EU28 countries

Changes in the Reference to the Baseline Scenario	GDP		Employment	
	2020	2030	2020	2030
EU15	0.3%	1.4%	185,200	509,600
EU13	1.9%	4.2%	155,300	287,500
EU28	0.4%	1.6%	340,500	797,000

Source: ASTRA model

In 2030, GDP is 4.2% higher for EU13 countries in the Reference Scenario compared to the Baseline Scenario, and 1.4% higher for EU15 countries (see Table 32). The growth path difference between EU13 and EU15 countries becomes smaller, as EU15 Member States seem to profit more from impact types (2) and (3). The modelling results show some convergence between the EU as a whole.



Source: ASTRA model

Figure 31: **Changes in GDP due to additional TEN-T investments for each EU28 country**

This argument is reinforced when looking at the breakdown of the country results shown in Figure 31. Many EU13 countries such as Latvia, Slovakia, Lithuania, Bulgaria and Poland already show significant GDP differences for 2020, while many EU15 countries such as Italy, Denmark, Finland or Greece have more substantial changes in GDP from 2020 to 2030.

Latvia has 3.0% TEN-T investments relative to GDP in the period from 2017 to 2020, which is the highest share of TEN-T investments of any Member State. The share decreases for the following period, but remains relatively high overall with an average of 2.0% from 2017 to 2030. The data is shown in Table 7.

Similarly, Slovakia has a high initial share of TEN-T investments of 2.4% relative to GDP for 2017 to 2020, with a share for the whole period from 2017 to 2030 of 1.2%.

Lithuania has an initial share of 1.6%, but the overall share for the whole period is 0.7%, meaning that second-round effects (or the impact types (2) and (3)) play a significant role for explaining the GDP difference in 2030.

This is similar forPoland. The share of TEN-T investments in relation to GDP for the period from 2017 to 2020 is 1.0%. The GDP difference in 2020 is thus also steered by the indirect effects of the investment, which have a small time-lag compared to the induced effects and can still be captured by the impact type (1).

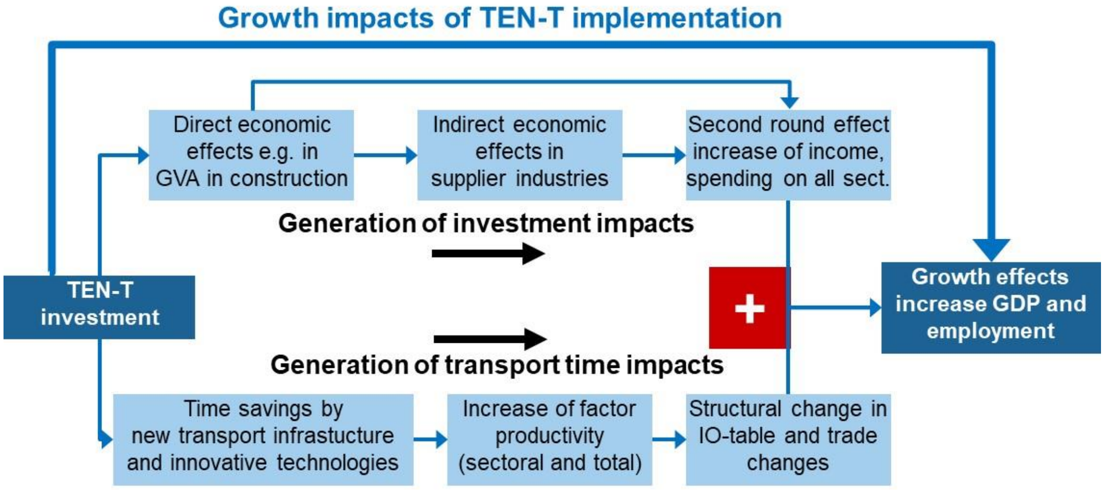
It is also important to report the cumulated impacts of the TEN-T core network implementation over the period 2017 to 2030 for two reasons. First, the impacts of the TEN-T implementation occur over a long period, starting from the first additional investment in 2017 and ending at the time horizon of our analysis in 2030. In fact, the impacts even go beyond 2030, as shown in section 8.4. Second, the investment amount is quantified over the whole period, although in reality it is distributed over 14 years. As the focus is often on the total investment budget it is also strongly recommended to compare with the total impacts of the investment, using the cumulated impact on GDP and employment over 2017 to 2030. Table 33 present the cumulated impacts. In 2030 the cumulated increase of job-years amounts to 7.5 million additional job-years by the TEN-T investment out of which 4.5 million job-years accrue in EU15 countries and 3 million job-years in EU13 countries.

Table 33: Cumulated impacts of TEN-T implementation on employment and GDP for EU15, EU13 and EU28

Changes from baseline to Reference Scenario	Cumulated GDP		Cumulated job years	
	2017 to 2020	2017 to 2030	2017 to 2020	2017 to 2030
EU15	95,000	1,400,000	457,000	4,537,000
EU13	47,000	426,000	394,000	2,963,000
EU28	143,000	1,826,000	851,000	7,501,000

Source: ASTRA model

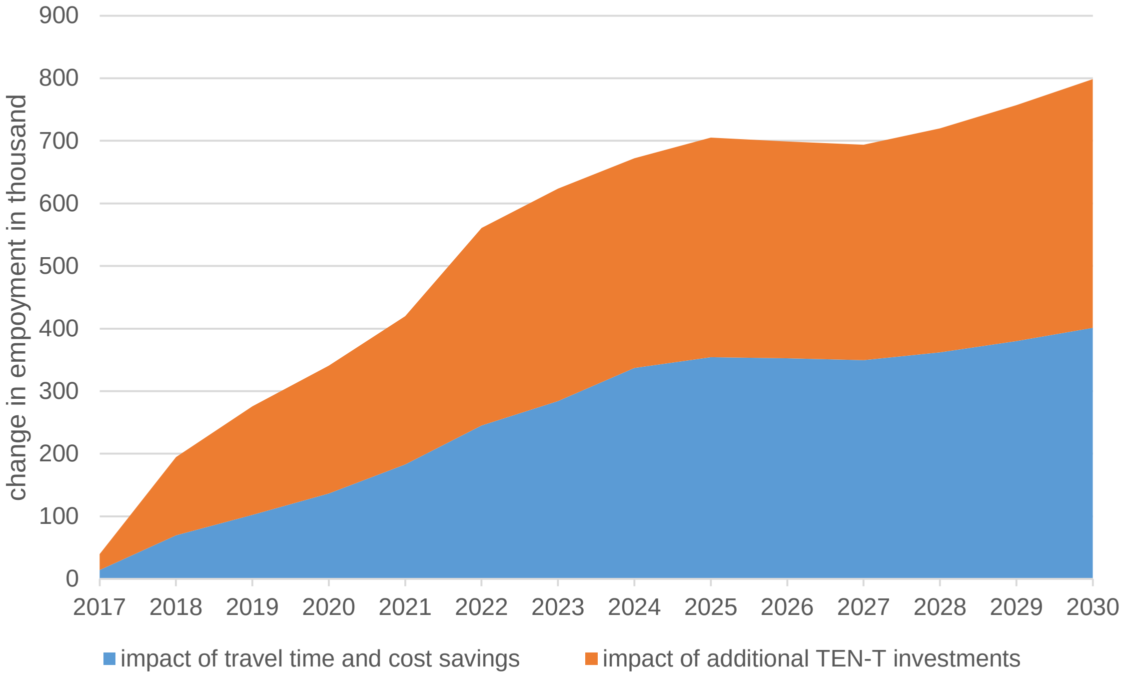
The analysis of economic impacts can be extended to capture impacts more closely linked to the transport sector impacts. The impacts discussed so far comprise classical economic analyses of demand shocks, capital stock enhancement and total factor productivity growth (impact type 1, 2, 3 from above). The major impact of transport infrastructure improvement is usually the reduction of travel times (time savings). These travel time savings can be converted into a (generalised) cost that affect the structure of the IO-table and the trade relationships. They can also be converted into average transport times that constitute one element of factor productivity in the different countries. This way of analysing separately the classical economic impacts of investment and the specific transport impacts on economic development is presented in Figure 32. The growth impacts of investment expenditures (upper chain of impacts) and the transport economic impacts (lower chain of impacts) together generate the total impacts on GDP growth and jobs.



Source: M-Five

Figure 32: Decomposition of growth impacts into investments impacts and transport time and productivity impacts

In practice, the two impact chains cannot be differentiated for several reasons. First, the two mechanisms are dependent on each other (there are no transport improvements without the investment). Second, there will be no transport investment without transport flow improvement as otherwise the project-based CBA would become negative as travel time improvements constitute one of the major benefits of any transport CBA. Thus a decomposition of impacts could only be undertaken by using a model in which either the impact chains can be included or excluded separately from the model or the impulses entering the model can be switched on and off separately. The latter approach was implemented using the ASTRA model and the decomposition results are presented in Figure 33.



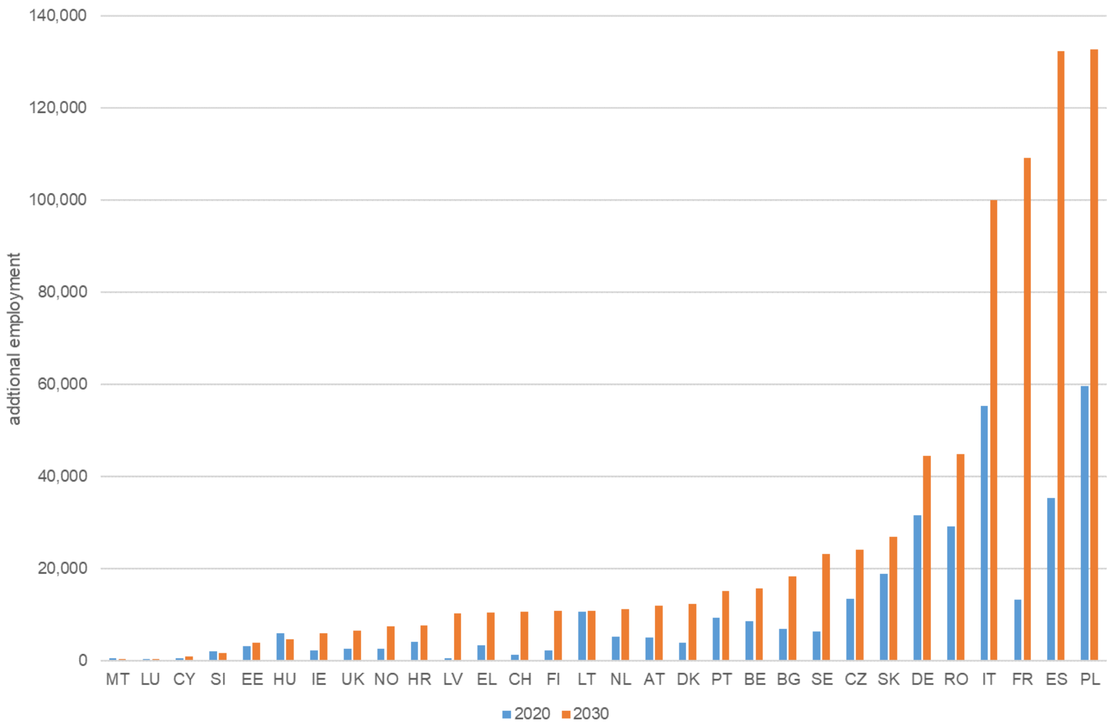
Source: ASTRA model

Figure 33: Decomposition of investment and transport time/cost impacts on jobs in EU28 countries

Figure 33 shows the approximation of the investment expenditure impacts versus the transport impacts on jobs in ASTRA. Over time the balance between the impacts is shifting from the investment expenditures that in 2020 account for 60% of impacts, towards the transport impacts which increase from 40% of impacts in 2020 to more than 50% of impacts in 2030. It can reasonably be argued that this shift of impacts from an investment expenditure driven growth stimulus to a transport and productivity driven growth stimulus will continue such that in the longer run the transport side stimulus takes the lions share and the investment expenditure stimulus depreciates.

It should be taken into account that the travel time improvements computed by the TRUST model in 5-year intervals are linearly interpolated between 2020 and 2025. This is likely to overestimate the time improvements in the initial years of the 5-year interval as improvements in the networks include synergies when more links are improved, following an exponential pattern rather than a linear pattern. This should then also hold for the impact curve of time and cost savings.

The same breakdown for the Member States shown in Figure 31 for GDP is done in Figure 34 for employment. Employment is derived from gross production (or value added) and sectoral labour productivity. Employment changes are the result of the direct, indirect and induced effects and a mixture of the three impact types.

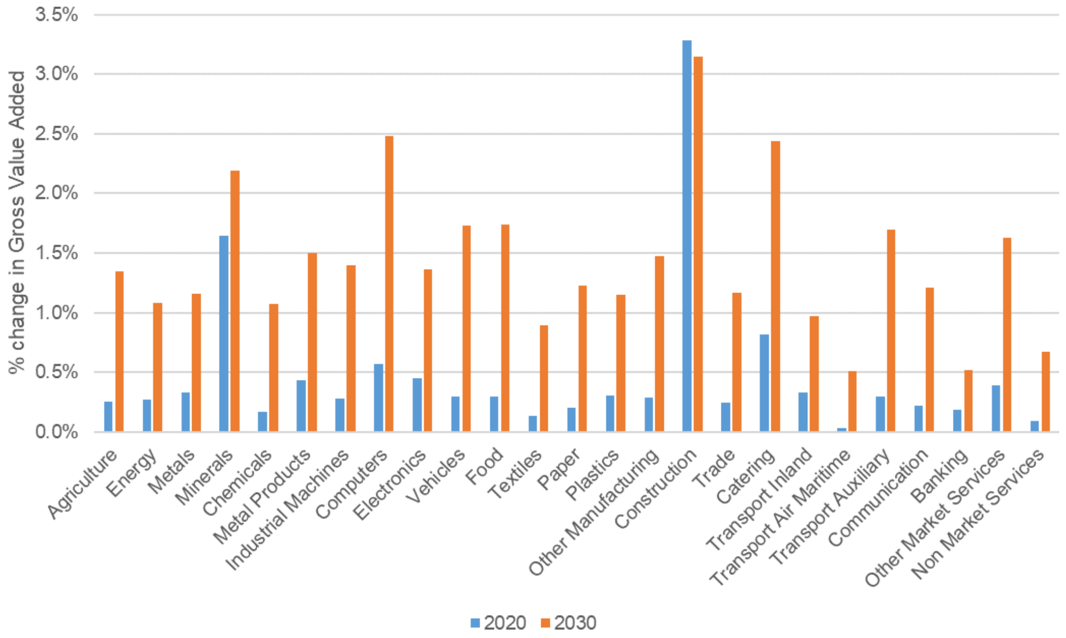


Source: ASTRA model

Figure 34: Jobs created due to additional TEN-T investments for each EU28 country

Figure 34 shows that in 2030 the bigger countries enjoy the largest employment gains. Poland shows a 4.7% increase in GDP in 2030 relative to the Baseline, which makes it the 5th biggest effect in this category, but in absolute employment this translates to approximately 133,000 additional jobs in 2030. With changes in GDP, overall production rises and a larger country requires more employment in absolute terms than a smaller country.

The same argument holds true for Spain. In 2030 the country enjoys a 3.3% increase in GDP relative to the Baseline, which is the 8th biggest effect on relative GDP changes. This results in approximately 133,000 additional jobs in 2030, which is due to the economy and working population in Spain being larger than in Poland, and that a larger number of jobs is needed to create GDP growth and higher production.



Source: ASTRA model

Figure 35: Changes in Gross Value Added for EU28 countries due to additional TEN-T investments

Finally, Figure 35 shows the development of sectoral growth. While in the period up to 2020 construction is clearly the sector with the highest impact in Europe, the other sectors catch up in 2030 due to the impact types (2) and (3). While construction is also affected by the wider economic impacts, its relative importance in 2030 decreases.

In particular, European added value arises from the implementation of cross-border projects, as has been shown in a study running a specific scenario on the non-implementation of cross-border projects (Schade et al. 2015). Such a sensitivity or scenario analysis of cross-border projects was not a separate part of this study. Therefore, European added value is included in our economic findings, but we are not able to separate it with the settings of our scenarios.

8.4 TEN-T economic impacts beyond 2030

This paragraph focuses on the long term economic impacts until 2040 resulting from the additional TEN-T investments in the period 2017 to 2030. The documented results do not include additional investments over the period 2031 to 2040. Instead they project the longer-term effects of those scenario changes that happened over the period 2017 to 2030 for the subsequent 10-year period. The argument to carry out such an analysis is that the TEN-T investment will shift the economy onto a higher long-term growth trajectory, which is confirmed by the following analysis.

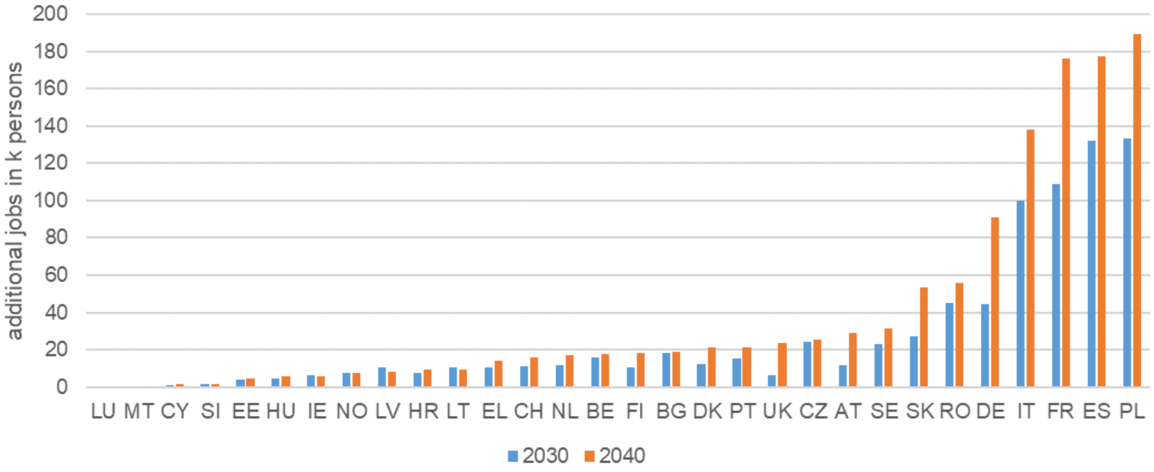
Table 34 provides an overview of the changes to employment and GDP in 2030 and 2040 in EU13, EU15 and EU28 countries. Overall, GDP grows on average by 2.6% in all Member States by 2040 relative to the Baseline. The GDP growth relative to the Baseline is higher in EU13 countries than the EU15 countries in both 2030 and 2040. GDP is 5.6% higher in EU13 countries, and 2.3% higher in EU15 countries in 2040. Due to the TEN-T investments, there are close to 1.2 million additional jobs in all EU28 countries in 2040 relative to the Baseline, of which 383,000 are located in EU13 countries and 783,000 in EU15 countries.

Table 34: Overview of TEN-T core network impacts on GDP and employment for 2030 and 2040 relative to the Baseline

	GDP		Employment	
	2030	**2040**	**2030**	**2040**
EU15	1.4%	2.3%	509,600	782,700
EU13	4.2%	5.6%	287,500	382,900
EU28	1.6%	2.6%	797,000	1 165,600

Source: ASTRA model

The analysis of the long-term growth trajectory can also be undertaken at the Member State level. The impact of the TEN-T investments for the years 2030 and 2040 on employment for each Member State relative to the Baseline are summarised in Figure 36. There are significant job increases in nearly all European countries in the period from 2030 to 2040. Germany, Italy, France, Spain and Poland in particular accrue large absolute employment effects over this period.



Source: ASTRA model

Figure 36: Impact of TEN-T investment on employment in 2030 and 2040 relative to the Baseline

9 Findings on the core network corridors (CNC)

The corridor results are presented by the following three sub-sections, describing first the transport results by CNC and then comparing the results across all CNC. Then, the economic results by CNC are presented following the same structure across all CNC. The last section provides a synthesis derived from the big picture of all single corridor analyses.

9.1 Transport impacts of CNC

The sections below provide transport results for the CNC Scenarios. In these scenarios, only the implementation of each individual corridor is simulated, meaning that each scenario does not include the other 8 CNCs or the completion of the Core-Non-CNCs network.

Results are provided both at the network level from TRUST and at an aggregate level from the ASTRA model. Network level results from TRUST are provided in terms of percentage change relative to a Baseline in 2030 of:

- Travel time by rail for passenger and freight.
- Travel time by road for passenger and freight.
- Operational cost by rail for passenger and freight.

Road operational costs remain basically unchanged across all scenarios. Travel time changes are provided as averages along the key corridor sections identified from representative Origin-Destinations (OD) pairs along the corridor, covering the whole corridors length and connecting major network nodes and/or country borders.

TRUST output (variation of OD travel costs and time by road and rail modes) was used as input for the ASTRA model to compute modal split changes determined by infrastructure improvement. The ASTRA model works with a NUTS 1 zoning system and therefore the most detailed results that can be provided are at NUTS 1 level.

The ASTRA model results for the CNC scenarios are provided at three levels of aggregation:

- EU level results, which show the impact of the scenario at the European level by summing up the results for all Member States (given for EU15, EU13 and EU28 country groups).
- CORRIDOR COUNTRIES level results, which show the impact of the scenario by summing up only the results for the countries crossed by the corridor.
- CORRIDOR NUTS1 level results, which show the impact of the scenario by summing up only the results for the NUTS1 zones crossed by the corridor.

This choice is driven by the need to allow for the comparability of the effects at different scales.

Passenger (car, bus, rail) and freight (road, rail and inland waterways) transport activities are computed according to the territoriality approach.

9.1.1 Transport impacts at the network level

The tables and charts below provide the average changes in travel time and costs for road and rail modes (for both passengers and freight demand) along all the CNC corridors relative to the Baseline, for different time horizons.

Changes in travel time, reported in Table 35, show that the investments planned on CNCs are expected to benefit rail freight performance more than passengers. The Mediterranean corridor benefits the most from the reduction in freight travel time in 2030 (-44.4%), followed by the Rhine-Alpine (-38.9%) and Atlantic (-36.7%) corridors. Other CNCs show a reduction in travel time ranging from -35.7% (Baltic-Adriatic) to -23.3% (North Sea-Baltic). Passenger train travel time shows significant reductions for the Mediterranean (-30.0%), the Orient-East-Med (-27.2%) and the North-Sea-Baltic (-26.1%) corridors. Smaller reductions in travel time, from -15.4% (Scan-Med) to -6.8% (Atlantic), are seen for the other corridors.

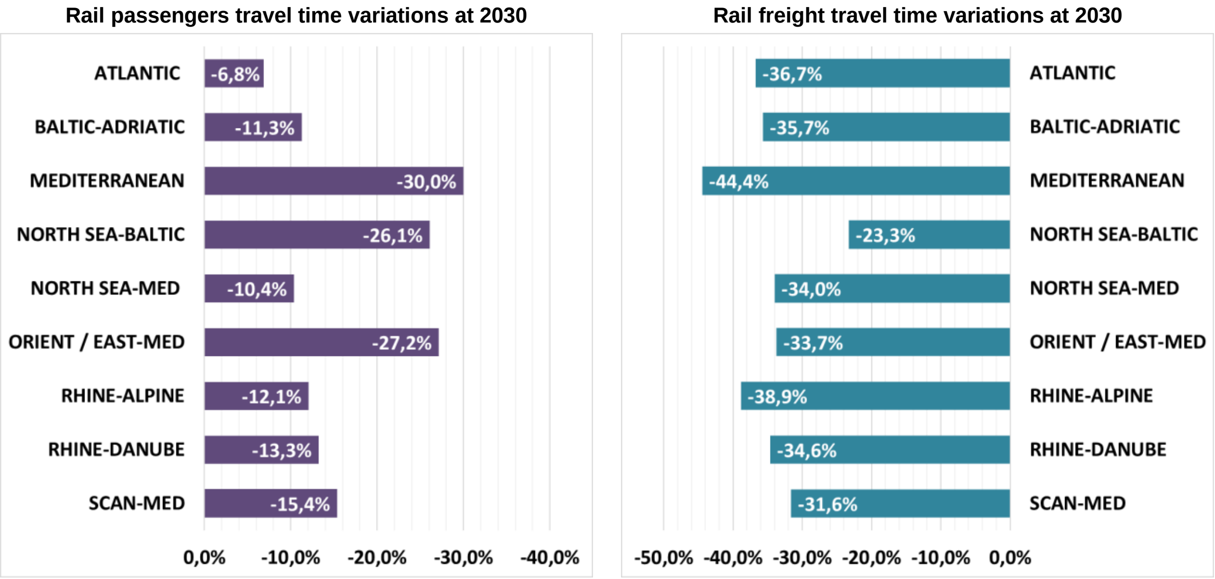
As mentioned above, higher reduction in travel time for freight rail is the outcome of a combination of the impacts of infrastructure investments which increase operational speeds on the corridor(s) and of the impacts of a general improvement of the efficiency of the rail freight system following the removal of several barriers to freight trains circulation.

Table 35: Changes in travel time by rail for passenger and freight in the CNC scenarios, relative to the Baseline in 2030 – (% change to the Baseline)

	RAIL TRAVEL TIME % CHANGE	
CORRIDOR	Passenger	Freight
ATLANTIC	-6.8%	-36.7%
BALTIC-ADRIATIC	-11.3%	-35.7%
MEDITERRANEAN	-30.0%	-44.4%
NORTH SEA-BALTIC	-26.1%	-23.3%
NORTH SEA-MED	-10.4%	-34.0%
ORIENT-EAST-MED	-27.2%	-33.7%
RHINE-ALPINE	-12.1%	-38.9%
RHINE-DANUBE	-13.3%	-34.6%
SCAN-MED	-15.4%	-31.6%

Source: TRUST model

The changes in rail operational costs along the CNCs, reported in Table 36, mirror the assumptions implemented for taking into account the ERTMS deployment over time.



Source: TRUST model

Figure 37: Changes of travel time by rail for both passengers and freight in the CNCs scenarios relative to Baseline at 2030 – (% change to the Baseline)

Table 36: Change of rail costs for passengers and freight in the CNCs scenarios relative to Baseline (% change to the Baseline)

CORRIDOR	TYPE	RAIL COST % CHANGE		
		2020	2025	2030
ATLANTIC	Freight	-0.2%	-0.3%	-9.0%
	Passengers	-0.2%	-0.3%	-9.0%
BALTIC-ADRIATIC	Freight	-0.4%	-2.5%	-9.0%
	Passengers	-0.4%	-2.5%	-9.0%
MEDITERRANEAN	Freight	-1.3%	-2.1%	-9.0%
	Passengers	-1.3%	-2.1%	-9.0%
NORTH SEA-BALTIC	Freight	0.0%	-0.5%	-9.0%
	Passengers	0.0%	-0.5%	-9.0%
NORTH SEA-MED	Freight	-0.3%	-5.6%	-9.0%
	Passengers	-0.3%	-5.6%	-9.0%
ORIENT-EAST-MED	Freight	0.0%	-1.2%	-9.0%
	Passengers	0.0%	-1.2%	-9.0%
RHINE-ALPINE	Freight	-1.0%	-4.1%	-9.0%
	Passengers	-1.0%	-4.1%	-9.0%
RHINE-DANUBE	Freight	-0.1%	-1.1%	-9.0%
	Passengers	-0.1%	-1.1%	-9.0%
SCAN-MED	Freight	0.0%	-0.5%	-9.0%
	Passengers	0.0%	-0.5%	-9.0%

Source: TRUST model

Changes in travel time along the **road** CNCs for passenger and freight are presented in Table 37. The results show that road changes are less significant than those observed for the rail network.

Table 37: Changes in travel time by road for passenger and freight in the CNC scenarios, relative to the Baseline – (% change to the Baseline)

CORRIDOR	TYPE	ROAD TRAVEL TIME % CHANGE		
		2020	2025	2030
ATLANTIC	Freight	0.0%	-3.3%	-3.3%
	Passengers	0.0%	-4.7%	-4.7%
BALTIC-ADRIATIC	Freight	0.3%	0.6%	-2.7%
	Passengers	-2.4%	-2.7%	-4.1%
MEDITERRANEAN	Freight	-0.7%	-1.0%	-2.9%
	Passengers	-1.1%	-4.1%	-6.8%
NORTH SEA-BALTIC	Freight	-2.7%	-11.3%	-11.4%
	Passengers	-4.4%	-15.9%	-16.9%
NORTH SEA-MED	Freight	-0.2%	-0.2%	-0.3%
	Passengers	-0.4%	-0.4%	-0.5%
ORIENT-EAST-MED	Freight	-1.3%	-4.1%	-4.2%
	Passengers	-1.8%	-5.7%	-6.1%
RHINE-ALPINE	Freight	0.0%	0.0%	0.0%
	Passengers	-0.1%	0.0%	-0.4%
RHINE-DANUBE	Freight	-2.9%	-7.9%	-8.1%
	Passengers	-0.6%	-7.8%	-8.1%
SCAN-MED	Freight	0.0%	-0.1%	-0.1%
	Passengers	-1.8%	-1.9%	-2.1%

Source: TRUST model

The reduction in travel time in 2030 is highest on the North Sea–Baltic (-16.9% for passenger and -11.4% for freight) resulting from the infrastructure investments on road connections between Warsaw and Baltic states capital cities, followed by the Rhine-Danube (-8.1% for passenger and freight) and the Orient-East-Med (-6.1% for passengers and -4.2% for freight). Other CNCs show a smaller impact. Road operational costs remain substantially unchanged.

9.1.2 Transport impacts at the aggregate level

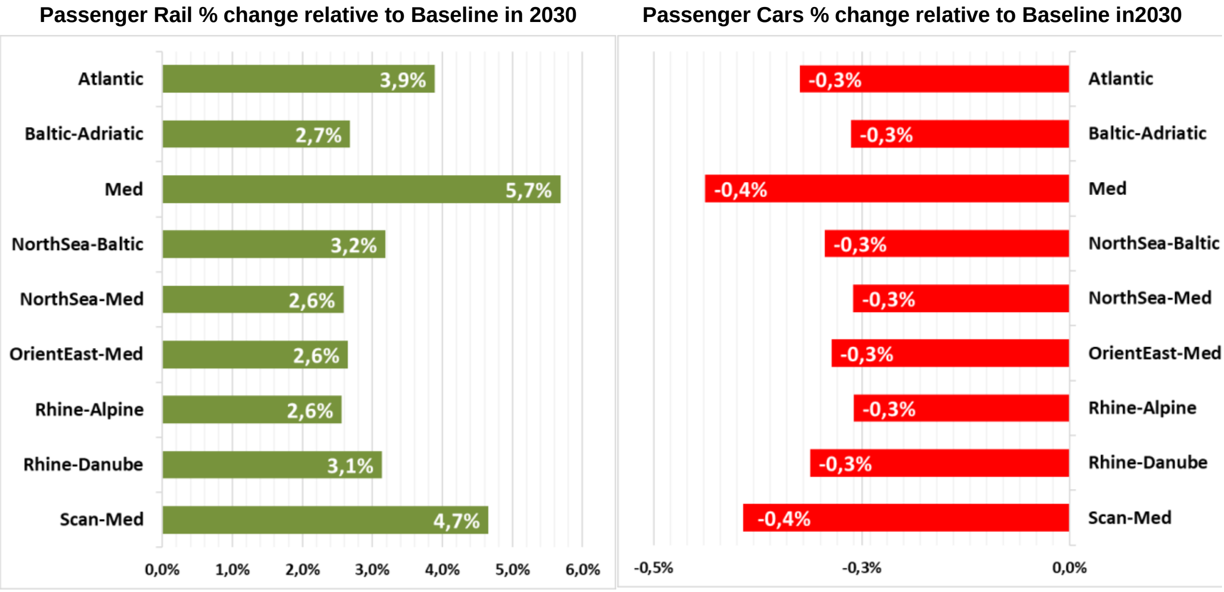
Change in passenger transport activity by car and rail (territoriality approach) in the NUTS1 regions crossed by the corridors for all CNC scenarios relative to Baseline in 2030 are given in Table 38 and Figure 38.

Table 38: Change in passenger transport activity (territoriality approach) in the NUTS1 regions crossed by the corridors for all CNC scenarios relative to Baseline in 2030 - (million pkm/year; % change to the Baseline)

	CAR		RAIL	
	Delta	% Change	Delta	% Change
Atlantic	-3,700	**-0.3%**	5,659	**3.9%**
Baltic-Adriatic	-1,781	**-0.3%**	2,507	**2.7%**
Mediterranean	-4,893	**-0.4%**	7,228	**5.7%**
North Sea-Baltic	-3,244	**-0.3%**	4,328	**3.2%**
North Sea-Med	-4,283	**-0.3%**	5,814	**2.6%**
Orient-East-Med	-2,092	**-0.3%**	2,868	**2.6%**
Rhine-Alpine	-2,907	**-0.3%**	3,571	**2.6%**
Rhine-Danube	-2,820	**-0.3%**	4,272	**3.1%**
Scan-Med	-7,048	**-0.4%**	9,707	**4.7%**

Source: ASTRA model

Increases in rail passenger activity range from 4.7% in the NUTS1 regions crossed by the Scan-Med corridor to 2.6% in those crossed by the Rhine-Alpine, Orient-East-Med and North Sea-Med corridors. Reductions in passenger car activity in the NUTS1 regions due to increased rail performances range from -0.3% to -0.4% for all the corridors.


Passenger Rail % change relative to Baseline in 2030

Passenger Cars % change relative to Baseline in2030

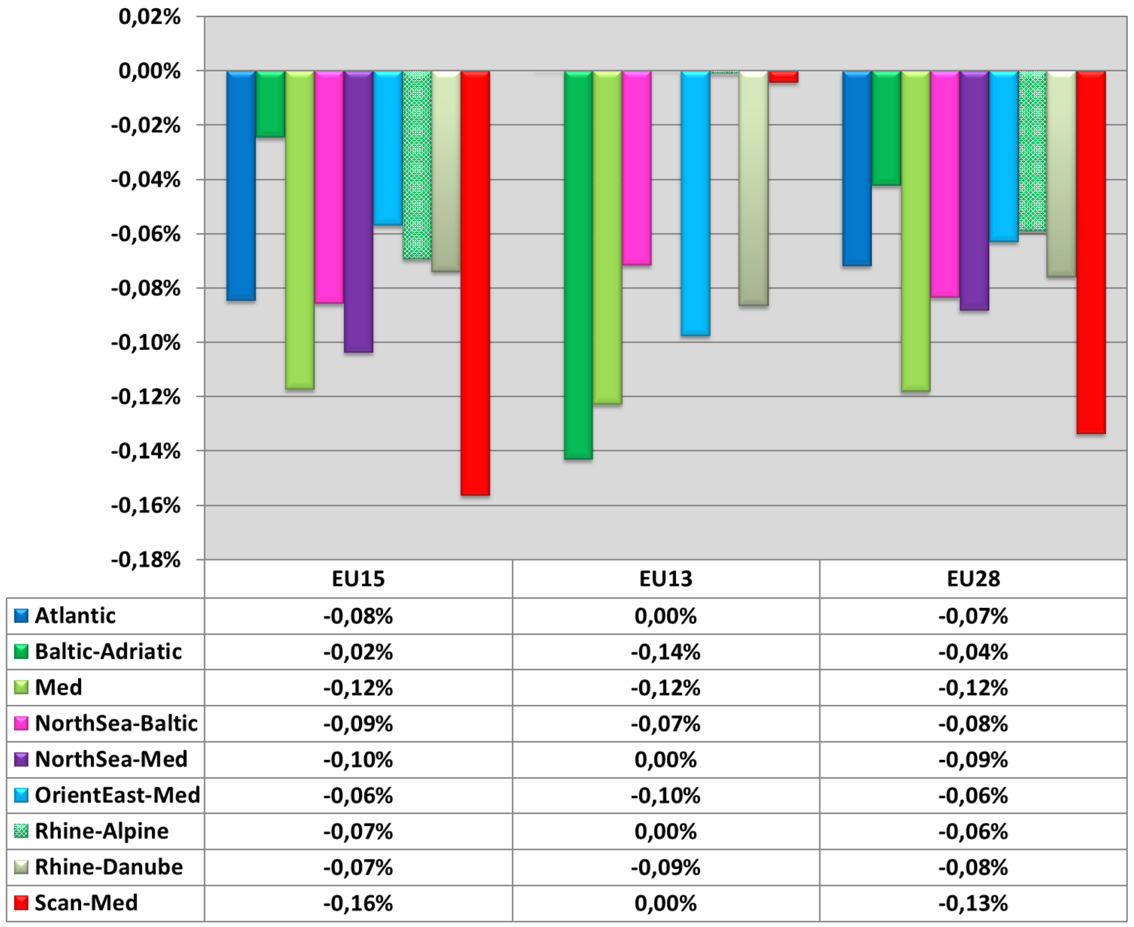
Source: ASTRA model

Figure 38: Change of passenger transport activity (territoriality approach) in the NUTS1 regions crossed by the corridors for all CNCs scenarios relative to Baseline in 2030 – (% change to the Baseline)

Change in passenger transport activity (territoriality approach) at the European level for all CNC scenarios relative to the Baseline in 2030 are given in Figure 39 for passenger cars and Figure 40 for rail.

Small reductions in car passenger activity can generally be noted because of increased rail performance. Reductions at the EU28 level are in the range of -0.04% for the Baltic-Adriatic corridor to -0.13% for the Scan-Med corridor (Figure 39).

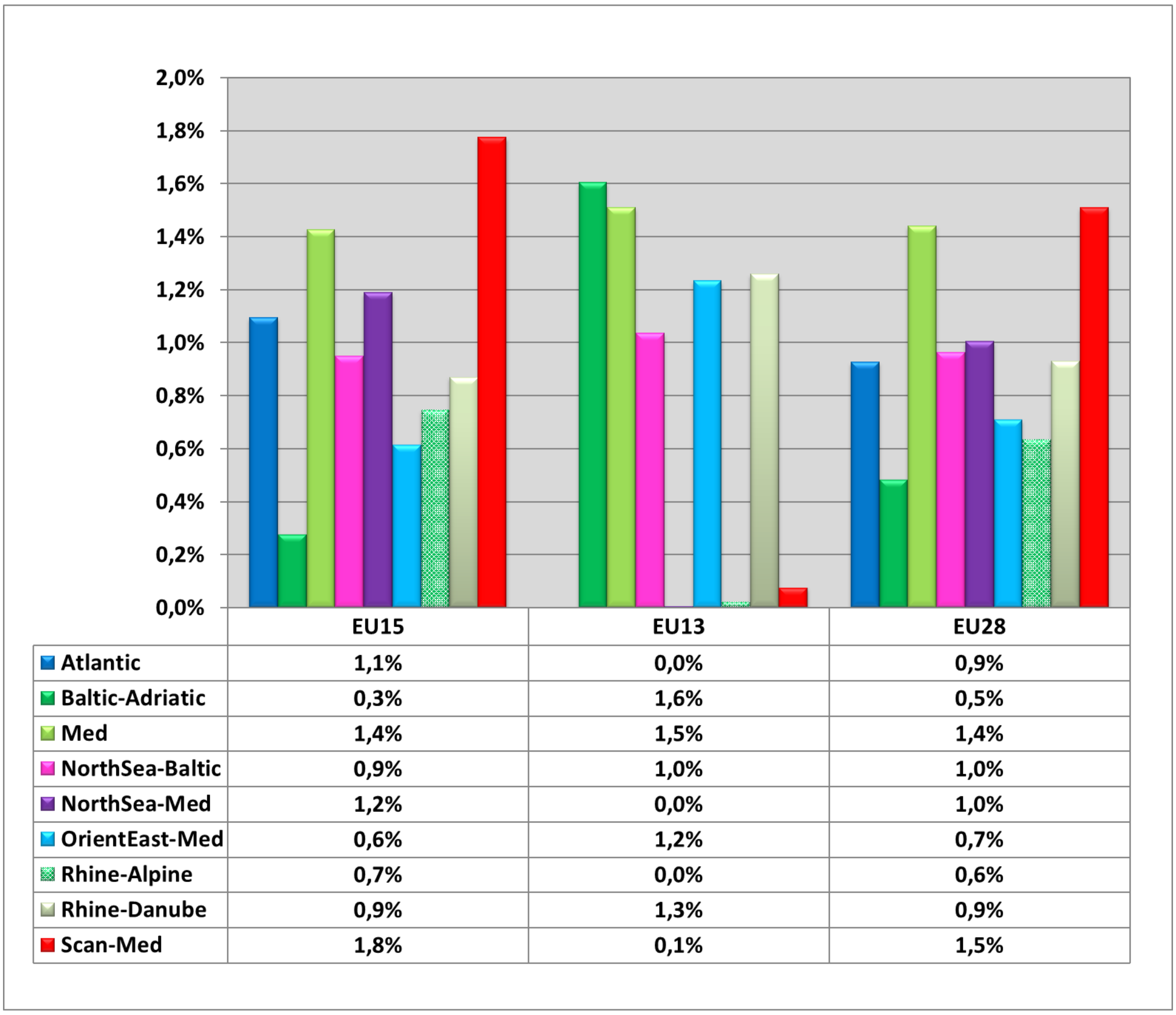
As expected, changes in rail activity, shown in Figure 40, are generally higher than those observed for road, and in the range of 1.5% for the Scan-Med corridor to 0.5% for the Baltic Adriatic corridor.



	EU15	EU13	EU28
🟦 Atlantic	-0,08%	0,00%	-0,07%
🟩 Baltic-Adriatic	-0,02%	-0,14%	-0,04%
🟩 Med	-0,12%	-0,12%	-0,12%
🟪 NorthSea-Baltic	-0,09%	-0,07%	-0,08%
🟪 NorthSea-Med	-0,10%	0,00%	-0,09%
🟦 OrientEast-Med	-0,06%	-0,10%	-0,06%
▨ Rhine-Alpine	-0,07%	0,00%	-0,06%
⬜ Rhine-Danube	-0,07%	-0,09%	-0,08%
🟥 Scan-Med	-0,16%	0,00%	-0,13%

Source: ASTRA model

Figure 39: Change in passenger cars activity (territoriality approach) at the EU level for all CNC scenarios relative to the Baseline in 2030 – (% change to the Baseline)



	EU15	EU13	EU28
■ Atlantic	1,1%	0,0%	0,9%
■ Baltic-Adriatic	0,3%	1,6%	0,5%
■ Med	1,4%	1,5%	1,4%
■ NorthSea-Baltic	0,9%	1,0%	1,0%
■ NorthSea-Med	1,2%	0,0%	1,0%
■ OrientEast-Med	0,6%	1,2%	0,7%
▨ Rhine-Alpine	0,7%	0,0%	0,6%
■ Rhine-Danube	0,9%	1,3%	0,9%
■ Scan-Med	1,8%	0,1%	1,5%

Source: ASTRA model

Figure 40: Change in rail passenger activity (territoriality approach) at the EU level for all CNC scenarios relative to the Baseline in 2030 – (% change to the Baseline)

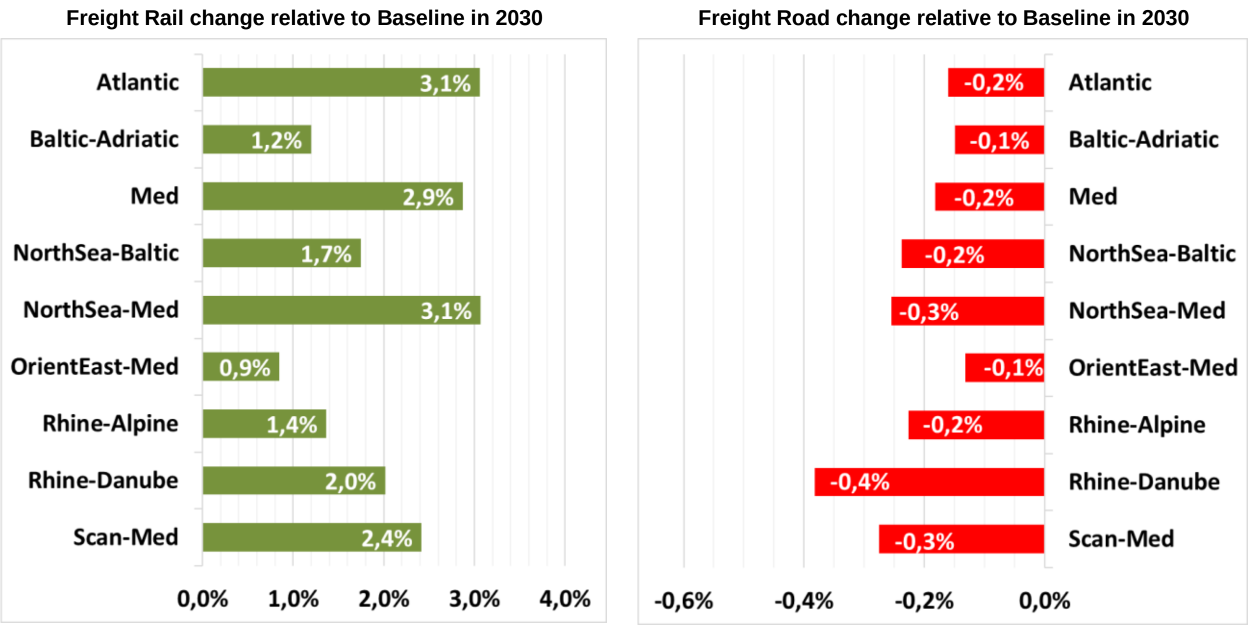
Changes in road and rail freight transport activity (territoriality approach) in the NUTS1 regions crossed by the corridors for all CNC scenarios relative to the Baseline in 2030 are given in Table 39 and Figure 41.

Rail freight variations range from 3.1% for the NUTS1 regions crossed by the North Sea-Med corridor to 0.9% for those crossed by the Orient-East-Med corridor. Road freight reductions following the increased rail performance range from 0.1% in the NUTS1 regions crossed by the Orient-East-Med and Baltic-Adriatic corridors to 0.4% in those crossed by the Rhine-Danube corridor.

Table 39: Change in freight transport activity by road and rail (territoriality approach) in the NUTS1 regions crossed by the corridors for all CNCs scenarios relative to Baseline in 2030 - (million tkm/year; % change to the Baseline)

	ROAD		RAIL	
	Delta	% Change	Delta	% Change
Atlantic	-788	**-0.2%**	1,716	**3.1%**
Baltic-Adriatic	-578	**-0.1%**	1,503	**1.2%**
Mediterranean	-889	**-0.2%**	1,873	**2.9%**
North Sea-Baltic	-1,373	**-0.2%**	3,728	**1.7%**
North Sea-Med	-1,616	**-0.3%**	2,477	**3.0%**
Orient-East-Med	-478	**-0.1%**	1,165	**0.8%**
Rhine-Alpine	-1,088	**-0.2%**	1,298	**1.3%**
Rhine-Danube	-1,474	**-0.4%**	2,760	**2.0%**
Scan-Med	-1,965	**-0.3%**	4,754	**2.4%**

Source: ASTRA model

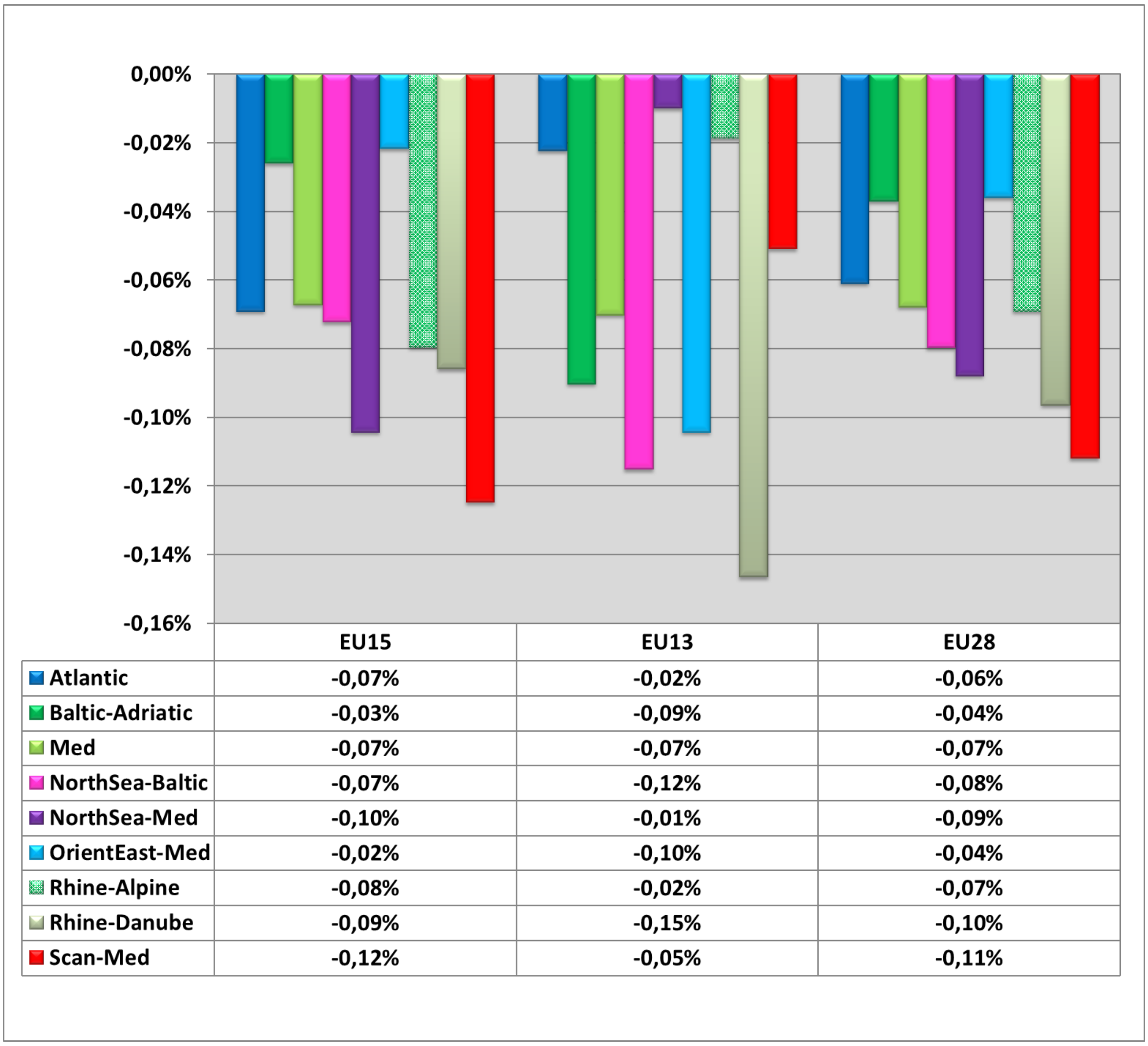


Source: ASTRA model

Figure 41: Change of freight transport activity by road and rail (territoriality approach) in the NUTS1 regions crossed by the corridors for all CNCs scenarios relative to Baseline in 2030 – (% change to the Baseline)

Change in freight transport activity by road, rail, and inland waterways (territoriality approach) at the European level for all CNC scenarios relative to the Baseline at 2030 are given respectively in Figure 42, Figure 43 and Figure 44.

Small reductions in road freight activity can generally be noted as a result of increased rail performance. Reductions at the EU28 level are in the range of -0.04% for the Baltic-Adriatic corridor to -0.11% for the Scan-Med corridor (see Figure 42). These small reductions also reflect the improvement of the road network in some countries which smooths the competition with the rail mode.

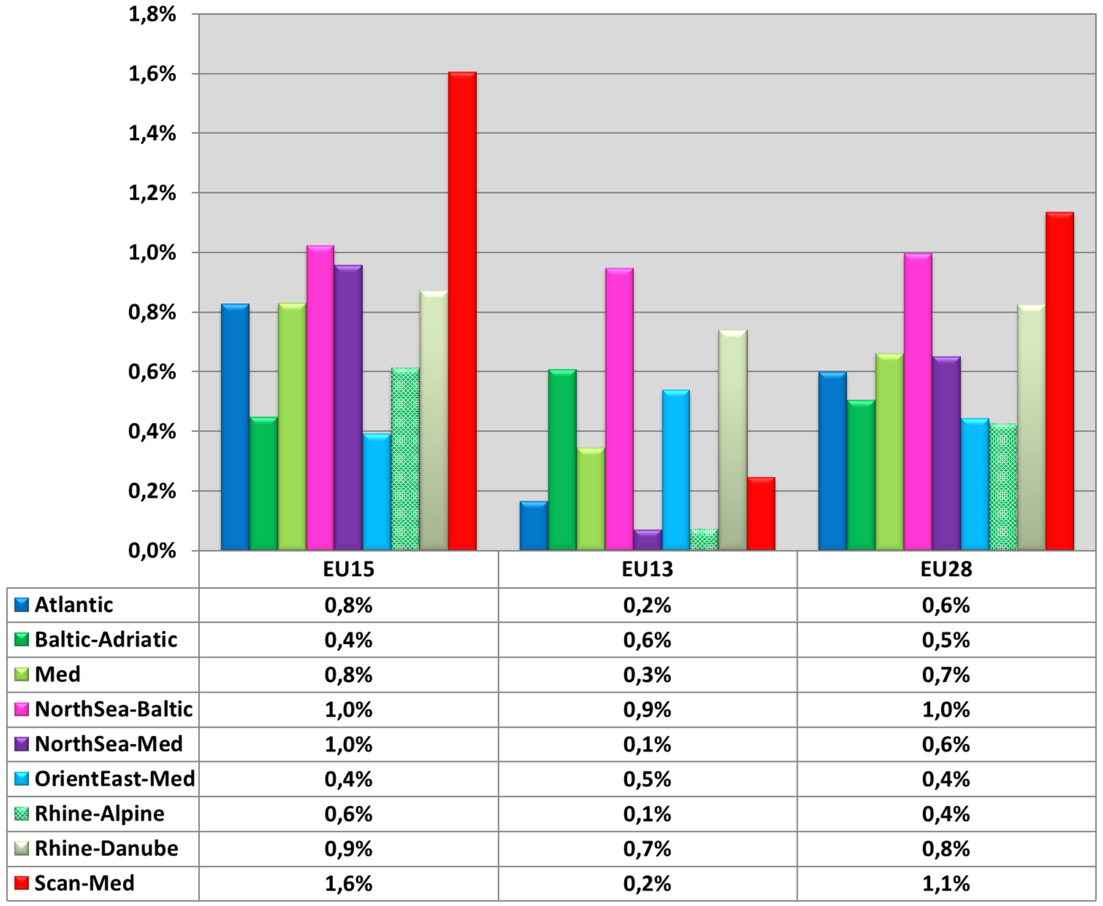


	EU15	EU13	EU28
🟦 Atlantic	-0,07%	-0,02%	-0,06%
🟩 Baltic-Adriatic	-0,03%	-0,09%	-0,04%
🟩 Med	-0,07%	-0,07%	-0,07%
🟪 NorthSea-Baltic	-0,07%	-0,12%	-0,08%
🟪 NorthSea-Med	-0,10%	-0,01%	-0,09%
🟦 OrientEast-Med	-0,02%	-0,10%	-0,04%
▨ Rhine-Alpine	-0,08%	-0,02%	-0,07%
⬜ Rhine-Danube	-0,09%	-0,15%	-0,10%
🟥 Scan-Med	-0,12%	-0,05%	-0,11%

Source: ASTRA model

Figure 42: Change in road freight activity (territoriality approach) at the EU level for all CNCs scenarios relative to the Baseline in 2030 – (% change to the Baseline)

As has been seen for passenger transport, rail freight changes, as shown in Figure 43, are also generally higher than those for road and are in the range of 1.1% for the Scan-Med corridor to 0.4% for the Rhine Alpine and Orient-East-Med corridors.

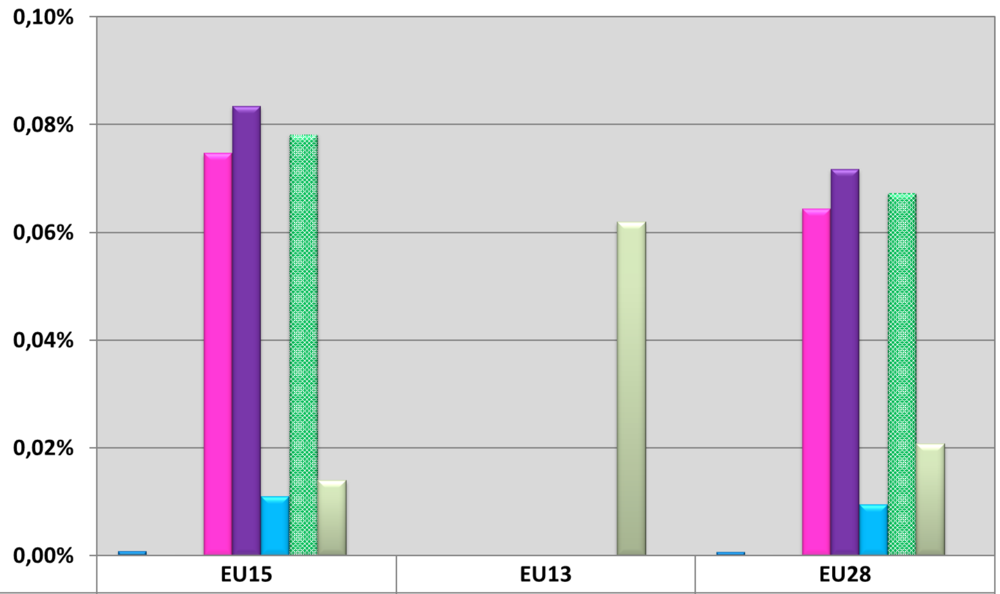


	EU15	EU13	EU28
Atlantic	0,8%	0,2%	0,6%
Baltic-Adriatic	0,4%	0,6%	0,5%
Med	0,8%	0,3%	0,7%
NorthSea-Baltic	1,0%	0,9%	1,0%
NorthSea-Med	1,0%	0,1%	0,6%
OrientEast-Med	0,4%	0,5%	0,4%
Rhine-Alpine	0,6%	0,1%	0,4%
Rhine-Danube	0,9%	0,7%	0,8%
Scan-Med	1,6%	0,2%	1,1%

Source: ASTRA model

Figure 43: Change in rail freight activity (territoriality approach) at the EU level for all CNCs scenarios relative to the Baseline in 2030 – (% change to the Baseline)

The change in inland waterways activity at the European level is shown in Figure 44. Traffic increases for the Rhine-Danube are about 0.6% in the Reference Scenario relative to the Baseline for EU13 countries. For EU15 countries, traffic on the Rhine-Alpine and North Sea-Med corridors increases by 0.8%.



	EU15	EU13	EU28
Atlantic	0,00%	0,00%	0,00%
Baltic-Adriatic	0,00%	0,00%	0,00%
Med	0,00%	0,00%	0,00%
NorthSea-Baltic	0,07%	0,00%	0,06%
NorthSea-Med	0,08%	0,00%	0,07%
OrientEast-Med	0,01%	0,00%	0,01%
Rhine-Alpine	0,08%	0,00%	0,07%
Rhine-Danube	0,01%	0,06%	0,02%
Scan-Med	0,00%	0,00%	0,00%

Source: ASTRA model

Figure 44: Change in inland waterways freight activity (territoriality approach) at the EU level for all CNC scenarios relative to the Baseline in 2030 – (% change to the Baseline)

9.1.3 Atlantic core network corridor (ATL)

9.1.3.1 Transport impacts at the network level

Table 40 shows the change in travel time relative to the Baseline by rail for both passenger and freight along different sections of the Atlantic corridor in 2030. As already mentioned above for the Reference Scenario, the investments planned on the Atlantic corridor are expected to benefit freight rail performance rail than passenger. The reduction in travel time is in the range of 0 to 14% for passenger trains and in the range of -28% to 43% for freight trains.

Table 40: Change in travel time by rail on the Atlantic corridor relative to Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME %CHANGE	
		Passenger	Freight
ATLANTIC	Lisbon (PT) -Vilar Formoso (PT)	-3%	-29%
	Vilar Formoso (PT) - Irun (ES)	0%	-31%
	Irun (ES) - Forbach (FR)	-14%	-43%
	Forbach (FR) - Mannheim (DE)	0%	-28%

Source: TRUST model

Changes in rail operational costs along the corridor, reported in Table 41, reflect the assumptions implemented for taking into account the ERTMS deployment over time. In particular it was assumed that full deployment in 2030 would reduce rail operational costs of all CNCs by 9% relative to the Baseline. In 2020 and 2025 a reduction of operational costs of 5% and 7% respectively was implemented only on those parts of the corridor presenting a certain continuity in ERTMS deployment. Thus, the cost variation for the whole corridor is lower than these figures.

Table 41: Change in rail cost for passengers and freight on the Atlantic corridor relative to the Baseline – (% change to the Baseline)

CORRIDOR	TYPE	RAIL COST %CHANGE		
		2020	2025	2030
ATLANTIC	Freight	-0.2%	-0.3%	-9%
	Passengers	-0.2%	-0.3%	-9%

Source: TRUST model

The average changes in travel time along the Atlantic road corridor for passengers and freight are presented in Table 42. Not surprisingly, these variations are less significant than those observed for the rail network, reflecting the priority of the rail network development in the EU TEN-T.

The reduction in travel time along the road sections ranges from 0 to 13% for freight and 0 to 17% for passenger, with time gains along the section Vilar Formoso (PT) - Irun (ES) due, among other interventions, to the completion of the missing cross-border link PT/ES with a new motorway branch bypassing Vilar Formoso Village. Road operational costs are basically unchanged.

Table 42: Change in travel time by road on the Atlantic corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
ATLANTIC	Lisbon (PT) -Vilar Formoso (PT)	0%	0%
	Vilar Formoso (PT) - Irun (ES)	-17%	-13%
	Irun (ES) - Forbach (FR)	0%	0%
	Forbach (FR) - Mannheim (DE)	0%	0%

Source: TRUST model

9.1.3.2 Transport impacts at the aggregate level

Changes in passenger and freight transport activity (computed according to the territoriality approach) for the Atlantic corridor scenario relative to Baseline at 2030 are reported in Table 43 and in Table 44 respectively.

Rail passenger activity at the European level increases by 1.0%. When looking at the corridor at a lower geographical scale, the impact on rail passenger activity in the countries crossed by the corridor increases by 2.1% while the impact on NUTS1 regions crossed by the corridor is 3.9%. Small reductions in road activities follow as a consequence of the increased rail performance.

Table 43: Changes in passenger transport activity (territoriality approach) for the Atlantic corridor scenario relative to the Baseline in 2030 – Delta in million pkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	CAR		BUS		RAIL	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-3,700	**-0.3%**	-82	**-0.1%**	5,659	**3.9%**
CORRIDOR COUNTRIES	-4,240	**-0.2%**	-91	**0.0%**	6,654	**2.1%**
EU28	-4,267	**-0.1%**	-94	**0.0%**	6,753	**1.0%**

Source: ASTRA model

Similarly, rail freight activity at the European level increases by 0.6%, while the impact in the countries crossed by the corridor shows an increase of 1.2%, and the increase for the NUTS1 regions crossed by the corridor is 3.1%. Activity by road and inland waterways remain relatively unchanged.

Table 44: Changes in freight transport activity (territoriality approach) for the Atlantic corridor scenario relative to Baseline in 2030 – Delta in Mio*tkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	ROAD		RAIL		IWW	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-788	**-0.2%**	1,716	**3.1%**	23	**0.1%**
CORRIDOR COUNTRIES	-1,275	**-0.1%**	2,833	**1.2%**	32	**0.0%**
EU28	-1,475	**-0.1%**	3,365	**0.6%**	48	**0.0%**

Source: ASTRA model

9.1.4 Baltic Adriatic core network corridor (BAC)

9.1.4.1 Transport impacts at the network level

The tables below provide the average changes of travel time and costs for passengers and freight demand on the Baltic-Adriatic corridor. Reductions in travel time along the corridor range from -7% to -20% for passenger trains and from -33% to -41% for freight trains.

Table 45: Change in travel time by rail on the Baltic-Adriatic corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME %CHANGE	
		Passenger	Freight
BALTIC-ADRIATIC	Ravenna (IT) - Villach (AT)	-7%	-36%
	Villach (AT) - Vienna(AT)	-20%	-41%
	Vienna (AT) - Poznan (PL)	-11%	-33%
	Poznan (PL) - Szczecin (PL)	-7%	-36%

Source: TRUST model

The considerations discussed above regarding the change of rail operational costs for Atlantic corridor similarly apply to the Baltic-Adriatic corridor. In the case of the Baltic-Adriatic corridor, reduction of rail operational costs following ERTMS implementation are expected to noticeable by 2025, with a 2.5% decrease for both passenger and freight trains (see Table 46).

Table 46: Change in rail cost for passengers and freight on the Baltic-Adriatic corridor relative to Baseline - (% change to the Baseline)

CORRIDOR	TYPE	RAIL COST % CHANGE		
		2020	2025	2030
BALTIC-ADRIATIC	Freight	-0.4%	-2.5%	-9.0%
	Passengers	-0.4%	-2.5%	-9.0%

Source: TRUST model

Changes in travel time by road along the corridor sections reported in Table 47 show limited time gains for Vienna (AT) - Poznan (PL).

Table 47: Change in travel time by road on the Baltic-Adriatic corridor relative to Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
BALTIC-ADRIATIC	Ravenna (IT) - Villach (AT)	0%	0%
	Villach (AT) - Vienna(AT)	0%	0%
	Vienna (AT) - Poznan (PL)	-5%	-6%
	Poznan (PL) - Szczecin (PL)	0%	0%

Source: TRUST model

9.1.4.2 Transport impacts at the aggregate level

Changes in passenger and freight transport activity (computed according to the territoriality approach) for the Baltic-Adriatic corridor scenario relative to Baseline at 2030 are reported in Table 48 and Table 49 respectively.

Rail passenger activity increases by 0.5% at the European level, by 2.0% in the countries crossed by the corridor, and by 2.7% in the NUTS1 regions crossed by the corridor. Consequently, tiny reductions in passenger car activity can be noted.

Table 48: Changes in passenger transport activity (territoriality approach) for the Baltic-Adriatic corridor scenario relative to Baseline in 2030 – Delta in million pkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	CAR		BUS		RAIL	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-1,781	**-0.3%**	-63	**-0.1%**	2,507	**2.7%**
CORRIDOR COUNTRIES	-2,324	**-0.2%**	-74	**0.0%**	3,256	**2.0%**
EU28	-2,424	**0.0%**	-90	**0.0%**	3,397	**0.5%**

Source: ASTRA model

On the freight side, rail activity increases by 0.5% at the European level, by 1.2% in the countries crossed by the corridor, and by 1.2% in the NUTS1 regions crossed by the corridor. Activity by road and inland waterways remain relatively unchanged.

Table 49: Changes in freight transport activity (territoriality approach) for the Baltic-Adriatic scenario relative to Baseline in 2030 – Delta in million tkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	ROAD		RAIL		IWW	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-578	**-0.1%**	1,503	**1.2%**	n.a.	n.a.
CORRIDOR COUNTRIES	-754	**-0.1%**	1,924	**1.2%**	n.a.	n.a.
EU28	-891	**0.0%**	2,834	**0.5%**	n.a.	n.a.

Source: ASTRA model

9.1.5 Mediterranean core network corridor (MED)

9.1.5.1 Transport impacts at the network level

Changes in travel time relative to the Baseline are reported for rail, in Table 50, and for road, in Table 52, for both passengers and freight along different sections of the Mediterranean corridor at 2030. Changes of rail operational costs along the corridor are reported in Table 51.

Reductions in travel time along the corridor range from -13% to -45% for passenger trains and from -40% to -53% for freight trains. Time gains by road range from 0% to -11% for passengers and from 0% to 7% for freight. Similar considerations provided above on the change of rail operational costs apply also for the Mediterranean corridor.

Table 50: Change in travel time by rail on the Mediterranean corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
MEDITERRANEAN	Sevilla (ES) - Barcelona (ES)	-13%	-43%
	Barcelona (ES) - Lyon (FR)	-37%	-40%
	Lyon (FR) - Trieste (IT)	-45%	-53%
	Trieste (IT) - Budapest (HU)	-25%	-41%

Source: TRUST model

Table 51: Change in rail cost for passengers and freight on the Mediterranean corridor relative to the Baseline – (% change to the Baseline)

CORRIDOR	TYPE	RAIL COST % CHANGE		
		2020	2025	2030
MEDITERRANEAN	Freight	-1.3%	-2.1%	-9.0%
	Passengers	-1.3%	-2.1%	-9.0%

Source: TRUST model

Table 52: Change in travel time by road on the Mediterranean corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
MEDITERRANEAN	Sevilla (ES) - Barcelona (ES)	-11%	-3%
	Barcelona (ES) - Lyon (FR)	-11%	-7%
	Lyon (FR) - Trieste (IT)	-2%	-1%
	Trieste (IT) - Budapest (HU)	0%	0%

Source: TRUST model

9.1.5.2 Transport impacts at the aggregate level

Changes in passenger and freight transport activity (computed according to the territoriality approach) for the Mediterranean corridor scenario relative to Baseline at 2030 are reported in Table 43 and in Table 44 respectively.

Rail passenger activity at the European level increases by 1.4%. The impact of the corridor at a lower geographical scale shows an increase of 3.3% in the countries crossed by the corridor of 5.7% in the NUTS1 regions crossed by the corridor.

Table 53: Changes in passenger transport activity (territoriality approach) for the Mediterranean corridor scenario relative to Baseline in 2030 – Delta in million pkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	CAR		BUS		RAIL	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-4,893	**-0.4%**	-204	**-0.1%**	7,228	**5.7%**
CORRIDOR COUNTRIES	-6,185	**-0.3%**	-214	**-0.1%**	9,225	**3.3%**
EU28	-6,839	**-0.1%**	-223	**0.0%**	10,189	**1.4%**

Source: ASTRA model

Rail freight activity at the European level increases by 0.7%, while the impact in the countries crossed by the corridor shows an increase of 2.4%, and the impact on the NUTS1 regions crossed by the corridor is of 2.9%. Activity by road and inland waterways remain relatively unchanged.

Table 54: Changes in freight transport activity (territoriality approach) for the Mediterranean scenario relative to Baseline in 2030 – Delta in Mio*tkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	ROAD		RAIL		IWW	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-889	**-0.2%**	1,873	**2.9%**	0	**0.0%**
CORRIDOR COUNTRIES	-1,208	**-0.1%**	2,750	**2.4%**	0	**0.0%**
EU28	-1,622	**-0.1%**	3,728	**0.7%**	0	**0.0%**

Source: ASTRA model

9.1.6 North-Sea-Baltic core network corridor (NSB)

9.1.6.1 Transport impacts at the network level

Table 55 shows the change of travel time relative to the Baseline by rail for both passenger and freight along different sections of the North Sea-Baltic corridor at 2030. The reduction in travel time ranges from 2% to 43% for passenger, and from -17% to 30% for freight.

Table 55: Change in travel time by rail on the North Sea-Baltic corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
NORTH SEA-BALTIC	Amsterdam (NL) - Hannover (DE)	-2%	-27%
	Hannover (DE) - Poznań (PL)	-1%	-17%
	Poznań (PL) - Vilnius (LT)	-24%	-17%
	Vilnius (LT) - Tallin (EE)	-43%	-30%

Source: TRUST model

Changes in rail operational costs along the corridor are reported in Table 56 and reflect the assumptions implemented for taking into account the ERTMS deployment over time.

Table 56: Change in rail cost for passengers and freight on the North Sea-Baltic corridor relative in Baseline – (% change to the Baseline)

CORRIDOR	TYPE	RAIL COST % CHANGE		
		2020	2025	2030
NORTH SEA-BALTIC	Freight	0.0%	-0.5%	-9.0%
	Passengers	0.0%	-0.5%	-9.0%

Source: TRUST model

Changes in travel time along the sections of the North Sea-Baltic road corridor are presented in Table 57. Time gains apply mainly in the Baltic area where about 400 km of the road corridor receives improvements through about 180 km of new expressways and town bypasses in the section Poznan Vilnius, and more than 200 km of new construction and upgrading in the section Vilnius-Tallin.

Table 57: Change in travel time by road on the North Sea-Baltic corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
NORTH SEA-BALTIC	Amsterdam (NL) - Hannover (DE)	-1%	0%
	Hannover (DE) - Poznań (PL)	0%	0%
	Poznań (PL) - Vilnius (LT)	-26%	-21%
	Vilnius (LT) - Tallin (EE)	-23%	-12%

Source: TRUST model

9.1.6.2 Transport impacts at the aggregate level

Changes in passenger and freight transport activity (computed according to the territoriality approach) for the North Sea-Baltic corridor scenario relative to the Baseline in 2030 are reported in Table 58 and in Table 59 respectively. Rail passenger activity increases by 1.0% at the European level, by 2.6% in the countries crossed by the corridor, and by 3.2% in the NUTS1 regions crossed by the corridor. Small reductions in passenger car activity are also noted.

Table 58: Changes in passenger transport activity (territoriality approach) for the North Sea-Baltic corridor scenario relative to Baseline in 2030 – Delta in million pkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	CAR		BUS		RAIL	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-3,244	**-0.3%**	-63	**-0.1%**	4,328	**3.2%**
CORRIDOR COUNTRIES	-3,973	**-0.2%**	-74	**0.0%**	5,397	**2.6%**
EU28	-4,814	**-0.1%**	-90	**0.0%**	6,762	**1.0%**

Source: ASTRA model

Rail freight activity increases by 1.0% at the European level, while the increase in the countries crossed by the corridor is of 1.5%, and of 1.7% on the NUTS1 regions crossed by the corridor. Activity by inland waterways increases by 0.5% at EU level (+0.6% for countries crossed by the corridor and of 0.6% for the NUTS1 regions crossed by the corridor).

Table 59: Changes in freight transport activity (territoriality approach) for the North Sea-Baltic scenario relative to Baseline in 2030 – Delta in Mio*tkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	ROAD		RAIL		IWW	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-1,373	**-0.2%**	3,728	**1.7%**	782	**0.6%**
CORRIDOR COUNTRIES	-1,627	**-0.2%**	4,509	**1.5%**	930	**0.6%**
EU28	-1,962	**-0.1%**	5,559	**1.0%**	1,006	**0.5%**

Source: ASTRA model

9.1.7 North-Sea-Mediterranean core network corridor (NSM)

9.1.7.1 Transport impacts at the network level

The tables below provide the average changes in travel time and costs for passenger and freight demand on the North Sea-Mediterranean corridor. Reductions in travel time along the rail corridor range from 0% to -32% for passenger and from -30% to -38% for freight.

Table 60: Change in travel time by rail on the North Sea-Mediterranean corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
NORTH SEA-MED	Edinburgh (UK) - London (UK)	0%	-38%
	London (UK) - Paris (FR)	0%	-33%
	Bruxelles (BE) - Dijon (FR)	-1%	-34%
	Dijon (FR) - Marseille (FR)	-32%	-30%

Source: TRUST model

The reduction in rail operational costs following ERTMS implementation is expected to be evident by 2025, with a 5.6% decrease for passenger and freight trains (see Table 61).

Table 61: Change in rail cost for passengers and freight on the North Sea-Mediterranean corridor relative to the Baseline – (% change to the Baseline)

CORRIDOR	TYPE	RAIL COST % CHANGE		
		2020	2025	2030
NORTH SEA-MED	Freight	-0.3%	-5.6%	-9.0%
	Passengers	-0.3%	-5.6%	-9.0%

Source: TRUST model

Almost no changes in travel time by road occur along the corridors' sections, as shown in Table 62.

Table 62: Change in travel time by road on the North Sea-Mediterranean corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
NORTH SEA-MED	Edinburgh (UK) - London (UK)	0%	0%
	London (UK) - Paris (FR)	0%	0%
	Bruxelles (BE) - Dijon (FR)	-1%	-1%
	Dijon (FR) - Marseille (FR)	-1%	-1%

Source: TRUST model

9.1.7.2 Transport impacts at the aggregate level

Table 63 and Table 64 report respectively the changes in passenger and freight transport activity (computed according to the territoriality approach) for the North Sea-Mediterranean corridor scenario relative to the Baseline in 2030.

At the European level rail passenger activity increases by 1%, while in the countries crossed by the corridor it increases by 2.5%, and in the NUTS1 regions crossed by the corridor by 2.6%. Activity by car and by bus remains relatively unchanged.

Table 63: Changes in passenger transport activity (territoriality approach) for the North Sea-Mediterranean corridor scenario relative to Baseline in 2030 – Delta in million pkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	CAR		BUS		RAIL	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-4,283	**-0 3%**	-42	**0 0%**	5,814	**2.6%**
CORRIDOR COUNTRIES	-5,052	**-0 2%**	-46	**0 0%**	6,851	**2.5%**
EU28	-5,80	**-0 1%**	-46	**0 0%**	7,079	**1.0%**

Source: ASTRA model

Rail freight activity increases by 0.6% at EU28 level. The countries crossed by the corridor show an increase of 2.9% in rail freight activity and the impact on the NUTS1 regions crossed by the corridor is of 3.1%. Activity by road remains relatively unchanged and inland waterways transport activity increases by 0.6% at EU28 level relative to the Baseline, shown in Table 64.

Table 64: Changes in freight transport activity (territoriality approach) for the North Sea-Mediterranean scenario relative to Baseline in 2030 – Delta in million tkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	ROAD		RAIL		IWW	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-1,616	**-0.3%**	2,477	**3.0%**	363	**0.5%**
CORRIDOR COUNTRIES	-1,736	**-0.2%**	2,777	**2.9%**	397	**0.5%**
EU28	-2,178	**-0.1%**	3,596	**0.6%**	1,074	**0.6%**

Source: ASTRA model

9.1.8 Orient-East-Med core network corridor (OEM)

9.1.8.1 Transport impacts at the network level

Transport impacts at the network level of the Orient-East-Med corridor are provided in the tables below. Similar considerations provided for the other CNCs also apply in this case.

Table 65: Change in travel time by rail on the Orient-East-Med corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
ORIENT-EAST-MED	Bremerhaven (DE) - Dresden (DE)	-16%	-37%
	Dresden (DE) - Budapest (HU)	-16%	-33%
	Budapest (HU) - Craiova (RO)	-22%	-37%
	Craiova (RO) - Athens (EL)	-45%	-31%

Source: TRUST model

Table 66: Change in rail cost for passengers and freight on the Orient-East-Med corridor relative to the Baseline – (% change to the Baseline)

CORRIDOR	TYPE	RAIL COST % CHANGE		
		2020	2025	2030
ORIENT-EAST-MED	Freight	0.0%	-1.2%	-9.0%
	Passengers	0.0%	-1.2%	-9.0%

Source: TRUST model

Table 67 shows the change in travel time by road on the Orient-East-Med corridor relative to the Baseline in 2030. Travel time gains mainly apply to the section Craiova (RO) - Athens (EL) where about 265 km of mainly new infrastructures will be completed by 2030.

Table 67: Change in travel time by road on the Orient-East-Med corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
ORIENT-EAST-MED	Bremerhaven (DE) - Dresden (DE)	0%	0%
	Dresden (DE) - Budapest (HU)	0%	-1%
	Budapest (HU) - Craiova (RO)	-6%	-4%
	Craiova (RO) - Athens (EL)	-11%	-8%

Source: TRUST model

9.1.8.2 Transport impacts at the aggregate level

Table 68 and Table 69 report the changes in passenger and freight transport activity (computed according to the territoriality approach) for the Orient-East-Med corridor scenario relative to the Baseline in 2030.

Rail passenger activity at the European level increases by 0.7%, 1.9% in the countries crossed by the corridor, and 2.6% in NUTS1 regions crossed by the corridor. Consequently, small reductions of passenger car activity are also noted.

Table 68: Changes in passenger transport activity (territoriality approach) for the Orient-East-Med corridor scenario relative to the Baseline in 2030 – Delta in million pkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	CAR		BUS		RAIL	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-2,092	**-0.3%**	-82	**-0.1%**	2,868	**2.6%**
CORRIDOR COUNTRIES	-2,953	**-0.2%**	-90	**-0.1%**	4,049	**1.9%**
EU28	-3,621	**-0.1%**	-96	**0.0%**	4,990	**0.7%**

Source: ASTRA model

Similarly, rail freight activity increases by 0.4% at the European level, 0.7% in the countries crossed by the corridor, and 0.8% in the NUTS1 regions crossed by the corridor. Activity by inland waterways increases by 0.2% at EU level relative to the Baseline.

Table 69: Changes in freight transport activity (territoriality approach) for the Orient-East-Med scenario relative to the Baseline in 2030 – Delta in Mio*tkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	ROAD		RAIL		IWW	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-478	**-0.1%**	1,165	**0.8%**	83	**0.2%**
CORRIDOR COUNTRIES	-810	**-0.1%**	1,853	**0.7%**	308	**0.3%**
EU28	-892	**0.0%**	2,453	**0.4%**	402	**0.2%**

Source: ASTRA model

9.1.9 Rhine-Alpine core network corridor (RALP)

9.1.9.1 Transport impacts at the network level

Transport impacts at the network level of the Rhine-Alpine corridor are provided in the tables below. Similar considerations provided for the other CNCs apply also in this case.

Table 70: Change in travel time by rail on the Rhine-Alpine corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
RHINE-ALPINE	Maasvlakte (NL) - Emmerich (DE)	-9%	-23%
	Emmerich (DE) - Basel (CH)	-10%	-44%
	Basel (CH) - Chiasso (CH)	-4%	-32%
	Chiasso (CH) - Genova (IT)	-26%	-40%

Source: TRUST model

Table 71: Change in rail cost for passengers and freight on the Rhine-Alpine corridor relative to the Baseline – (% change to the Baseline)

CORRIDOR	TYPE	RAIL COST % CHANGE		
		2020	2025	2030
RHINE-ALPINE	Freight	-1.0%	-4.1%	-9.0%
	Passengers	-1.0%	-4.1%	-9.0%

Source: TRUST model

No changes of travel time along the Rhine-Alpine **road corridor** are expected in comparison with the Baseline Scenario, showin in Table 72.

Table 72: Change in travel time by road on the Rhine-Alpine corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
RHINE-ALPINE	Maasvlakte (NL) - Emmerich (DE)	0%	0%
	Emmerich (DE) - Basel (CH)	0%	0%
	Basel (CH) - Chiasso (CH)	0%	0%
	Chiasso (CH) - Genova (IT)	0%	0%

Source: TRUST model

9.1.9.2 Transport impacts at the aggregate level

Changes in passenger and freight transport activity (computed according to the territoriality approach) for the Rhine-Alpine corridor scenario relative to Baseline at 2030 are given in Table 73 and Table 74 respectively. Rail freight activity at the European level increases by 0.4%, while the impact in the countries crossed by the corridor shows an increase of 0.8%, and the impact on the NUTS1 regions crossed by the corridor is of 1.3%. Activity for inland waterways increases by 0.5% at the European level.

Rail passenger activity increases by 0.6% at the European level, 1.2% in the countries crossed by the corridor, and 2.6% in NUTS1 regions crossed by the corridor.

Table 73: Changes in passenger transport activity (territoriality approach) for the Rhine-Alpine corridor scenario relative to the Baseline in 2030 – Delta in million pkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	CAR		BUS		RAIL	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-2,907	**-0.3%**	-12	**0.0%**	3,571	**2.6%**
CORRIDOR COUNTRIES	-3,718	**-0.1%**	-17	**0.0%**	4,778	**1.2%**
EU28	-3,411	**-0.1%**	-17	**0.0%**	4,445	**0.6%**

Source: ASTRA model

Similarly, rail freight activity increases by 0.4% at the European level, 0.8% in the countries crossed by the corridor, and 1.3% in NUTS1 regions crossed by the corridor. Inland waterways activity is projected to increase by 0.5% at the European level relative to the Baseline.

Table 74: Changes in freight transport activity (territoriality approach) for the Rhine-Alpine corridor scenario relative to Baseline in 2030 – Delta in million tkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	ROAD		RAIL		IWW	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-1,088	**-0.2%**	1,298	**1.3%**	688	**0.6%**
CORRIDOR COUNTRIES	-1,611	**-0.1%**	2,231	**0.8%**	993	**0.6%**
EU28	-1,713	**-0.1%**	2,331	**0.4%**	1,008	**0.5%**

Source: ASTRA model

9.1.10 Rhine-Danube core network corridor (RHD)

9.1.10.1 Transport impacts at the network level

Transport impacts at the network level of the Rhine-Danube corridor are provided in the tables below. Similar considerations provided for the other CNCs apply also in this case.

Table 75: Change in travel time by rail on the Rhine-Danube corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
RHINE-DANUBE	Frankfurt (DE) - Linz (AT)	-8%	-34%
	Linz (AT) -Timisoara (RO)	-11%	-35%
	Timisoara (RO) - Bucharest (RO)	-26%	-40%
	Bucharest (RO) - Costanza (RO)	0%	-21%

Source: TRUST model

Table 76: Change in rail cost for passengers and freight on the Rhine-Danube corridor relative to the Baseline – (% change to the Baseline)

CORRIDOR	TYPE	RAIL COST % CHANGE		
		2020	2025	2030
RHINE-DANUBE	Freight	-0.1%	-1.1%	-9.0%
	Passengers	-0.1%	-1.1%	-9.0%

Source: TRUST model

Table 77 shows the change in travel time by road on the Rhine-Danube corridor relative to the Baseline in 2030. Travel time gains mainly apply to the section Timisoara (RO) - Bucharest (RO) where about 360 km of roads will be upgraded to expressways technical standards.

Table 77: Change in travel time by road on the Rhine-Danube corridor relative to Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
RHINE-DANUBE	Frankfurt (DE) - Linz (AT)	-1%	0%
	Linz (AT) -Timisoara (RO)	0%	0%
	Timisoara (RO) - Bucharest (RO)	-23%	-25%
	Bucharest (RO) - Costanza (RO)	-1%	-1%

Source: TRUST model

9.1.10.2 Transport impacts at the aggregate level

Table 78 and Table 79 show the changes in transport activity (computed according to the territoriality approach) for the Rhine-Danube corridor scenario relative to the Baseline at 2030 for passenger and freight respectively.

Rail passenger activity increases by 0.9% at the European level, by 2.5% in the countries crossed by the corridor, and 3.1% in the NUTS1 regions crossed by the corridor.

Table 78: Changes in passenger transport activity (territoriality approach) for the Rhine-Danube corridor scenario relative to Baseline in 2030 – Delta in million pkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	CAR		BUS		RAIL	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-2,820	**-0.3%**	-89	**-0.1%**	4,272	**3.1%**
CORRIDOR COUNTRIES	-3,716	**-0.2%**	-90	**-0.1%**	5,502	**2.5%**
EU28	-4,367	**-0.1%**	-92	**0.0%**	6,544	**0.9%**

Source: ASTRA model

At the EU28 level rail freight activity increases by 0.8%. The countries crossed by the corridor show an increase of rail freight activity of 1.4%. The impact on the NUTS1 regions crossed by the corridor is an increase of 2.0%. Inland waterways activity is projected to increase by 0.3% relative to the Baseline at EU level.

Table 79: Changes in freight transport activity (territoriality approach) for the Rhine-Danube corridor scenario relative to Baseline in 2030 – Delta in million tkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	ROAD		RAIL		IWW	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-1,474	**-0.4%**	2,760	**2.0%**	164	**0.4%**
CORRIDOR COUNTRIES	-1,967	**-0.3%**	3,651	**1.4%**	411	**0.4%**
EU28	-2,350	**-0.1%**	4,595	**0.8%**	506	**0.3%**

Source: ASTRA model

9.1.11 Scandinavian-Mediterranean core network corridor (SCM)

9.1.11.1 Transport impacts at the network level

Transport impacts at the network level of the Scandinavian-Mediterranean corridor are provided in the tables below. Similar considerations provided for the other CNCs apply also in this case.

Table 80: Change in travel time by rail on the Scandinavian-Mediterranean corridor relative to the Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
SCAN-MED	Palermo (IT) - Verona (IT)	-31%	-31%
	Verona (IT) - Monaco (DE)	-10%	-27%
	Monaco DE - Padborg (DK)	-13%	-38%
	Padborg (DK) - Oslo (NO)	-9%	-29%

Source: TRUST model

Table 81: Change in rail cost for passengers and freight on the Scandinavian-Mediterranean corridor relative to the Baseline – (% change to the Baseline)

CORRIDOR	TYPE	RAIL COST % CHANGE		
		2020	2025	2030
SCAN-MED	Freight	0.0%	-0.5%	-9.0%
	Passengers	0.0%	-0.5%	-9.0%

Source: TRUST model

Table 82: Change in travel time by road on the Scandinavian-Mediterranean corridor relative to Baseline in 2030 – (% change to the Baseline)

CORRIDOR	SECTION	TRAVEL TIME % CHANGE	
		Passenger	Freight
SCAN-MED	Palermo (IT) - Verona (IT)	0%	0%
	Verona (IT) - Monaco (DE)	0%	0%
	Monaco DE - Padborg (DK)	-3%	0%
	Padborg (DK) - Oslo (NO)	-4%	0%

Source: TRUST model

9.1.11.2 Transport impacts at the aggregate level

Changes in passenger and freight transport activity (computed according to the territoriality approach) for the Scandinavian-Mediterranean corridor scenario relative to Baseline at 2030 are reported in Table 83 and Table 84 respectively. Rail passenger activity increases by 1.5% at the European level, by 3.9% in the countries crossed by the corridor, and by 4.7% in the NUTS1 regions crossed by the corridor.

Table 83: Changes in passenger transport activity (territoriality approach) for the Scandinavian-Mediterranean corridor scenario relative to Baseline in 2030 – Delta in million pkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	CAR		BUS		RAIL	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-7,048	**-0.4%**	-122	**-0.1%**	9,707	**4.7%**
CORRIDOR COUNTRIES	-7,581	**-0.3%**	-127	**-0.1%**	10,461	**3.9%**
EU28	-7,693	**-0.1%**	-135	**0.0%**	10,618	**1.5%**

Source: ASTRA model

At the European level, rail freight activity increases by 1.1%, while in the countries crossed by the corridor it show an increase of 2.1%, and the impact on the NUTS1 regions crossed by the corridor is 2.4% (see Table 84).

Table 84: Changes in freight transport activity (territoriality approach) for the Scandinavian-Mediterranean corridor scenario relative to Baseline in 2030 – Delta in million tkm/year for the Baseline and the CNC scenario and % changes to the Baseline

	ROAD		RAIL		IWW	
	Delta	% Change	Delta	% Change	Delta	% Change
CORRIDOR NUTS 1	-1,965	**-0.3%**	4,754	**2.4%**	n.a.	n.a.
CORRIDOR COUNTRIES	-2,282	**-0.2%**	5,532	**2.1%**	n.a.	n.a.
EU28	-2,686	**-0.1%**	6,397	**1.1%**	n.a.	n.a.

Source: ASTRA model

9.2 Economic impacts of CNC

The following sections describe the economic results for each of the nine CNC.

9.2.1 Atlantic core network corridor (ATL)

There are nine projects on the ATL with a project size of over €1 billion. In total, these nine projects amount to €19 billion. These projects are located in Portugal, Spain and France. Germany is only relevant for some cross-border connections in this corridor.

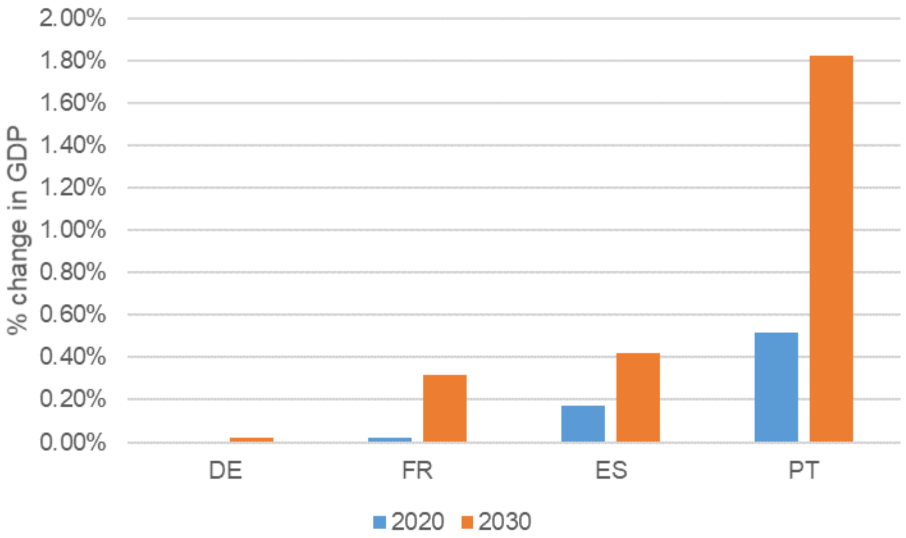
Overall, there are 289 projects on the ATL. Table 85 lists the project volume that form the direct impulses in the economic model. In comparison to all CNC projects, the ATL is the smallest regarding the investment volume.

Table 85: TEN-T investments on Atlantic CNC per country in million €$_{2005}$

TEN-T investments per country	2017-2030
PT	5,279
ES	11,389
FR	12,711
DE	1,401

Source: project list EC

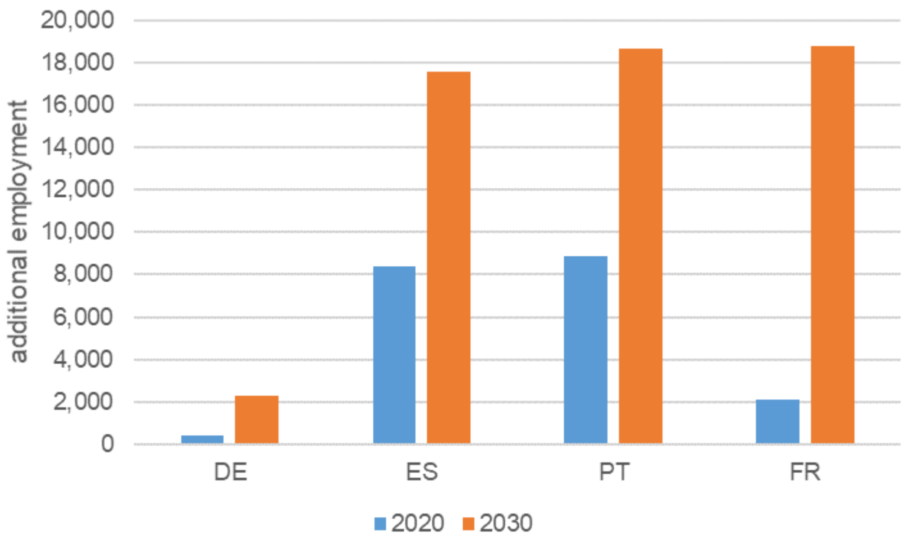
Portugal profits the most from completion of the ATL, with a change in GDP compared to the Baseline Scenario of 1.8% in 2030. While the investments in this corridor are relatively evenly distributed across the time period, the impact types (2) and (3) (second-round effects and wider economic impacts respectively) play a more significant role. 30% of the investments in the ATL are made in the period 2017-2020, 44% in the period 2021-2025 and the remaining 26% in the last 5 years.



Source: ASTRA model

Figure 45: Change in GDP due to TEN-T investments on Atlantic CNC

The positive effects on employment for the three major countries on the ATL are quite similar in absolute terms. Figure 46 shows the changes in full-time equivalent jobs. In 2030, Spain has an additional 17,600 jobs, while Portugal has 18,700 and France has 18,800, compared to the Baseline Scenario.



Source: ASTRA model

Figure 46: **Change in employment due to TEN-T investments on Baltic Adriatic CNC**

9.2.2 Baltic Adriatic core network corridor (BAC)

BAC includes nine projects with an investment volume of more than €1 billion. These nine projects account for a total of €25 billion in investment. Italy and Austria both have three of these largest projects, with the remaining three occurring in Slovakia, Czech Republic and Poland.

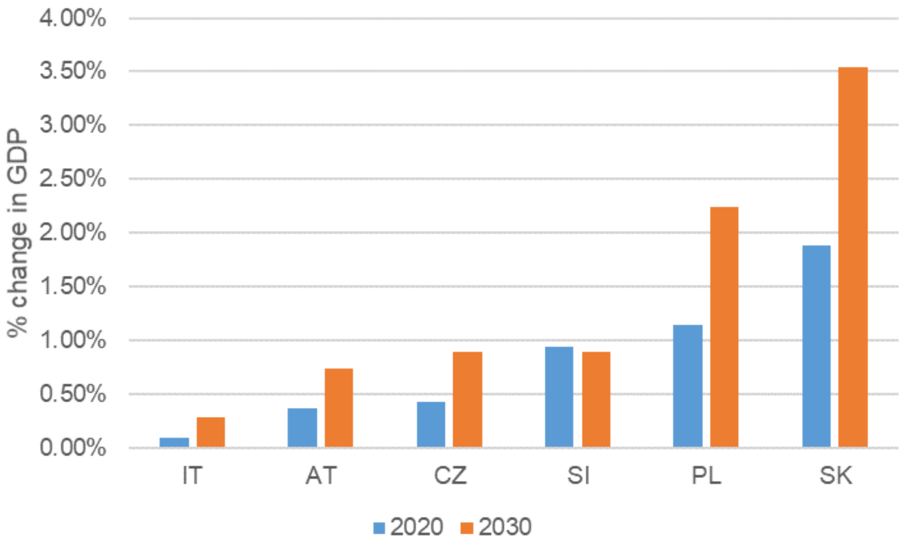
Table 86 gives the overall investment volume for each country. 52% of the overall investment volume is made in the period from 2017 to 2020, 34% from 2021 to 2025, and only 15% in the period from 2026 to 2030.

Table 86: **TEN-T investments on Baltic Adriatic CNC per country in million €$_{2005}$**

TEN-T investments per country	2017-2030
PL	16,519
CZ	4,788
AT	5,570
IT	11,221
SI	2,488
SK	5,205

Source: project list EC

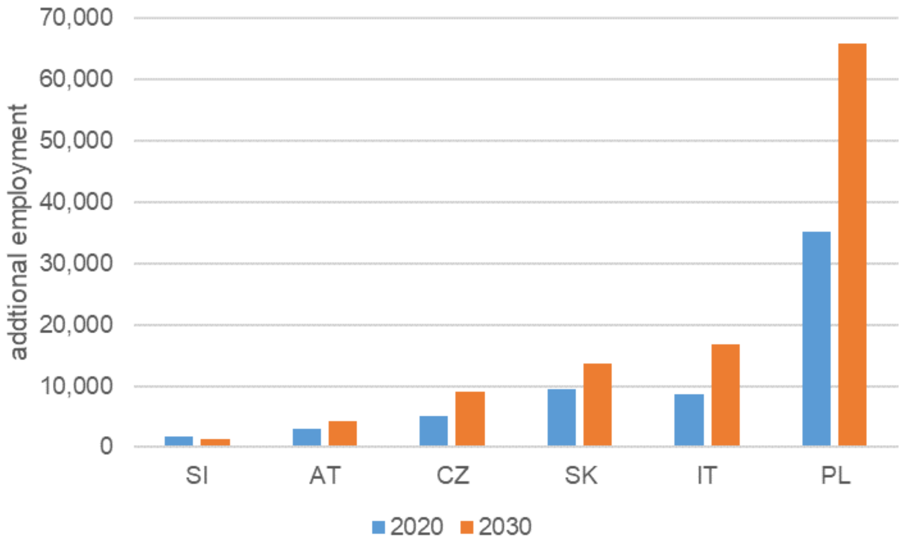
As the majority of the investment is in the earlier part of the overall investment period, there GDP changes compared to the Baseline Scenario materialise at 2020. Figure 47 shows significant changes in GDP in 2020 for Poland, Slovakia and Slovenia.



Source: ASTRA model

Figure 47: **Change in GDP due to TEN-T investments on Baltic Adriatic CNC**

In 2030, Slovakia shows an increase in GDP of 3.5%, while Poland gains 2.2% of GDP, and both Slovenia and the Czech Republic show increases of 0.9% of GDP.



Source: ASTRA model

Figure 48: **Additional employment due to TEN-T investments on Baltic Adriatic CNC**

The employment effects of BAC are largest for Poland compared to the Baseline Scenario, creating 66,000 full-time equivalent jobs in 2030. Comparatively, Italy has 17,000 more jobs in 2030 and Slovakia has14,000 more jobs.

9.2.3 Mediterranean core network corridor (MED)

There are 22 projects in MED that cost more than €1 billion, totalling €78 billion in investment. The largest project by investment is the Lyon Turin Base tunnel. There are 518 projects on the MED in the project database.

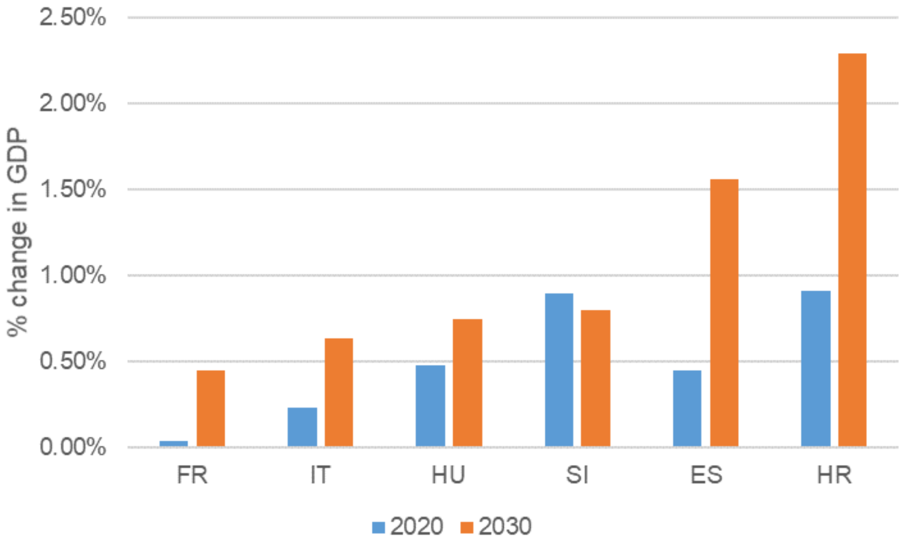
Detailed information on the Member State investments on the MED is provided in , with 28% of the investment taking place from 2017 to 2020, 45% from 2021 to 2025 and 27% in the last 5 years.

Table 87: TEN-T investments on Mediterranean CNC per country in million €$_{2005}$

TEN-T investments per country	2017-2030
ES	15,011
FR	32,879
IT	33,178
HR	2,015
SI	2,784
HU	3,997

Source: project list EC

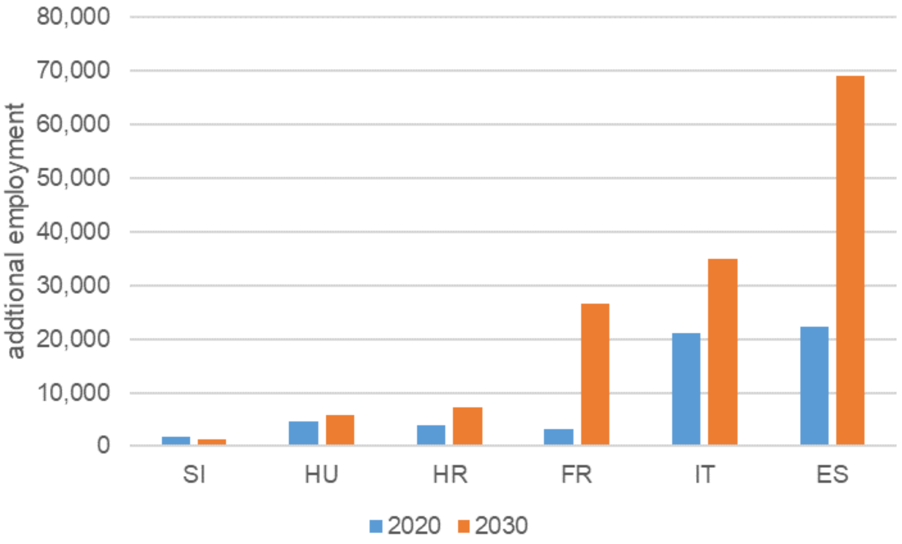
GDP changes are strongest in Croatia with a 2.3% increase in 2030 compared to the Baseline Scenario. Spain has a GDP growth of 1.6%, while Slovenia and Hungary see GDP increases of 0.8% by 2030.



Source: ASTRA model

Figure 49: Change in GDP due to TEN-T investments on Mediterranean CNC

Despite the large investments in both France and Italy in the connection from Lyon to Turin, the GDP gains for both countries are relatively modest. However, both countries enjoy an increase in jobs created, with France gaining 27,000 jobs and Italy gaining 35,000 in 2030. However, the second-round effects in these countries are negligible. Comparatively, Spain gains 70,000 full-time equivalent jobs in 2030 (Figure 50).



Source: ASTRA model

Figure 50: Change in employment due to TEN-T investments on Mediterranean CNC

9.2.4 North Sea Baltic core network corridor (NSB)

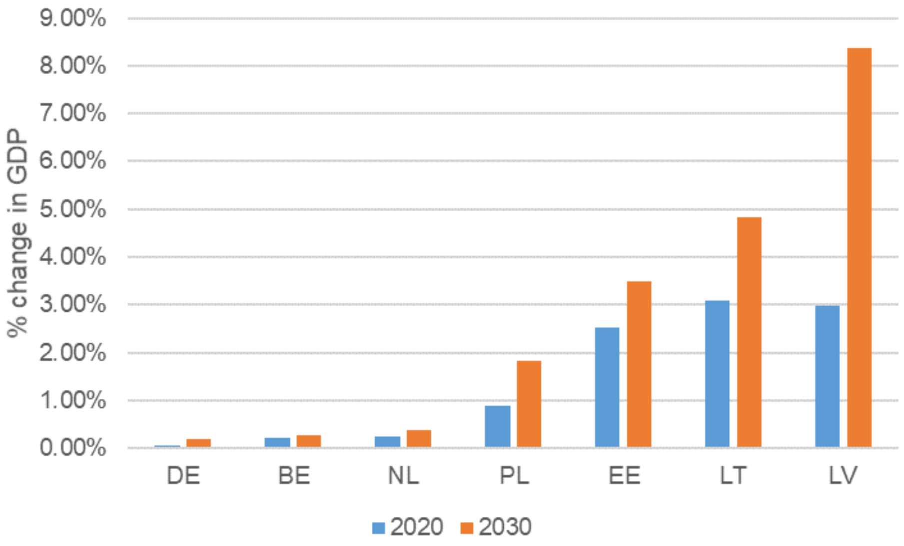
There are 20 projects on the NSB with TEN-T investments larger than €1 billion, out of a total 564 projects on the Corridor. The two largest projects are Rail Baltica and the road update around Amsterdam. Both account for more than €5 billion. Table 88 provides an overview of the TEN-T investments on the NSB by Member State. 88% of the investments are made in or before 2025.

Table 88: TEN-T investments on North Sea Baltic CNC per country in million €2005

TEN-T investments per country	2017-2030
EE	2,360
LV	5,136
LT	2,894
PL	12,702
DE	18,649
NL	11,391
BE	5,456

Source: project list EC

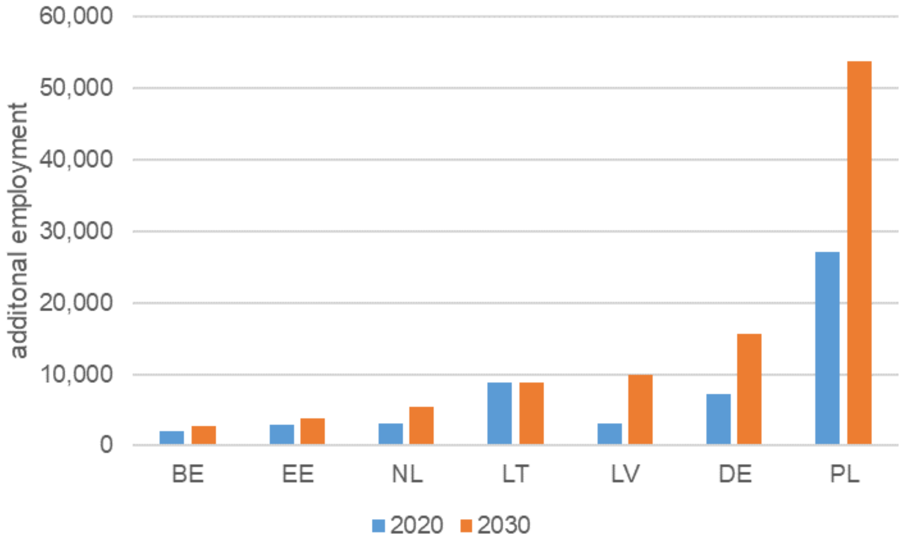
Latvia has the largest GDP growth in 2030, with an increase of 8.4% resulting from the TEN-T investments, compared to an increase of 3.0% in 2020. GDP in Lithuania increases 3.1% in 2020 and 4.8% in 2030, while GDP in Estonia increases by 2.5% in 2020 and 3.5% in 2030.



Source: ASTRA model

Figure 51: **Change in GDP due to TEN-T investments on North Sea Baltic CNC**

The effects on employment show a different picture. Poland has additional 54,000 full time equivalent jobs in 2030 compared to the baseline, while Germany gains 16,000 jobs and Latvia gains 10,000 jobs in 2030. As above, the low GDP change despite large changes in employment is due to the fact that both Poland and Germany need more labour in absolute terms to create substantial GDP growth figures.



Source: ASTRA model

Figure 52: **Change in employment due to TEN-T investments on North Sea Baltic CNC**

9.2.5 North-Sea Mediterranean core network corridor (NSM)

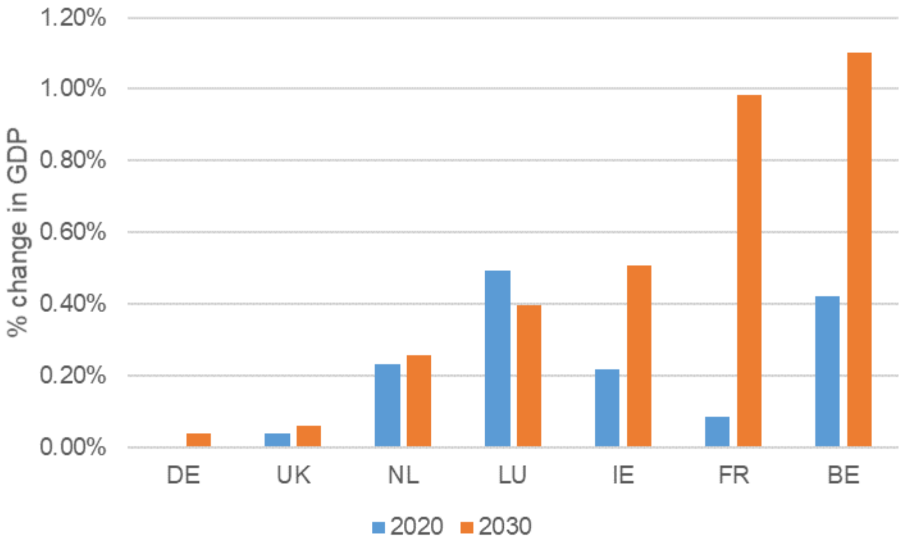
There are 363 projects in the project database on the NSM. Some of the largest projects on the NSM cover inland waterways, such as Seine Scheldt, with many smaller projects regarding locks and connections to ports. Table 89 summarises the TEN-T investments for each Member State on the NSM. 69% of the investment is taking place in the period from 2021 to 2030.

Table 89: **TEN-T investments on North Sea Mediterranean CNC per country in million €$_{2005}$**

TEN-T investments per country	2017-2030
IE	6,004
UK	2,761
FR	31,002
BE	7,671
NL	9,976
LU	1,287
DE	169

Source: project list EC

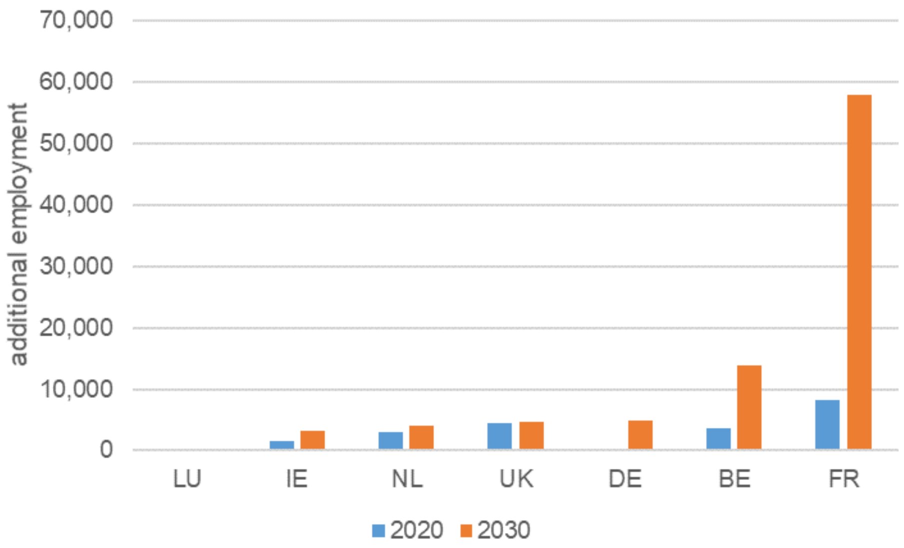
As a result of the project's timeline, Ireland, France and Belgium enjoy most of their GDP changes at the end of the period. In 2030, Belgium has 1.1% more GDP, France 1.0% and Ireland 0.5%. Not only are these projects late in their completion for the evaluation of this corridor, but one can also expect that the major economic gains will happen after a substantial reallocation of transport resources on the inland water ways, which includes a significant time lag even after the opening date.



Source: ASTRA model

Figure 53: **Change in GDP due to TEN-T investments on North Sea Mediterranean CNC**

France gains 58,000 full time equivalent jobs and Belgium 14,000 jobs, in 2030. The additional employment in other countries is comparably small, but, as has been noted above, significant second-round effects can be expected after the inland waterways are fully operational.



Source: ASTRA model

Figure 54: **Change in employment due to TEN-T investments on North Sea Mediterranean CNC**

9.2.6 Orient East Med core network corridor (OEM)

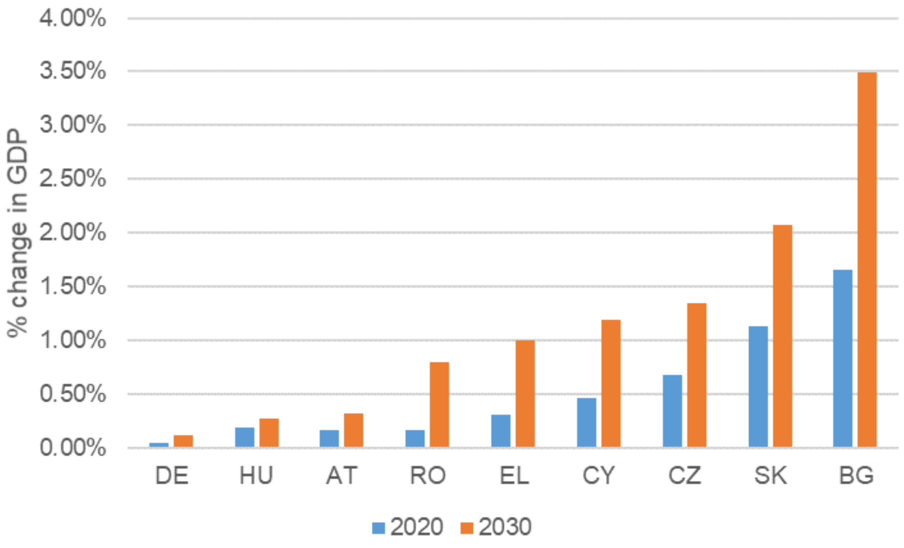
The OEM includes five projects with an investment of more than €1 billion. The largest project by investment is the upgrade of the German railway connecting Hamburg, Bremen and Hannover. The investments are characterised by a large share of cross-border connections. 526 projects are on the OEM, with 78% of the investment taking place before 2025 (see Table 90).

Table 90: **TEN-T investments on Orient-East-Med CNC per country in million €$_{2005}$**

TEN-T investments per country	2017-2030
DE	17 360
CZ	9 689
AT	1 539
SK	3 037
RO	3 622
BG	6 459
EL	3 634
HU	1 224
CY	518

Source: project list EC

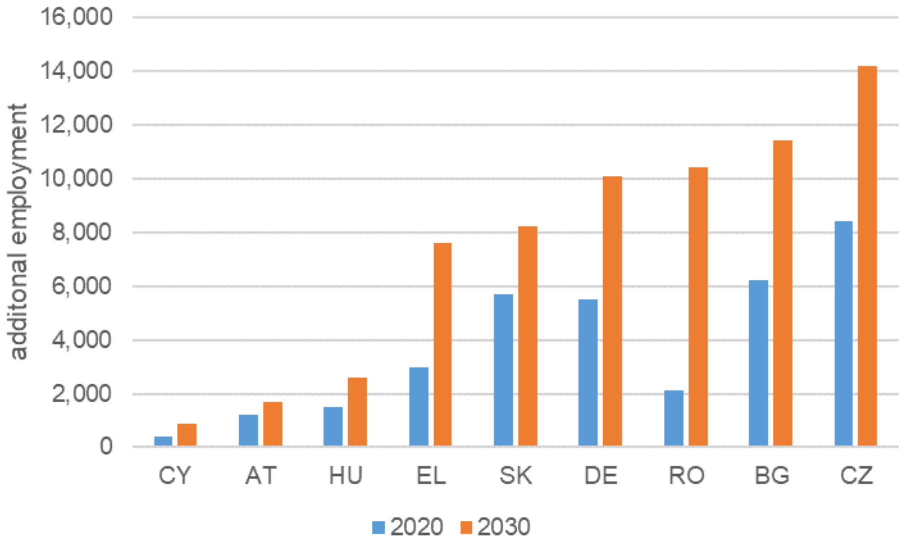
As shown in Figure 55, GDP is 3.5% higher in Bulgaria and 2.09% higher in Slovakia in 2030, compared to the Baseline Scenario.



Source: ASTRA model

Figure 55: **Change in GDP due to TEN-T investments on Orient East Mediterranean CNC**

As shown in Figure 56, there are 14,000 additional jobs in the Czech Republic, 11,000 in Bulgaria, and 10,000 in both Romania and Germany in 2030.



Source: ASTRA model

Figure 56: **Change in employment due to TEN-T investments on Orient East Mediterranean CNC**

9.2.7 Rhine Alpine core network corridor (RALP)

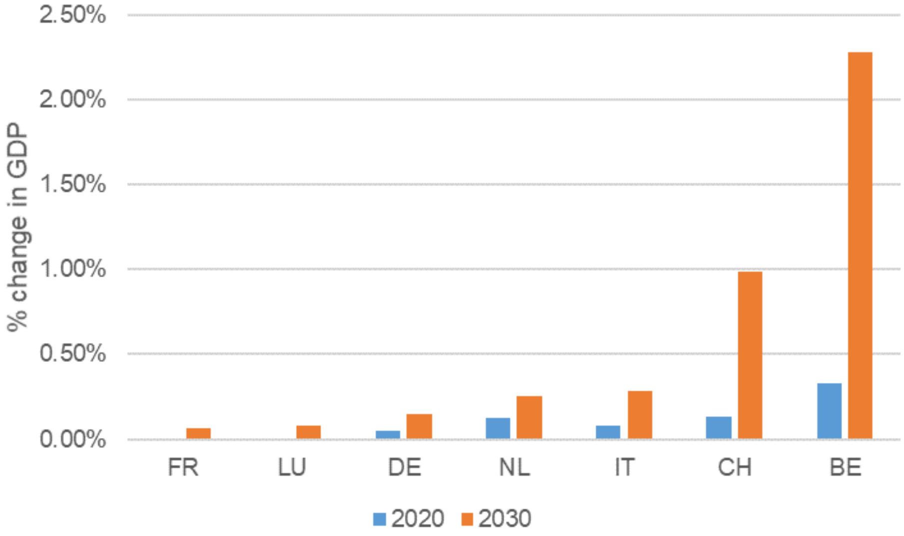
The single largest project on the RALP is the Gotthard base tunnel, which is already in operation. Ongoing projects on this corridor are to a large extent capacity increasing projects in Switzerland, mostly tunnels, which are relatively cost-intensive. As a consequence, Switzerland is the largest single bearer of investment costs on the RALP, as shown in Table 91.

Table 91: **TEN-T investments on Rhine Alpine CNC per country in million €$_{2005}$**

TEN-T investments per country	2017-2030
NL	4,296
BE	5,733
DE	17,050
FR	200
IT	11,448
LU	9
CH	22,889

Source: project list EC

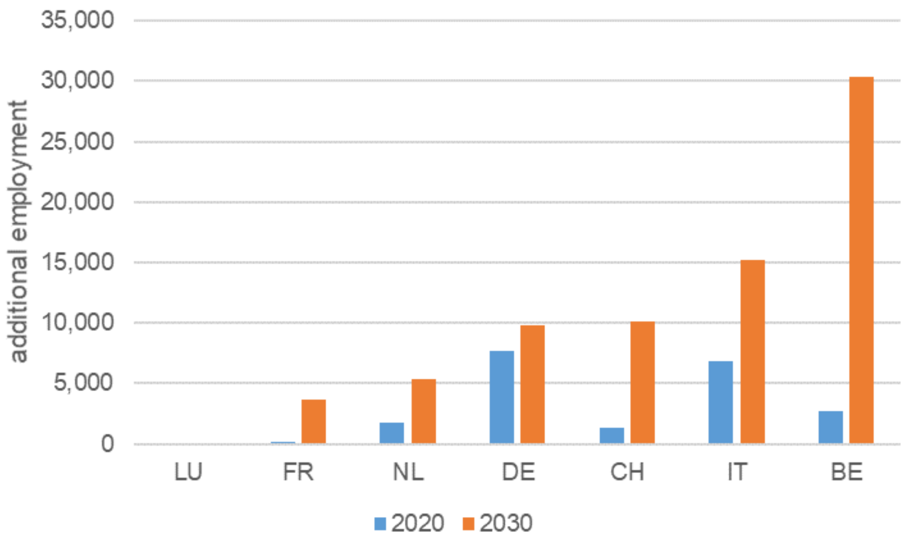
Switzerland shows an increases in GDP of 1.0% in 2030, however Belgium, with two major upgrades of the ring including Brussels and Antwerp, profits most from the completion of the RALP with 2.3% more GDP in 2030. This is supported by the completion of some port facilities in Belgium, which are known to produce pronounced growth effects.



Source: ASTRA model

Figure 57: **Change in GDP due to TEN-T investments on Rhine Alpine CNC**

In line with the changes in GDP, Belgium also sees substantial gains in employment. The completion of RALP leads to 30,000 more jobs in Belgium in 2030. Also, not surprisingly, Italy and Switzerland experience a growth in jobs, with 15,000 more full-time equivalent jobs for Italy and 10,000 more in Switzerland in 2030.



Source: ASTRA model

Figure 58: **Change in GDP due to TEN-T investments on Rhine Alpine CNC**

9.2.8 Rhine Danube core network corridor (RHD)

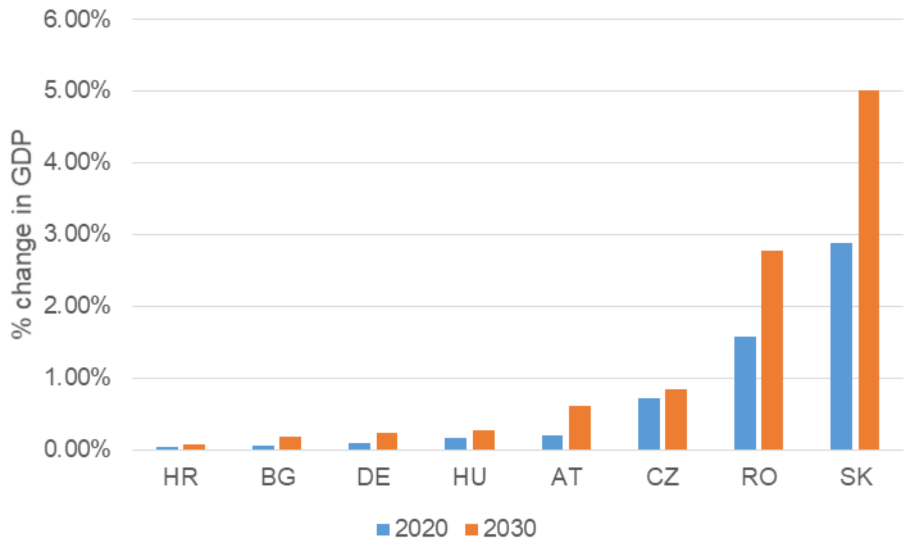
The biggest single projects on the RHD are railway connections in southern Germany. Consequently, Germany is also the country with the largest overall investments. The RHD is also a corridor with a substantial share of cross-border connections, especially in the Eastern European part of it. Although many of these projects are not high in investment volume, they are nevertheless high in number, with 595 projects on the RHD.

Table 92: **TEN-T investments on Rhine Danube CNC per country in million €$_{2005}$**

TEN-T investments per country	2017-2030
DE	33,229
AT	1,764
CZ	4,562
SK	8,156
RO	13,525
HR	98
BG	179
HU	1,284

Source: project list EC

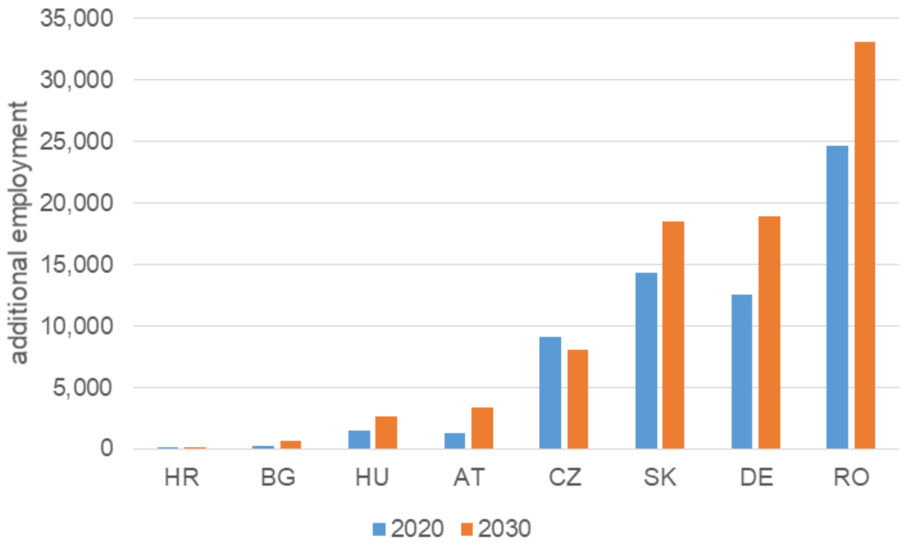
Slovakia as a major transit country can profit from the completion of the RHD with a growth in GDP of 5.0% in 2030, compared to the Baseline Scenario. The completion is also very favourable for Romania with 2.8% higher GDP in 2030.



Source: ASTRA model

Figure 59: **Change in employment due to TEN-T investments on Rhine Danube**

Together with their high GDP growth, Slovakia also has a significant growth in jobs created by the completion of the RHD, with 19,000 in 2030. Romania profits most in the creation of jobs with 33,000 more in 2030.



Source: ASTRA model

Figure 60: **Change in GDP due to TEN-T investments on Rhine Danube CNC**

9.2.9 Scandinavian Mediterranean core network corridor (SCM)

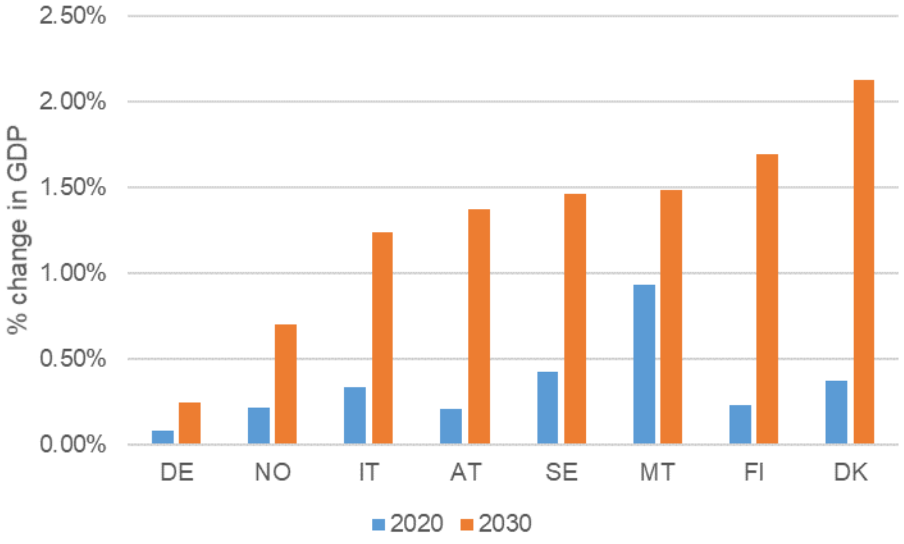
Besides the famous Fehmarn belt, the SCM includes the high-speed rail link to Calabria which is the single costliest investment of the whole TEN-T network. The SCM includes 695 projects, and is also the corridor with the highest investment volume of all nine CNCs.

Table 93: **TEN-T investments on Scandinavian Mediterranean CNC per country in million €$_{2005}$**

TEN-T investments per country	2017-2030
IT	51,367
AT	1,590
DE	34,062
DK	5,598
NO	4,118
SE	14,910
FI	5,986
MT	352

Source: project list EC

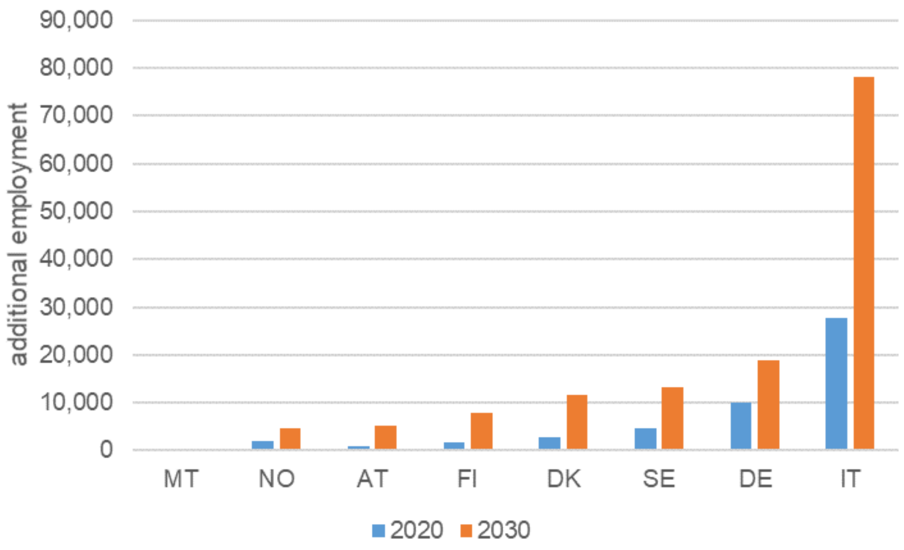
Denmark, Finland and Sweden are the major countries whose economies benefit most from the completion of the SCM. Denmark sees an additional 2.1% GDP in 2030. All the major countries on this corridor see larger GDP gains in the later part of the investment period.



Source: ASTRA model

Figure 61: **Change in GDP due to TEN-T investments on Scandinavian Mediterranean CNC**

Italy benefits the most from additional employment, with 78,000 more jobs in 2030. The Nordic countries, despite reasonable impacts on GDP, have a lower number of jobs created. This is a result of above average labour productivity in those countries.



Source: ASTRA model

Figure 62: Change in employment due to TEN-T investments on Scandinavian Mediterranean CNC

9.2.10 Comparison of economic impacts of CNC

Table 94 summarises the changes for all nine CNC in terms of GDP and employment gains in 2030. One can observe that there is a strong link between the overall investment volume on each corridor and a growth in GDP, although this link is clearly not a simple linear relationship.

Regarding the gains in employment the picture is more nuanced. This stems from the fact that the Member States are very diverse in their respective labour productivity. Some countries with higher labour productivity see smaller changes in GDP from additional employment compared to those with lower labour productivity. The gains from employment also varies depending on the benefits in particular sectors in each country (for example, whether the benefits are in the construction sector or those sectors benefitting most from second-round effects). The simplest way to understand this is to imagine the same investment amount of €1 million over one year. In a country with a labour productivity of €100,000 the investment would generate 10 job-years. In a country with labour productivity of €20,000 Euro it would be 50 job-years.

Table 94: Changes in GDP and employment for the nine CNC relative to the Baseline

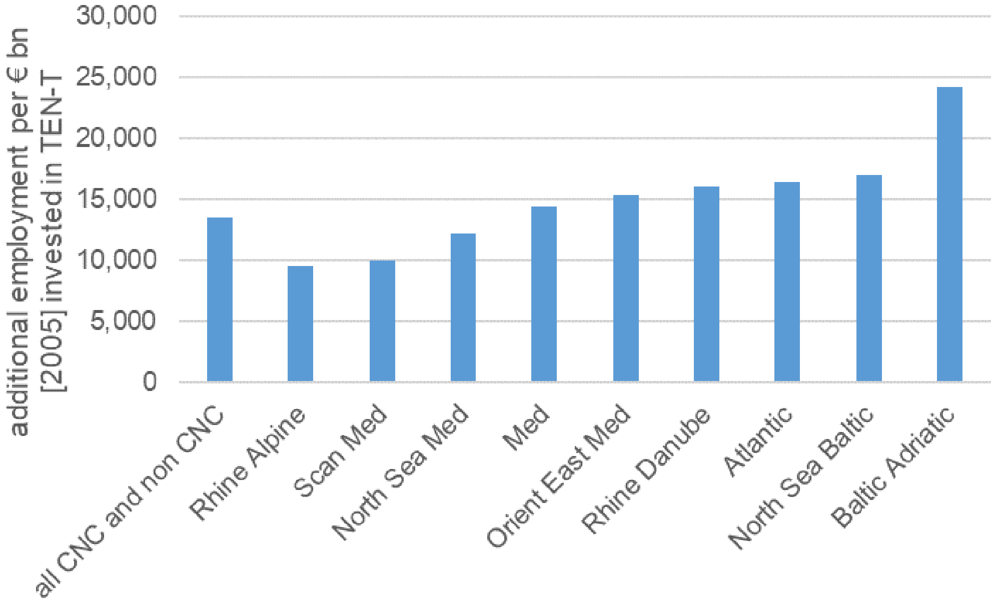
	∆GDP in 2030	∆Employment in 2030
Scan-Med	0.3%	142,000
Med	0.3%	153,000
Atlantic	0.1%	62,000
Rhine-Danube	0.1%	93,000
Rhine-Alpine	0.2%	69,000
Baltic-Adriatic	0.2%	122,000
Orient-East-Med	0.1%	76,000
NorthSea-Baltic	0.2%	115,000
NorthSea-Med	0.2%	94,000
Total of nine CNC and CNoCNC	**1.6%**	**797,000**

Source: ASTRA model

In Table 94 it is important to note that the total of the nine CNCs is not the aggregation of the single numbers (which would be 926,000 additional employment). Instead the total is derived through simulation of the models with the implementation of all projects of the CNC together, which eliminates the double counting of projects that are part of more than one CNC.

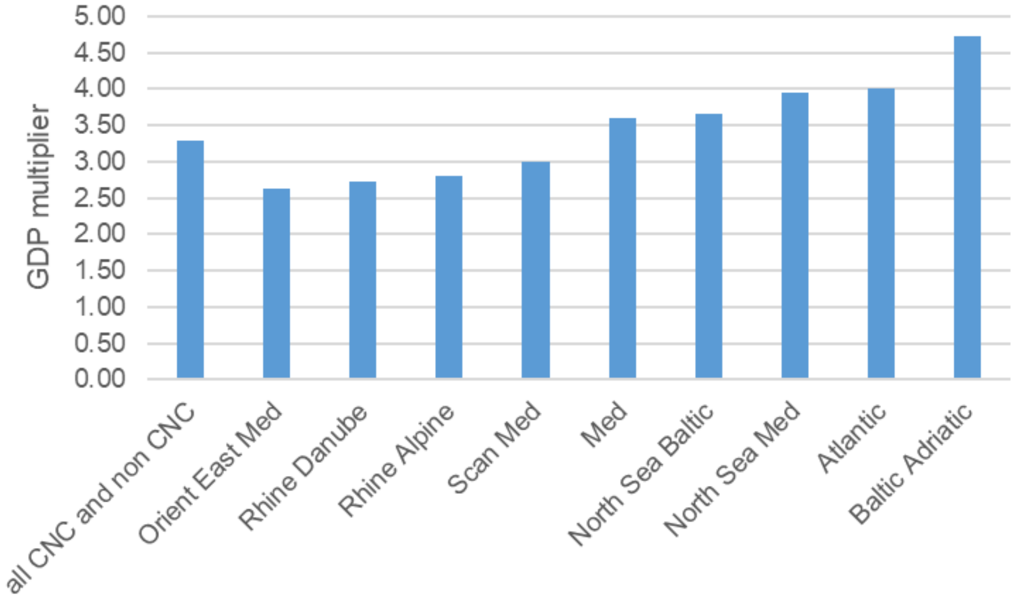
Figure 63 and Figure 64 show the multipliers for the jobs and additional GDP for each of the nine CNC, and for the TEN-T core network including the CNoCNC projects. The multipliers were calculated by taking the integral of the changes between 2017 and 2030 and dividing them by the integral of the investments made for the respective CNC and the TEN-T core network.

The picture for the GDP multiplier is quite nuanced; one can see that there are no substantial differences between the CNC or the TEN-T core network. The multipliers for employment differ more, which can be accounted for by the differences in labour productivity in the respective countries.



Source: ASTRA model

Figure 63: **Employment multiplier for EU28 – 2017 to 2030**



Source: ASTRA model

Figure 64: **GDP multiplier for TEN-T core network investments – 2017 to 2030**

The GDP multipliers of the TEN-T network implementation can be compared with other sectors that receive European funding. Monsalve et al. (2016) noted a multiplier for value added for rural development of less than one. However, especially for low-skilled employment it is considerably higher. It must be noted, though, that they used only a multiregional Input-Output model, which did not consider induced effects. The analysis by Mary et al. (2013) with a CGE model showed a cumulative multiplier for rural development of 2.1 in an ex-post evaluation. For urban policies the multiplier is considerably higher. However, the analysis only covered one region (Cordoba in Spain) and most likely cannot be generalised for the whole EU. Psaltopoulos et al. (2011) do not directly calculate multipliers of the Common Agricultural Policy on six different regions, but, using a CGE model they showed that they yield percentage changes for overall GDP ranging between -0.2 and +0.25. Only for one specific case regarding one policy was the annual percentage change in rural GDP above 4, while in almost all other cases it was smaller than one. Helming et al. (2011) analysed a financial reform scenario of the Common Agricultural Policy with a macro-econometric model and found an increase of ~0.53% in GDP for a tax rebate policy and an increase of ~2.57% in GDP for a R&D policy. In general, it seems that the average GDP multiplier for the TEN-T core network implementation of 3.3 lies moderately above the impacts of funds dedicated to agriculture. The same holds for the percentage changes in comparison with a reference without such funds.

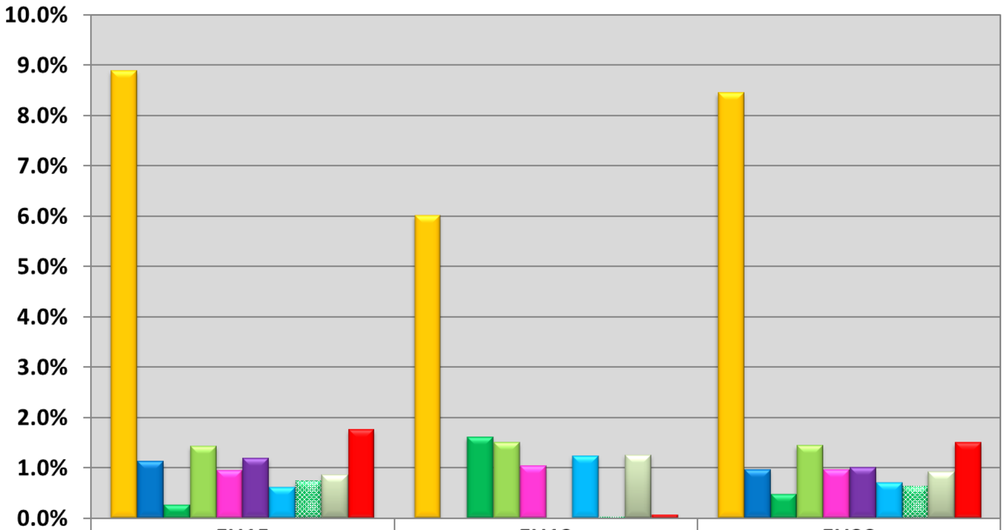
9.3 Impact of TEN-T at corridor level

The transport results for 2030 show that the nine corridors perform differently and that they cause different impacts for passengers and freight. Many factors contribute to these results, and they are difficult to disentangle; most importantly, the length of the corridor, the volume and the type of the investments, the time profile, the performance of the networks in the Baseline which varies corridor by corridor, and the structure and the elasticities of the demand.

Rail transport activity at NUTS1 level was considered as a synthetic indicator of the impacts of the CNCs, given that the corridors workplans include a significant amount of investment on rail. The results show that in general impacts on passengers are higher, ranging from +2.6% to +5.7%, than for freight where the changes are between 3.1% and 0.9%.

Looking at the results at NUTS1 level, it is possible to identify some difference among groups of corridors. There is a group of corridors (the Mediterranean, the Scan-Med, and the Atlantic) that show greater impacts in terms of change in rail transport activity for passengers and freight. These three corridors show an in increase in rail transport activity above 2% for freight (3.1% Atlantic, 2.9% the Mediterranean) and above 3% for passengers (with peaks of 5.7% and 4.7% respectively in the Mediterranean and Scan-Med corridors). Looking at other corridors, North Sea-Baltic and Rhine-Danube show average impacts with around 3% change in transport activity for passengers and 1.7% and 2% respectively for freight. The impacts on the Orient-East-Med, Rhine-Alpine and the Baltic-Adriatic are below average for passengers and for freight, while the North Sea-Med corridor shows high impact on freight rail activity, similar to the one of the first group, but not for passengers.

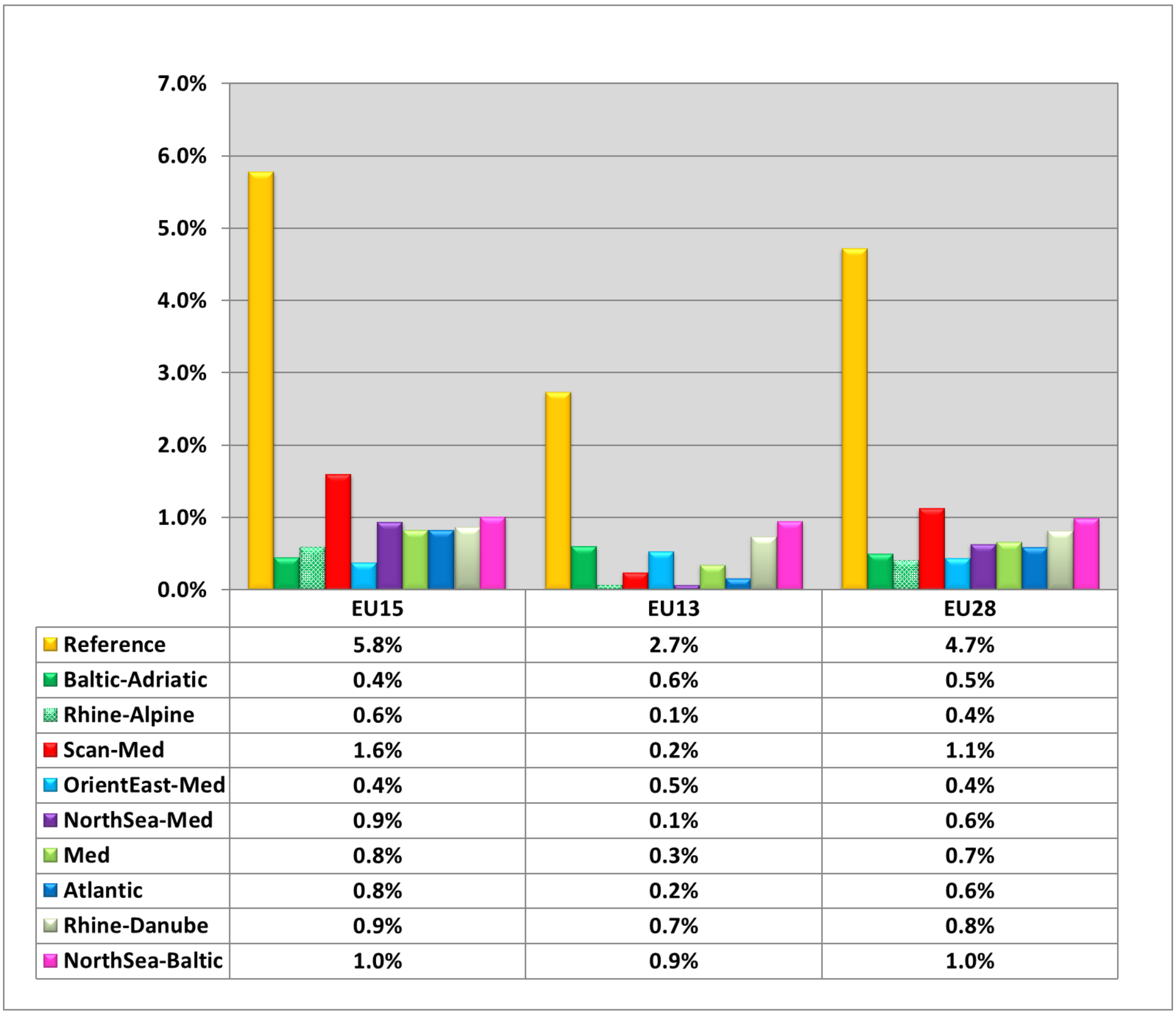
The following graphs are an attempt to highlight the contribution of the single corridors to the overall results of the Reference Scenario. We note that the Reference and the aggregation of the Corridor results are not fully comparable, as the Reference includes not only the Corridors but also the completion of the CNoCNC projects, and the Corridors have many overlapping sections which impact on the changes in transport demand. It should also be noted that the CNoCNC is more balanced between road and rail than the CNCs, and does not show the same impact on freight as on passengers, benefitting passengers more as it mainly affects medium distance travel. The Scandinavia-Mediterranean Corridor is the CNC that contributes most to the overall impact at EU28 level, followed by the Mediterranean CNC in the case of passengers, and by the North Sea Baltic for freight. The other Corridors contribute to both passengers and freight in a similar way.



	EU15	EU13	EU28
🟨 Reference	8.9%	6.0%	8.4%
🟦 Atlantic	1.1%	0.0%	1.0%
🟩 Baltic-Adriatic	0.3%	1.6%	0.5%
🟩 Med	1.4%	1.5%	1.4%
🟪 NorthSea-Baltic	0.9%	1.0%	1.0%
🟪 NorthSea-Med	1.2%	0.0%	1.0%
🟦 OrientEast-Med	0.6%	1.2%	0.7%
▨ Rhine-Alpine	0.7%	0.0%	0.6%
⬜ Rhine-Danube	0.9%	1.3%	0.9%
🟥 Scan-Med	1.8%	0.1%	1.5%

Source: ASTRA model

Figure 65: Change of rail passenger activity (territoriality approach) at the EU level for the Reference Scenario and all CNCs scenarios relative to Baseline in 2030 – (% change to the Baseline)



	EU15	EU13	EU28
🟨 Reference	5.8%	2.7%	4.7%
🟩 Baltic-Adriatic	0.4%	0.6%	0.5%
▨ Rhine-Alpine	0.6%	0.1%	0.4%
🟥 Scan-Med	1.6%	0.2%	1.1%
🟦 OrientEast-Med	0.4%	0.5%	0.4%
🟪 NorthSea-Med	0.9%	0.1%	0.6%
🟩 Med	0.8%	0.3%	0.7%
🟦 Atlantic	0.8%	0.2%	0.6%
⬜ Rhine-Danube	0.9%	0.7%	0.8%
🟪 NorthSea-Baltic	1.0%	0.9%	1.0%

Source: ASTRA model

Figure 66: Change of rail freight activity (territoriality approach) at the EU level for the Reference Scenario and all CNCs scenarios relative to Baseline in 2030 – (% change to the Baseline)

The effect of the Corridors at the European level is higher for freight than for passengers; this can be noted when comparing the impacts at the NUTS 1 level with the impacts at EU28 level, as shown in Table 95 and Table 96 below.

The impact on passenger activity at the European level is between 10% to 30% on average, with the exception of the North Sea-Baltic, the Orient-East-Med and Rhine-Danube, which show an even higher impact. However, the impact on freight activity is greater on all corridors, and for some, like the Atlantic, is more than double the impact on passenger activity. Freight demand along the corridor is mainly long distance, and therefore the increased performance on the corridor has a more visible effect on the demand on other parts of the European core network. This effect is less evident for passenger demand which has a higher local component.

It should be noted that as the corridors have several overlapping sections, impacts cannot be summed vertically; it is therefore impossible to compare the overall NUTS 1 and EU28 impacts for the nine Corridors all together.

Table 95: Ratio between the impact on passenger activity at NUTS1 and EU28 levels relative to Baseline in 2030 – (million pkm/year; %)

		CAR		RAIL	
		Delta	Ratio	Delta	Ratio
Atlantic	**CORRIDOR NUTS 1**	-3,700	**13%**	5,659	**16%**
	EU28	-4,267		6,753	
Baltic-Adriatic	**CORRIDOR NUTS 1**	-1,781	**27%**	2,507	**26%**
	EU28	-2,424		3,397	
Mediterranean	**CORRIDOR NUTS 1**	-4,893	**28%**	7,228	**29%**
	EU28	-6,839		10,189	
North Sea-Baltic	**CORRIDOR NUTS 1**	-3,244	**33%**	4,328	**36%**
	EU28	-4,814		6,762	
North Sea-Med	**CORRIDOR NUTS 1**	-4,283	**16%**	5,814	**18%**
	EU28	-5,080		7,079	
Orient-East-Med	**CORRIDOR NUTS 1**	-2,092	**42%**	2,868	**43%**
	EU28	-3,621		4,990	
Rhine-Alpine	**CORRIDOR NUTS 1**	-2,907	**15%**	3,571	**20%**
	EU28	-3,411		4,445	
Rhine-Danube	**CORRIDOR NUTS 1**	-2,820	**35%**	4,272	**35%**
	EU28	-4,367		6,544	
Scan-Med	**CORRIDOR NUTS 1**	-7,048	**8%**	9,707	**9%**
	EU28	-7,693		10,618	

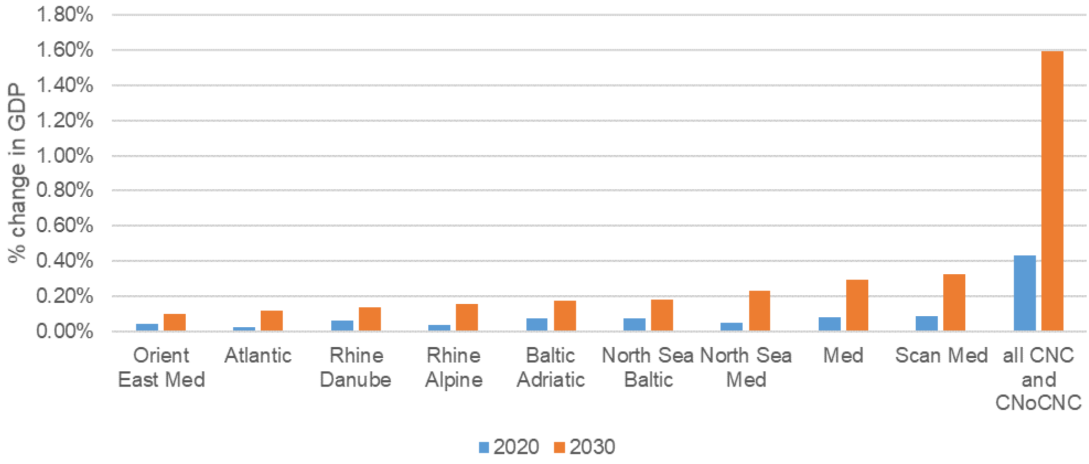
Source: TRT analysis

Table 96: Ratio between the impact on freight activity at NUTS1 and EU28 levels relative to Baseline in 2030 – (million tkm/year; %)

		ROAD		RAIL	
		Delta	Ratio	Delta	Ratio
Atlantic	**CORRIDOR NUTS 1**	-788	**47%**	1,716	**49%**
	EU28	-1,475		3,365	
Baltic-Adriatic	**CORRIDOR NUTS 1**	-578	**35%**	1,503	**47%**
	EU28	-891		2,834	
Mediterranean	**CORRIDOR NUTS 1**	-889	**45%**	1,873	**50%**
	EU28	-1,622		3,728	
NorthSea-Baltic	**CORRIDOR NUTS 1**	-1,373	**30%**	3,728	**33%**
	EU28	-1,962		5,559	
NorthSea-Med	**CORRIDOR NUTS 1**	-1,616	**26%**	2,477	**31%**
	EU28	-2,178		3,596	
Orient-East-Med	**CORRIDOR NUTS 1**	-478	**46%**	1,165	**53%**
	EU28	-892		2,453	
Rhine-Alpine	**CORRIDOR NUTS 1**	-1,088	**37%**	1,298	**44%**
	EU28	-1,713		2,331	
Rhine-Danube	**CORRIDOR NUTS 1**	-1,474	**37%**	2,760	**40%**
	EU28	-2,350		4,595	
Scan-Med	**CORRIDOR NUTS 1**	-1,965	**27%**	4,754	**26%**
	EU28	-2,686		6,397	

Source: TRT analysis

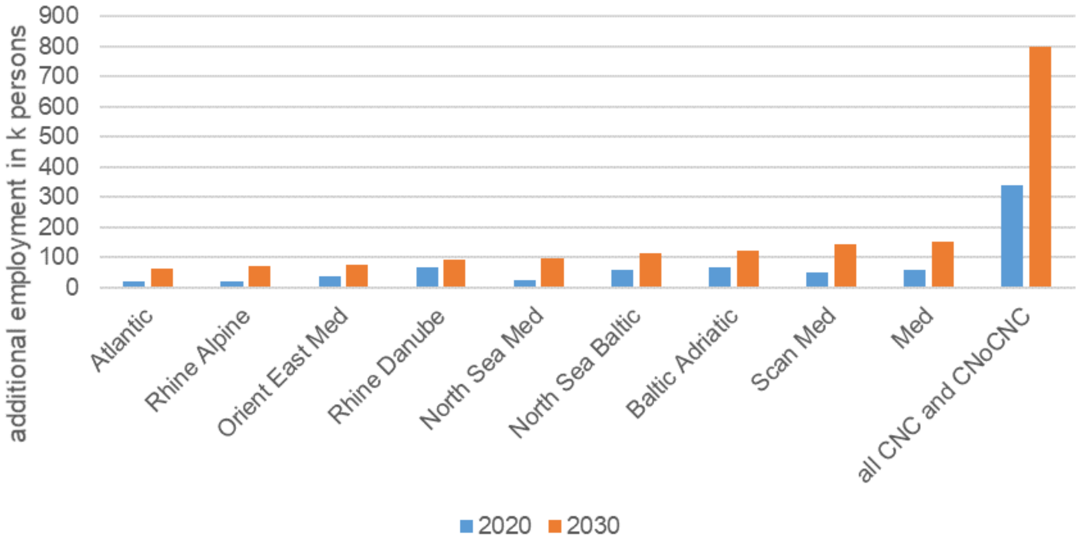
The economic stimulus of TEN-T investments is highest for the Scandinavian Mediterranean Corridor, measured as GDP change in 2030. The Scan Med also involves the largest investment sum, revealing a correlation between investment and additional GDP. This relationship is also evident for the Mediterranean Corridor, which has the second largest investment sum, and the second largest change in GDP in 2030. Figure 67 gives an overview of the impact of TEN-T investments on GDP for each CNC and all CNCs and CNoCNC relative to the Baseline.



Source: ASTRA model

Figure 67: **Impact of TEN-T investments in EU28 on GDP relative to the Baseline**

Similar to GDP changes, the two CNCs that gain the highest additional employment are the Scandinavian Mediterranean and the Mediterranean CNC. Overall in 2030, there is an additional 797,000 people employed in EU28 countries due to the TEN-T investments relative to the Baseline.



Source: ASTRA model

Figure 68: **Impact of TEN-T investments in EU28 on employment relative to the Baseline**

However, as the economic multipliers have shown (Figure 63, Figure 64), the efficiency of investments is highest for the Baltic-Adriatic Corridor. The Scan-Med and Med corridors saw the highest gains in GDP and employment, but were not as efficient as their multipliers are estimated in the middle of the range. Thus the CNCs with the highest absolute economic gains (highest effectiveness) were not identical to those in which gains were achieved most efficient (highest efficiency).

It is also important to highlight that the corridor results tend to provide an underestimation of the impacts. The reason for this is that the agreed settings in our analyses comparing the single CNC against a baseline without any CNCs will not capture the network effects of that single CNC that emerges when all CNC are implemented in total. However, in order to test this, different baselines would be required for each CNC analysis, including the 8 CNCs except the one that at this stage is analysed.

10 Conclusions

CNC are the most important instrument to organise and drive the implementation of the TEN-T core network. The CNC benefit from a focussed effort to upgrade the networks to high quality standards as defined by the TEN-T regulation. In particular, rail networks are addressed by the CNC, as well as inland waterway networks on selected corridors. Along the CNC, bottlenecks are eliminated, cross-border links are established or upgraded, and the travel speeds are increased. The results are very promising, with two-digit percentage rail travel time savings stimulating modal-shift along the CNC.

Across the whole transport system, an important element of which is the core network, and taking all rural and urban transport infrastructure into account, the impact on total modal-split is in the order of one-digit percentage changes. This is still remarkable considering that in some Member States (such as Spain or Poland) just two corridors pass through the country, and in many Member States only one CNC is established. The economic impacts, delivering a 1.6% increase in GDP across Europe relative to the Baseline, reveal the benefit of the TEN-T policy to focus on a core network that eliminates bottlenecks and connects European regions. The concept of the CNC can be productively extended by connecting with regional networks, which can be done in several ways:

- Via multi-modal terminals enabling the use of other modes for regional distribution.
- Via upgrading selected links of the comprehensive network to close gaps in the regional distribution networks.
- Via eliminating organisational barriers that might still exist at borders even after the cross-border infrastructure has been upgraded to environmentally friendly modes.

The next decade still requires a focus on completing the CNC to reap the benefits of a strong and integrated network covering Europe, which over time will be seamlessly integrated with the regional networks. This approach is well aligned with the vision of an integrated Europe that benefits the people and the economy, compared with an approach that would first fully implement regional networks and secondly link national regional networks together across borders.

An objective of complementary and equal importance is that of transport decarbonisation. The TEN-T core network implementation is contributing to decarbonisation by fostering modal-shift towards low-carbon modes. However, like other infrastructure programmes it cannot solve the decarbonisation problem alone. It must be complemented by other policies increasing the efficiency of the transport system, promoting low-emission alternative energy for transport, and low- and zero-emission vehicles, as acknowledged in the 2016 EU strategy on low-emission mobility.

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