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

FINAL REPORT - Part I - DRAFT

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Report on behalf of the European Commission

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Table of contents

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
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.
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
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

I Executive summary

Objectives

The objective of this study is to **assess the growth, jobs and greenhouse gas (GHG) emissions impacts** of the implementation of the TEN-T core network. This reflects three core objectives of European policy-making: fostering growth, creating jobs and mitigating climate change. Transport policy contributes to fulfil these objectives and one of the major pillars of the European transport policies is the implementation of the Trans-European-Transport-Network (TEN-T), which consists of a core network layer to be completed by 2030 and of a comprehensive network layer to be completed by 2050.

This study **focuses on the impacts of the core network**. It largely builds on the projects along the core network corridors and projects concerning the horizontal priorities ERTMS and Motorways of the Sea, which have been identified in the framework of the analysis undertaken on behalf of the European Commission in 2016/2017. This analysis has constituted the basis of the 3rd work plans of the eleven European Coordinators, who are facilitating cooperation along these corridors and promoting development. In addition to these coordination activities, the implementation of the core network is also supported financially, notably from the Connecting Europe Facility (CEF) and the Cohesion Fund.

It should be noted that for inland waterways the focus of the current study is on the implementation of the projects of the core network corridors (CNC) studies, while the maritime sector is not covered by the analysis. 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.

For the analysis of the **impact of the investment in the TEN-T core network between 2017 and 2030**, two scenarios have been defined: the *Baseline Scenario* and the *Reference Scenario*. In the Baseline Scenario, the implementation of the core network stops at the end of 2016 and until 2030 no further investments are assumed to be made. In the Reference Scenario the core network is assumed to be fully implemented by 2030. The Reference Scenario is consistent with the EU Reference Scenario 2016 (Capros et al. 2016).

Key results

Full implementation of the core network by 2030 has been estimated to generate the following impacts:

- An **additional 800 000 European people will be employed in 2030**

- **7,5 million person-years of jobs will be generated** between 2017 and 2030, both related to construction and to wider economic benefits thanks to improved connectivity

- An additional **GDP increase of 1,6 %** will be realised **in 2030**, compared to a situation without further TEN-T investment beyond 2016
- **26 million tons of carbon dioxide emissions will be saved** between 2017 and 2030 in the transport sector. This is expected to be complemented by noticeable additional savings which will be enabled by further alternative fuel infrastructure (electricity, natural gas, hydrogen) and their use by cleaner vehicles.

Impact of the TEN-T core network

The study has analysed the full TEN-T core network implementation by 2030 consisting of the nine core network corridors (CNC) and the remaining part of the core network that is not part of any CNC. On the CNC including horizontal priorities (in particular ERTMS) 3 037 projects have been identified to become completed between now and 2030 requiring an investment of 438 billion Euro in prices of 2005. Additional investments of 118 billion Euro are assumed to take place outside the CNC on the core network. In total the core network investment considered by the study amounts to 556 billion Euro until 2030.

Following the full implementation of the TEN-T core network in 2030, rail passenger activity is expected to increase by 8.4% in the Reference scenario relative to the Baseline (8.9% at the EU15 level and 6.0% at the EU13 level) while road (-0.7%) and air transport (-0.4%) activity slightly decreases as a consequence of the increased rail performance. The completion of the core TEN-T network is also expected to lead to an increase in rail freight transport activity of 4.7% in 2030 relative to the Baseline (2.7% for EU13 countries and 5.8% for EU15); road freight transport activity would decrease by about 0.4% and the activity of inland waterways would go up by 0.6% in 2030 relative to the Baseline. The results show thus modal shift towards more sustainable transport modes like rail and inland waterways, which increase their competitive position.

In terms of carbon dioxide (CO_2), savings of 12.5 million tonnes take place in 2030 relative to the Baseline as a result of the full TEN-T core network implementation. This is expected to lead to a cumulative reduction of CO_2 emissions from the transport sector of about 71.6 million tonnes between 2017 and 2030, out of which 26 million tonnes are expected deriving from 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. This adds to the savings already generated by the part of TEN-T network completed between 1990 and 2016.

Modal-shift to environmental friendly modes is also reducing the emissions of air pollutants from transport. The NO_x-emissions decrease by 11,000 tons in 2030 compared with the Baseline. This is equivalent to 0,7% of NO_x emissions from transport. Also the decrease of emissions of particulate matter (PM) amounts to 0,7% in 2030 in the Reference versus the Baseline.

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). Taking these policies into account would lead to much higher CO2 emissions savings on the core TEN-T network.

In terms of economic impact, the modelling exercise shows that GDP would increase by 1.6% in 2030 relative to the Baseline and additional 797,000 full-time equivalent jobs would be generated due to the completion of the core TEN-T network. The growth impact differs substantially between the newer Member States - referred to as EU13 - (+4.2%) and the older Member States – referred to as EU15 (+1.4%), with Poland and Latvia showing substantial increases. These large differences between countries are linked to: (1) the share of TEN-T investments in the total investments undertaken in a country, and (2) country specific economic endowments (e.g. labour productivity in certain sectors).

The economic impact can also be shown in relation to the level of investments. The GDP multiplier of the TEN-T investments, which amounts to 3.3, shows that for every euro invested 3.3 euros of additional GDP are created. Similarly, a multiplier can be calculated for employment. It is estimated that for every billion euro invested into the TEN-T core network between 2017 and 2030 an average of 13,000 additional job-years are generated.

In fact, the full TEN-T impacts are larger since TEN-T implementation already commenced during the 1990ies and accelerated during the 2000s, gaining further momentum after 2010, in particular also fostered by the increased funds provided by the EU to network elements delivering high EU added-value (e.g. cross-border projects).

Impact of single core network corridors

Along the CNC travel time improvements by the TEN-T implementation are remarkable, in particular for rail transport. Substantial passenger travel time savings are expected for the Mediterranean CNC with 30%, for Orient-East-Med CNC with 27.2% and North-Sea-Baltic CNC with 26.1%. Rail freight transport on CNC is accelerated stronger. Here the most considerable time savings amount to 44.4% for the Mediterranean CNC, 38.9% for the Rhine-Alpine CNC and 36.7% for the Atlantic CNC.

Looking at the transport impacts of these improvements at the level of the NUTS-I zones concerned substantial modal-shift can be observed. Passenger rail demand along the CNC increases in the range from +2.4% to +5.7%, while road loses between -0.3% to -0.4%. Thus, on the passenger side the objective to shift demand from road to rail is fulfilled. On the freight side the impacts remain more moderate with demand of rail transport increases between +0.9% to 3.1%, while trucks lose between -0.1% and -0.4%. Here it should be mentioned that the growth of GDP stimulated by TEN-T implementation is also driving freight demand such that the minor reduction of road is achieved despite an overall growing demand.

For each CNC the increased employment following its implementation has been estimated. The largest jobs stimuli are observed for the Mediterranean CNC with 153,000 additional jobs in 2030, which corresponds to the largest travel time savings of any CNC generated by implementing this CNC. Scandinavian-Mediterranean CNC comes in with 142,000 additional jobs in 2030, which corresponds to the fact that investment amount to implement this CNC are largest. The third largest employment stimulus results from the implementation of the Baltic-Adriatic CNC, which is caused by a mix of factors including substantial investment, significant time savings and the fact that Baltic-Adriatic CNC is the only CNC passing completely through newer MS (EU13). These MS have a lower labour productivity than the older MS (EU15) such that the same GDP growth in absolute terms in newer MS generates a higher number of additional jobs than it would generate in older MS.

Methodology

The study builds on (1) an extensive database of projects collected by a team of nine corridor consortia in close contact with the MS and the project promoters, (2) a thorough data validation and gap filling process, and (3) an elaborated and sophisticated modelling approach building on a transport network model (TRUST) and a transport-economy-environment integrated assessment model (ASTRA) that have been coupled to estimate the impacts of TEN-T implementation both a network level and at the level of economic agents i.e. economic sectors and MS economies.

With such an approach it is possible not only to capture the direct effects of the new transport infrastructure on the transport system and in the transport sector, but also the indirect effects in supplying industries and the second-round effects or wider economic impacts kicked-off by the economic impulses and then diffusing by economic mechanisms like higher productivity to other economic agents and into future years.

Conclusions

Implementation of the TEN-T core network following the TEN-T guidelines contributes to shifts towards more sustainable transport modes and results in significant CO_2 emissions savings. It stimulates growth in the EU, where the relative economic improvements are substantially higher in the EU13 MS than in the EU15 MS. Wider economic impacts of the core network implementation also foster employment.

II Methodological proceeding and result overview

This section summarizes the input data and the results obtained at the network level and the level of CNC for both transport impacts and economic impacts.

Investment in projects

The projects, which need to be implemented until 2030 in order to ensure core network completion, have been identified in the framework of the 'corridor studies' (status as of mid 2017) as well as of a study on the European Rail Traffic Management System (ERTMS), which were carried out on behalf of the European Commission.[1] These projects, which are directly linked with the 3rd work plans of the European Coordinators, represent a total investment sum of 438 billion Euro.

The investment required to implement the Core Network Corridors (CNC) are summarized in Table 1. In total 3 037 single projects are considered in the analysis.

Table 1: TEN-T investments on the CNC by project type (in million of euros in 2005 prices)

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
Total CNC	159 298	214 533	63 937	437 767

** Study: includes feasibility studies, market studies, technology demonstrations, etc.*
*** Construction refers to implementation of networks i.e. rail tracks, roads, tunnels, bridges, canals, etc.*
**** Rolling stock refers to investments into locomotives and rail waggons*

Source: EC, M-Five analysis

Additionally, core network projects outside the corridors are also covered in the assessment. Since no centralised information, comparable to that of the core network corridors and horizontal priorities, is available for such projects, the following approach was chosen for assessing investment needs: Gaps between existing standards (drawn from the TENtec system) and target infrastructure standards, as required by the TEN-T guidelines (EU REG 1315/2013), have been identified. They have been translated into investment needs on the basis of commonly agreed benchmark unit cost. The needs thus estimated amount to 97,4 billion Euro for railway projects and 21,1 billion Euro for road projects, i.e. 118,6 billion Euro in total.

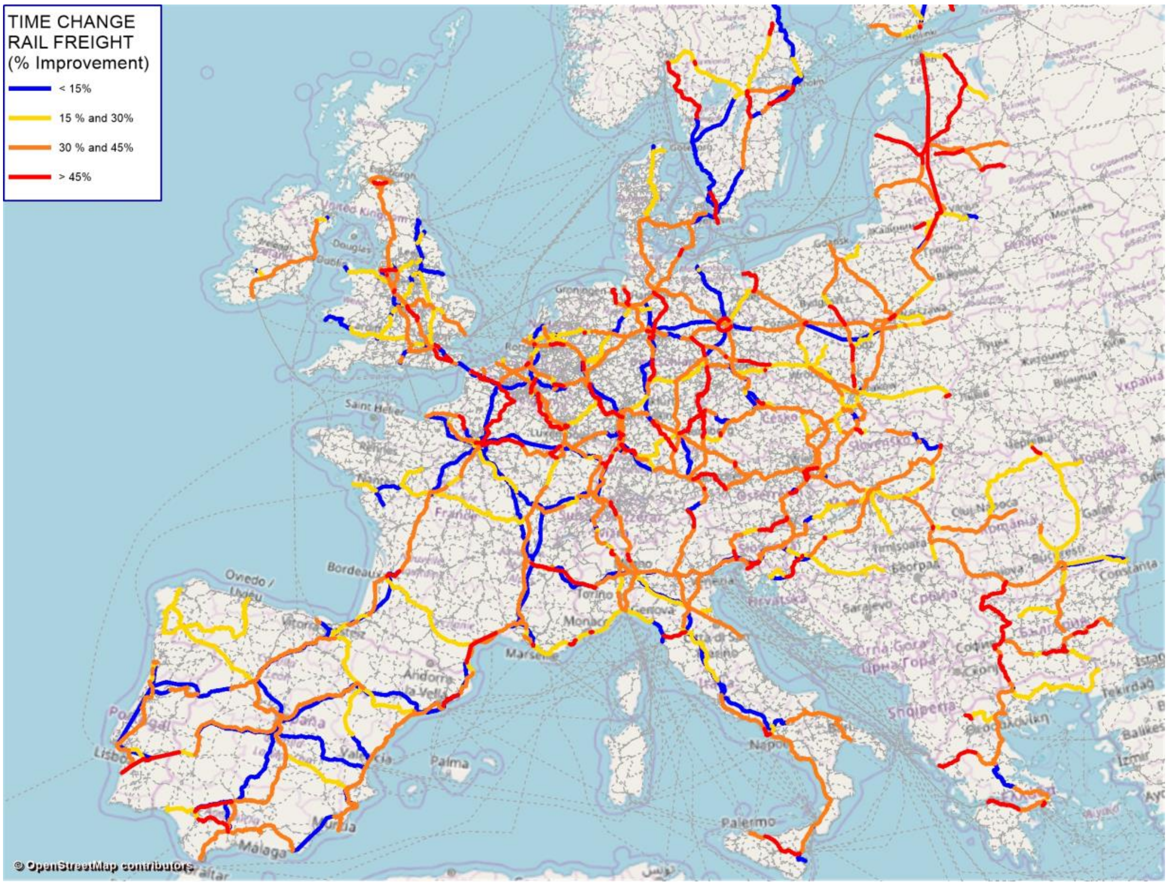
[1] The work plans and the corridor studies of each CNC including the horizontal priorities can be downloaded from this website (please click on the link of the CNC that you are interested in): https://ec.europa.eu/transport/themes/infrastructure/downloads_en

Modelling suite

A combination of two models is used for the analysis of impacts of the TEN-T: TRUST, a transport network model, and ASTRA an integrated assessment model. Both models have been applied successfully to previous impact assessment studies in the transport policy field. Modelling assumptions on the amount of investment and on the technical design parameters of the TEN-T projects have been derived from work on project identification as explained above.

Modelling results: time savings and changes in freight transport activity

The modelling of the impacts of TEN-T core network' implementation in the period 2017 to 2030 leads to estimates of travel time improvements of freight as shown in Figure 1. On some links, in particular for rail, time savings due to TEN-T core network investment will be larger than 45%.



Source: TRUST model

Figure 1: **Changes of travel time by rail freight in the Reference Scenario relative to Baseline in 2030 (% change to the Baseline)**

The improvements in travel time by rail, but also inland waterways, are expected to change the transport activity by mode. The relative position of rail and inland waterways is improving by 2030 relative to the Baseline scenario. As Table 2 shows, the rail freight activity in tonne-kilometres (tkm) increases by 5.8% in the EU15, more pronounced than in the EU13 where the increase amounts to 2.7%. Overall, at EU28 level, rail activity goes up by 4.7% in 2030 relative to the Baseline scenario.

The activity of inland waterway also increases, by 0.6% in 2030 relative to the Baseline scenario. It should be noted that for inland waterways the focus of the current study is on the implementation of the projects of the core network corridors (CNC) studies, while the maritime sector is not covered by the analysis. 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.

The demand is shifting from road to rail and inland waterways such that road transport activity decreases by around 0.4% at EU28 level (in tkm) relative to the Baseline scenario. The total freight transport performance increases by 0.6% at EU28 level, driven by the positive impacts of the core TEN-T network investments on economic growth relative to the Baseline scenario.

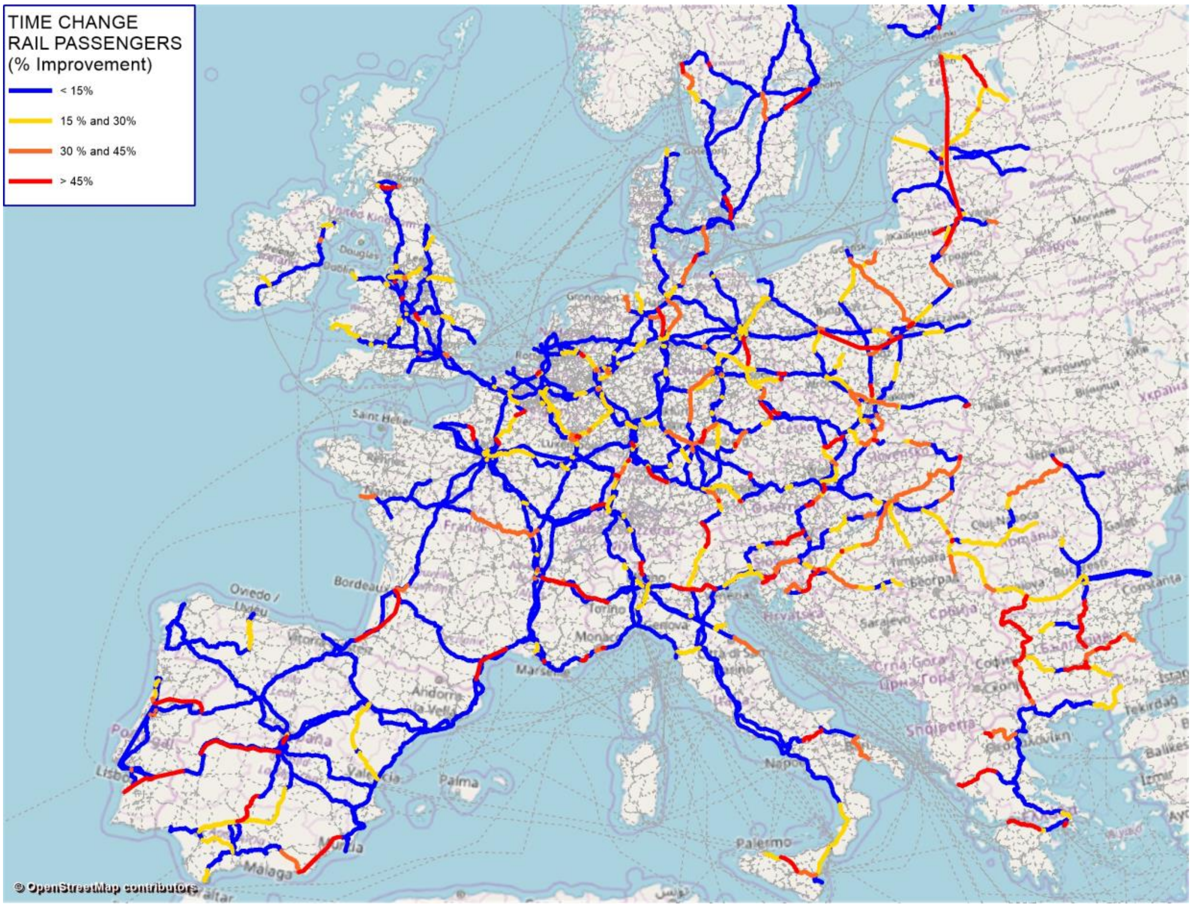
Table 2: Changes in inland freight transport activity (territoriality approach) in the Reference scenario relative to Baseline in 2030 – difference in million of tonne-kilometres and % changes

	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.

Modelling results: time savings and changes in passenger transport activity

The improvements in rail passenger travel time are slightly lower than those for rail freight, as Figure 2 reveals. For Western-Central Europe (Benelux, Germany, France) the improvements are most often less than 15% in 2030 relative to the Baseline scenario. In Eastern Europe, the improvements reach more than 45% in certain cases. The stronger improvements in rail freight transport reflect projects implementation that have the objective of making long distance rail freight transport competitive with road freight. Rail investments include substantial amounts of funds to remove bottlenecks for freight (e.g. to implement 740 metres long sidings) and to implement additional and/or more efficient freight transhipments facilities from road to rail.



Source: TRUST model

Figure 2: **Changes of travel time by passenger rail in the Reference Scenario relative to Baseline in 2030 (% change to the Baseline)**

Passenger rail transport activity also increases significantly relative to the Baseline scenario (see Table 3). Higher increase is observed for EU15 (+8.9%) compared to EU13 (+6%). Following the TEN-T core network implementation the transport performance of rail increases by 8% at the EU28 level in 2030 relative to the Baseline. On the other hand, road transport activity goes down by around 0.7% at EU28 level in 2030 relative to the Baseline.

Table 3: **Changes in inland passenger transport activity (territoriality approach) in the Reference scenario relative to Baseline in 2030 – difference in million passenger-kilometres and % changes**

	ROAD		RAIL		TOTAL	
	Delta	% Change	Delta	% Change	Delta	% Change
EU15	-38 156	**-0.7%**	52 646	**8.9%**	14 753	**0.2%**
EU13	-3 888	**-0.4%**	6 561	**6.0%**	2 673	**0.2%**
EU28	-42 044	**-0.7%**	59 207	**8.4%**	17 426	**0.2%**

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

The investment into the TEN-T core network over the period 2017 until 2030 improves the efficiency of the transport system and the competitive position of rail and inland waterways transport in Europe.

Modelling results: wider economic impacts for the EU

The effects of the core TEN-T network investments go beyond the transport system. The modelling exercise shows a wealth of economic impacts:

- Infrastructure investments have a positive impact on value-added and employment in the construction sector.
- Investments in technology like locomotives or components of the European Rail Traffic Managements System (ERTMS) foster growth and employment in the railway and electronics industry.
- Supply industries to these sectors (i.e. construction, railway, electronics industry) provide for intermediate goods and services, improving their own economic outcome.
- Transport time savings increase the productivity of the supply chains in Europe and create new opportunities for business trips in turn improving productivity.
- Sectoral productivity gains increase total factor productivity of the European economy with positive impacts on GDP.
- Increased GDP leads to second round impacts, with additional income spent by households on sectors producing goods and services.

The main macro-economic indicators calculated by the ASTRA model to measure such economic impacts induced by the implementation of the TEN-T core network are gross domestic product (GDP) and employment. Both impacts are provided by comparing the Reference Scenario (TEN-T core network fully implemented by 2030) with the Baseline Scenario (the implementation of the core network projects by 2016). The economic impacts of investments undertaken over 2017 to 2030 are presented in Table 4.

The table shows that the economic impacts are not evenly distributed over the European Union. In particular, GDP in EU13 Member States (MS) increases by 4.2% in 2030 (1.9% in 2020) relative to the Baseline thanks to the completion of the TEN-T core network. For the EU15, GDP increase is lower (0.3% in 2020 and 1.4% in 2030). Overall, GDP at EU28 level goes up by 1.6% in 2030 (0.4% in 2020) relative to the Baseline.

Since population and labour force in the EU15 are substantially larger than in EU13, the absolute increase in employment in EU15 in 2030 (about 510,000 jobs) is higher than in EU13 (around 288,000 jobs). In relative terms however, employment in EU13 goes up by 0.4% in 2030 relative to the Baseline and by 0.1% in EU15. For the EU28, 797,000 additional jobs are created in 2030 thanks to the completion of the core TEN-T network. Employment numbers are provided as full-time equivalent (FTE), in other words equivalent employees working full-time.

Table 4: Changes in GDP and employment in the Reference scenario relative to the Baseline due to the TEN-T core network implementation between 2017 and 2030

Changes in the Reference scenario relative to the Baseline	GDP		Employment (FTE)	
	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

The economic impacts can also be measured as cumulated impacts over the whole time period 2017 until 2030. To calculate this indicator the difference between the Reference and the Baseline is calculated for each year and then aggregated. The resulting cumulated impacts are shown in Table 5.

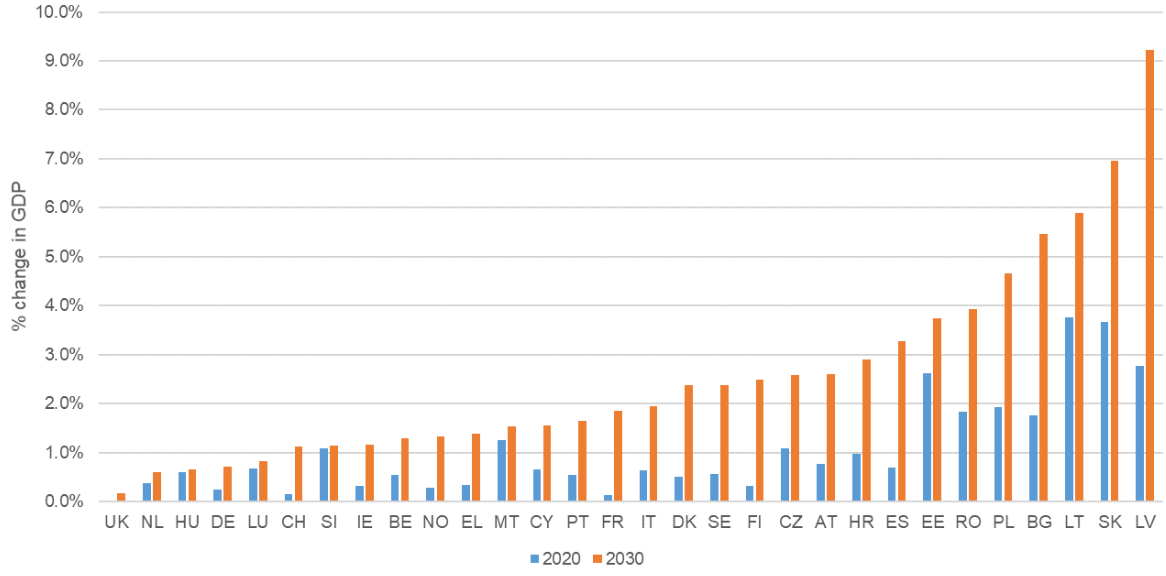
Table 5: Changes in cumulated GDP and cumulated jobs due to the TEN-T core network implementation between 2017 and 2030

Changes from baseline to reference scenario	Cumulated GDP		Cumulated job years	
	2017 to 2020	2017 to 2030	2017 to 2020	2017 to 2030
EU 15	95,000	1,400,000	457,000	4,537,000
EU 13	47,000	426,000	394,000	2,963,000
EU 28	143,000	1,826,000	851,000	7,501,000

Source: ASTRA model

Modelling results: wider economic impacts at the level of MS

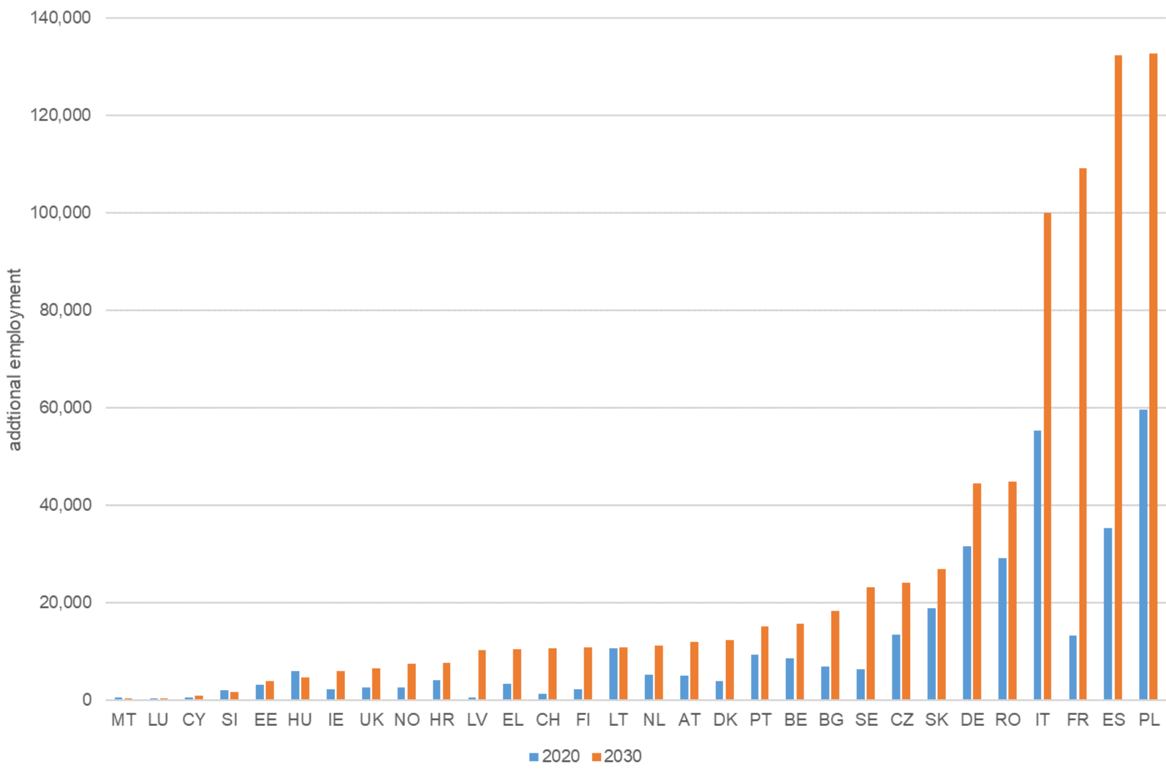
At country level, the impacts are different depending on factors, such as: the size of TEN-T investment in relation to their GDP or to their total investment; the sectoral structure of their economy; their specific improvements of transport performance; their dependency on trade and trade structure, etc. The time profile of investments and thus of improvements of travel time is also different between countries. As a consequence, the impacts on GDP vary country by country. Moderate increases in GDP of around 1% in 2030 relative to the Baseline are projected for several EU15 countries, while more substantial increases of above 3% of GDP are shown for many EU13 countries. Comparing the impacts on GDP in 2020 and in 2030 allows distinguishing, as a rough approximation, countries that benefit most from direct impacts of investments and those where the impacts due to second-round effects are more significant. For instance, countries like Luxembourg, Slovenia and Hungary, where the positive impacts on GDP are similar in 2020 (blue bar in Figure 3) and in 2030 (red bar in Figure 3), benefit most from direct impacts of investments. At the other end, countries like Bulgaria, Denmark, Sweden and Latvia, where GDP impacts in 2030 are more than the threefold of the impacts in 2020, benefit significantly of second-round effects.



Source: ASTRA model

Figure 3: **Changes in GDP in 2020 and 2030 in the Reference scenario relative to the Baseline, by country**

The impacts on employment by MS for 2020 and 2030 are presented in Figure 4. Similarly to GDP, they are different across MS. For employment, the labour productivity in the Baseline scenario (i.e. by country and at sectoral level) represents an additional important factor influencing the impacts across MS. Similarly to the GDP analysis above, MS can be differentiated between those who primarily benefit from direct effects of investments - with impacts in 2020 (blue bar in Figure 4) and in 2030 (red bar in Figure 4) being similar - and those who mostly benefit from second-round effects (i.e. 2030 impacts being two to three times higher than in 2020). The results are presented in terms of additionally jobs created, expressed as full-time equivalent (FTE). Hence, higher increases in absolute terms correspond to larger MS, with Italy, France, Spain and Poland showing more than 100,000 additional jobs created in 2030 relative to the Baseline. The impact in these MS steams mainly from the second-round effects.



Source: ASTRA model

Figure 4: **Additional jobs created in 2020 and 2030 in the Reference scenario relative to the Baseline, by country**

Impacts on decarbonisation

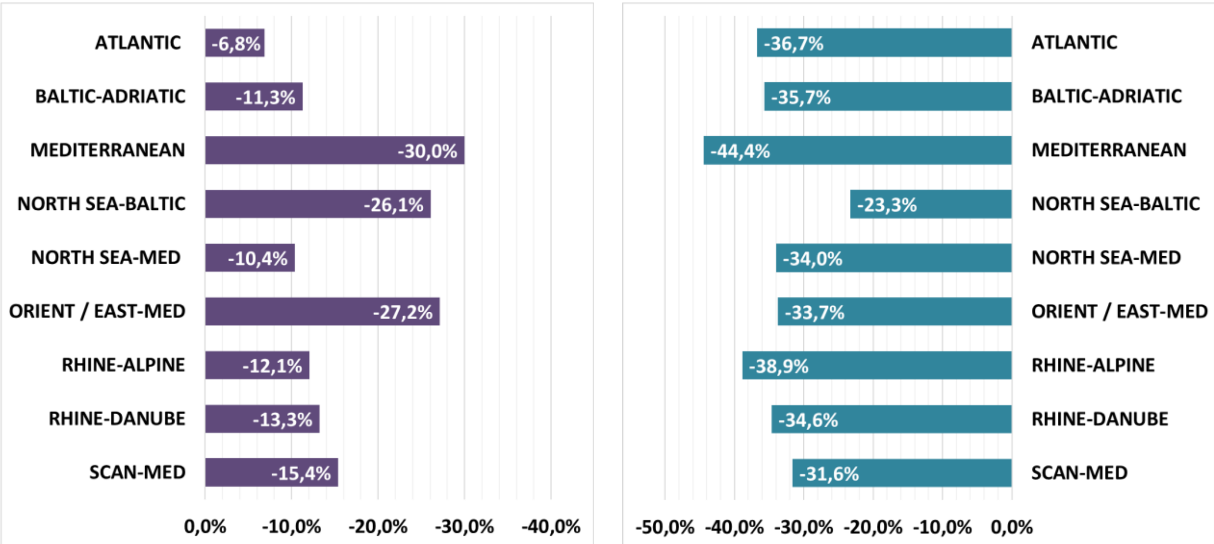
The implementation of the core TEN-T network also leads to a reduction of CO_2 emissions from transport, associated with the shift from road to more sustainable transport modes (i.e. rail and inland waterways). In 2030, the transport CO_2 emissions in the EU28 are reduced by 12.5 Mt CO_2 relative to the Baseline. Thus, we can conclude that the TEN-T core network implementation will lead to a reduction of transport CO_2 emissions by 1,4% in 2030 due to modal-shift. This is expected to lead to a cumulative reduction of CO_2 emissions from the transport sector of about 71.6 million tonnes between 2017 and 2030, out of which 26 million tonnes are expected deriving from 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. This adds to the savings already generated by the part of TEN-T network completed between 1990 and 2016.

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). Taking these policies into account would lead to much higher CO2 emissions savings on the core TEN-T network.

Modal-shift to environmental friendly modes is also reducing the emissions of air pollutants from transport. The NO_x-emissions decrease by 11,000 tons in 2030 compared with the Baseline. This is equivalent to 0,7% of NO_x emissions from transport. Also the decrease of emissions of particulate matter (PM) amounts to 0,7% in 2030 in the Reference versus the Baseline.

Modelling results: transport impacts at the level of individual core network corridors

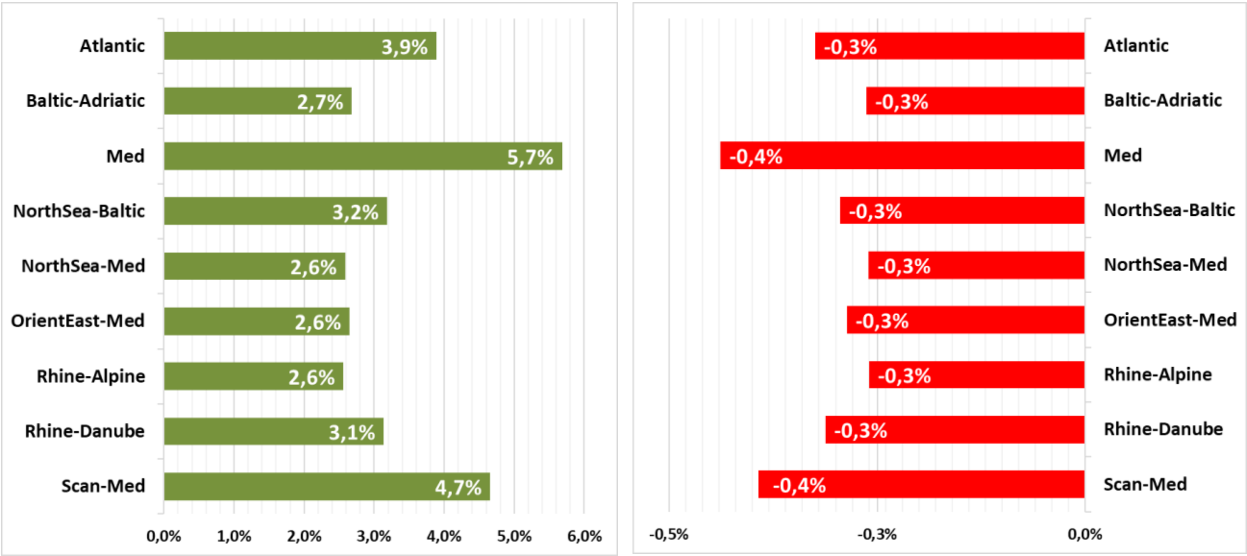
Looking at the level of corridors, Figure 5 shows that travel time improvements for passengers (left hand side in Figure 5) and freight (right hand side in Figure 5) for rail are substantial. Passenger rail time savings along the corridors range between 6.8% for the Atlantic CNC and 30% for the Mediterranean CNC in 2030 relative to the Baseline. For rail freight, the time savings range between 23.3% for the North-Sea Baltic CNC and 44.4% for the Mediterranean CNC in 2030 relative to the Baseline. Apart from North-Sea Baltic CNC, the time savings for rail freight are generally higher than those for passenger rail.



Source: TRUST model

Figure 5: **Changes in travel time by rail for passengers (left hand side) and freight (right hand side) by CNC relative to the Baseline in 2030 (% change)**

The completion of the TEN-T core network leads to a substantial increase of passenger rail transport activity (left hand side of Figure 6) and a small reduction of passenger road transport activity (right hand side of Figure 6) along the corridors in 2030 relative to the Baseline. The largest changes are observed for the Mediterranean and the Scandinavian-Mediterranean CNCs, which also constitute the two CNC with the largest investment.

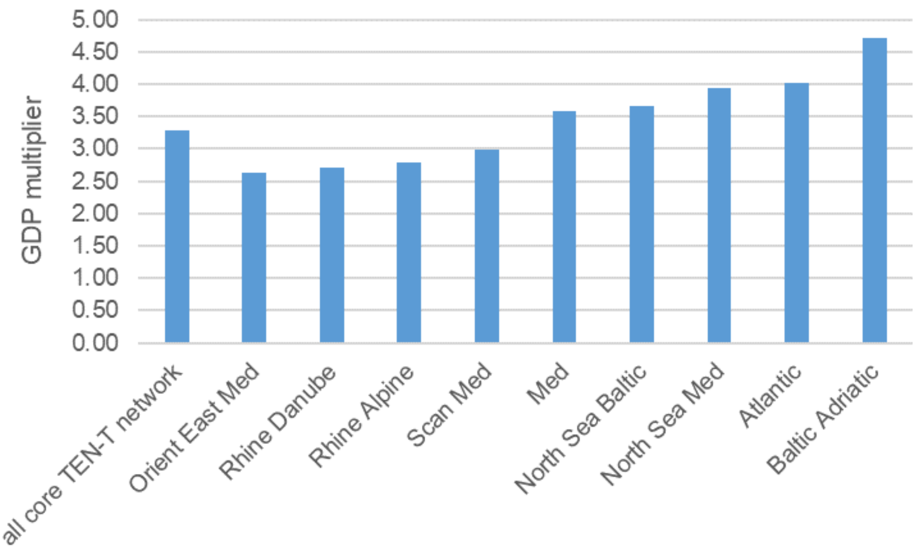


Source: ASTRA model

Figure 6: **Changes in passenger transport activity (territoriality approach) of the NUTS1 regions crossed by the core network corridors (CNC) relative to the Baseline in 2030 (% change)**

Modelling results: economic impacts at the level of individual core network corridors

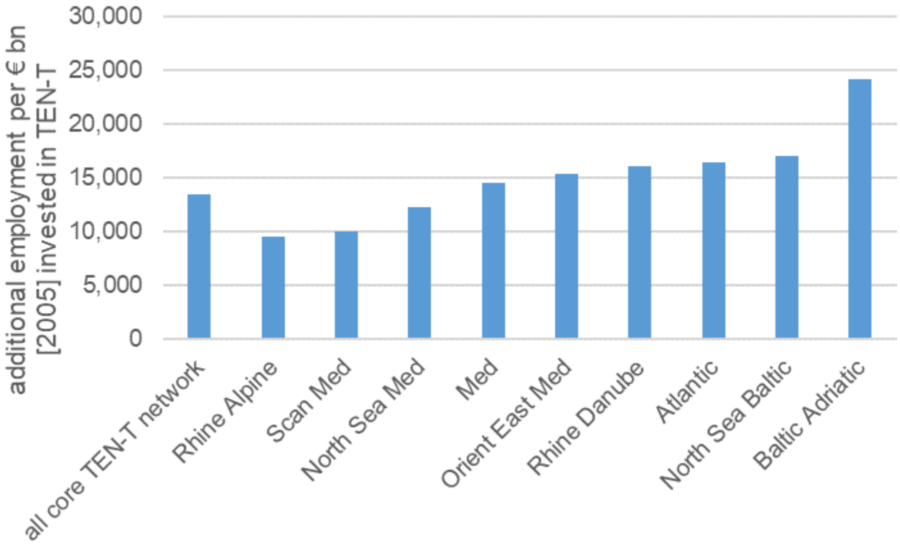
The economic impacts of the implementation of each core network corridor are summarised in Figure 7 and Figure 8. The increase of GDP in Figure 7 is represented through the GDP multiplier that provides the change of GDP aggregated over the period 2017 to 2030 in relation to the total investments along the corridor over the same period. Thus, the GDP multipliers shown in Figure 7 provide an indicator of the additional GDP created by euro invested (expressed in 2005 prices). The GDP multipliers of the corridors range between 2.6 for the Orient-East-Med CNC and 4.7 for the Baltic-Adriatic corridor. The GDP multiplier for the whole TEN-T core network over the period 2017 to 2030 amounts to 3.3, meaning that every euro invested, creates 3.3 euros of additional GDP.



Source: ASTRA model

Figure 7: **GDP multipliers for the TEN-T core network implementation between 2017 and 2030**

The change in employment induced by the TEN-T core network implementation between 2017 and 2030 is presented in Figure 8. The Baltic Adriatic (BAC) corridor shows the highest multiplier with about 24,000 additional job-years per billion Euro invested (expressed in 2005 prices) by 2030. This explains why Poland (see Figure 4), an important MS on the BAC, is benefitting most in terms of additional job-years created. Low multipliers are projected for the Rhine-Alpine and the Scandinavian-Mediterranean corridors, below 10,000 additional job-years per billion Euro invested (expressed in 2005 prices). The reason is that these corridors pass through countries with comparably high labour productivity so the same increase in investments would translate into a significantly lower impact on employment. The average multiplier for the whole TEN-T core network lies above 13,000 additional job-years per billion Euro invested (expressed in 2005 prices).



Source: ASTRA model

Figure 8: Employment multipliers for the TEN-T core network implementation between 2017 and 2030

Modelling results: long-term economic outlook

Finally, the long-term impacts of the full implementation of the TEN-T core network by 2030 have been analysed by running the ASTRA model until 2040 without adding further investments or other policy measures between 2030 and 2040. The results show the medium to long-term (until 2040) second-order effects of the TEN-T core network implementation. EU GDP is projected to increase by 2.6% relative to 1.6% in 2030. The additional jobs created amount to 1,166,000 in 2040, compared to 797,000 in 2030.

III Main text

1 Introduction

The objective of this study is to assess the growth, jobs and greenhouse gas (GHG) emissions impacts of the implementation of the TEN-T core network. This reflects the three core objectives of European policy-making: fostering growth, creating jobs and mitigating climate change. Transport policy contributes to fulfil these objectives and one of the major European transport policies is the implementation of the Trans-European-Transport-Network (TEN-T), which consists of a core network layer to be completed by 2030 and of a comprehensive network layer to be completed by 2050. The major instrument to implement the TEN-T core network is a set of nine core network corridors (CNC). The objective of this study is to assess the growth, jobs and climate impacts of the implementation of each CNC and of the TEN-T core network.

A second important element of EU transport policy concerns the funding of TEN-T projects. Therefore, assessing the impacts of the CEF funding constitutes a second objective of the study. 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 in a separate report.

For the analysis of the impact of the investment in the TEN-T core network between 2017 and 2030, two scenarios have been defined: the Baseline Scenario and the Reference Scenario. In the Baseline Scenario, the implementation of the core network stops at the end of 2016 and until 2030 no further investments are assumed to be made. In the Reference Scenario the core TEN-T network is assumed to be fully implemented by 2030. The Reference Scenario is consistent with an update of the EU Reference Scenario[2] 2016. The TEN-T core network is defined in the present study by the infrastructure projects collected in the context of the core network corridors (CNC) studies as of mid 2017 plus the sections of the core TEN-T network which are not part of the CNCs (CNoCNC), to be implemented by 2030.

The purpose of this Draft Final Report (Part I) is to report on the findings of the Reference Scenario versus the Baseline Scenario and the results of the implementation of each core network corridor. This is equivalent to the impact of the TEN-T core network implementation between 2017 and 2030. The analysis is building on a modeling 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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2 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

The report is structured into seven sections including this introduction. The section following this introduction provides a brief on the methodology for the assessment of impacts building on the integrated approach of the two models, TRUST and ASTRA. The third section explains the design of the scenarios including also 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 fifth section describes the transport impacts and the economic impacts of the implementation of the CNC, while the sixth section provides an overview on the impacts of single CNCs. A closer look at the impacts at the level of each CNC is provided in the Annex Section 11. The seventh section presents the conclusions.

The report is accompanied by an Annex with three sections with numbering subsequent tp the main text. The first section of the Annex (section 10) clarifies the economic terminology used to analyse economic impacts of transport and subsequently discusses the literature on impacts of transport infrastructure investments. The second section of the Annex (section 11) presents first the detailed transport results of each single CNC and second the detailed economic results. The third section of the Annex (section 12) elaborates on the calibration of the TRUST and ASTRA model to the update of the EU Reference Scenario 2016.

2 Brief on the project methodology

The core of the analysis of impacts builds on the interaction between a transport network model (TRUST) and an integrated assessment model (ASTRA). TRansport eUropean Simulation Tool (TRUST model) 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 of tonnes and passenger trips are estimated from various sources, including Eurostat, national statistics and the European ETIS database. The model is calibrated to reproduce tonnes-km and passengers-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 can be applied to estimate environmental impacts, in particular of road transport (i.e. CO_2 emissions and other air pollutants, such as nitrogen oxides (NOx)) considering also congestion effects).

Assessment of Transport Strategies (ASTRA model) is a System Dynamics model designed for the impact assessment of various transport policies and strategies (Fiorello et al. 2012, Schade et al. 2015). The model was also applied for economic assessment of energy and climate policies (Schade et al. 2009a, Schade et al. 2009b). The model is one of the very few tools that integrates the full transport system. It comprises a transport demand modeling, a vehicle fleet modeling, an environmental modeling with 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. With this model setting ASTRA enables 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 designed by a suitable methodology (i.e. System Dynamics simulation). It enables to run scenarios and sensitivity tests in a comparably low running time (minutes) compared with other methodologies that take hours or days for just one model simulation. 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 in ASTRA and (3) the linkages between the transport module and the macro-economic module, including the transport linkages that were fed by the TRUST model.

The macro-economic modeling of 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 all differentiated by 25 economic sectors (NACE-CLIO system) and the 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.

Core of the macro-economic modeling in ASTRA is the determination of GDP for each future year, which is resulting 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 behavior 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.

Figure 9 presents the interactions between the TRUST and the ASTRA model as well as the major inputs required by the project. Both models are calibrated to an update of the **EU Reference Scenario 2016**[3] 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

3 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

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 provided by the European Commission. Eliminating double counting of projects, 2,931 projects have been identified which are needed to implement the CNC.

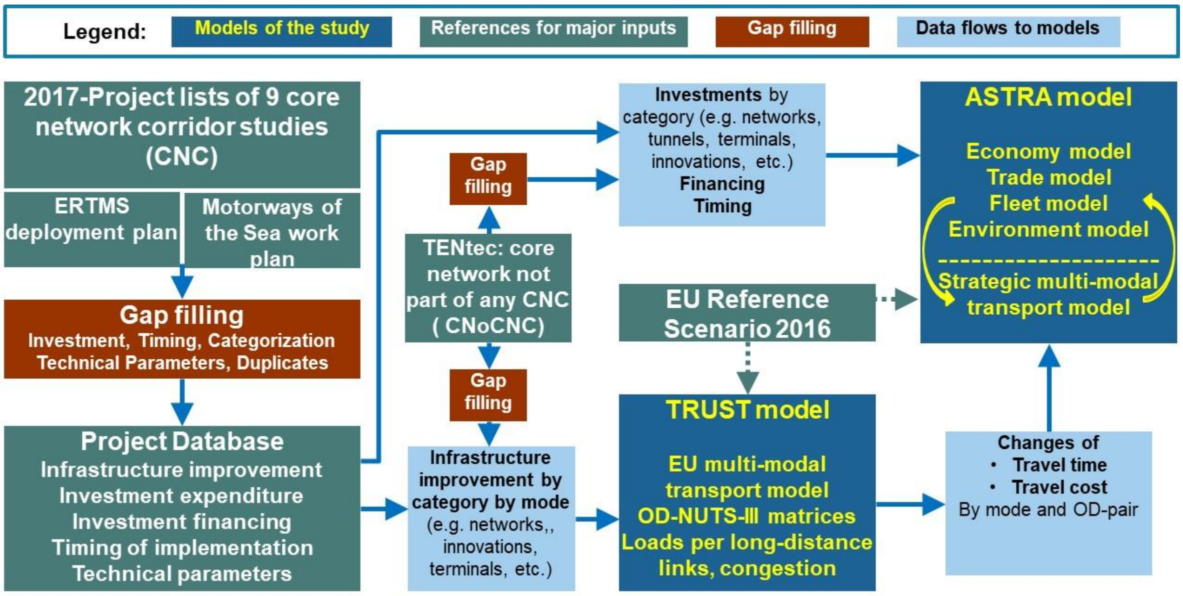
Assumptions on the implementation of the TEN-T core network over time constitute the major specific input to both models ASTRA and TRUST. Assumptions are derived from a **Project Database** specifically developed by the project team for the purpose of this assessment by building upon various sources: 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 9).

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

In addition, assumptions had to be formulated on the development of the CNoCNC network over time, estimating technical improvements and investments for the network parts that do not yet comply with TEN-T standards.

These inputs are required 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 alter directly the corresponding variables in ASTRA, which then generate new developments 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 one of ASTRA (NUTS I level) and fed into the ASTRA model such that the impacts on transport activity and, through the feedback loops of the model, on GDP, income, consumption, etc. in the Reference scenario are computed. It should be noted that the TRUST model as any transport network model is run for selected years only (i.e. 2016, 2020, 2025 and 2030), while ASTRA is projecting the impacts on all variables on a yearly basis.

It should be noted that 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 9: **Major elements of the project methodology**

Figure 9 presents major linkages of the ASTRA economic modeling with the transport sector (i.e. infrastructure investment, travel time and cost). Further linkages exist between the vehicle purchase models feeding into sectoral investment in the same way as the infrastructure investment into TEN-T do. Transport expenditures of households are considered in the household consumption models. Transport cost by mode are affecting the trade model, as an input to trade flow modeling, 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.

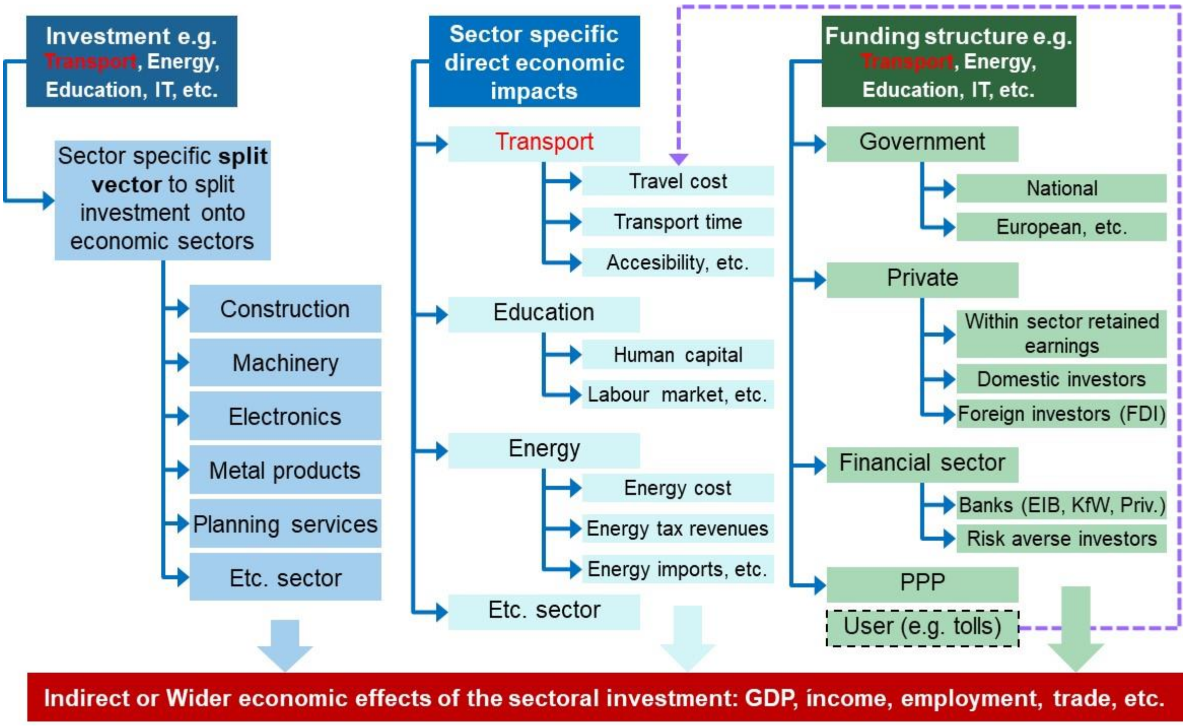
Finally, investment into TEN-T but also into other domestic transport infrastructure is considered as part of the government budget. The investments for cross-border projects for larger projects are split according to the involvement of the respective countries, where this information is available from 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).

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

Figure 10 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 the 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, like 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. In case of a road, the largest share would go by far 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 needs to be considered in the modeling, 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 modeling 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 10: **Impacts generated by transport infrastructure investments compared with investments in other sectors**

3 Design of scenarios

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

3.1 Baseline and Reference scenarios

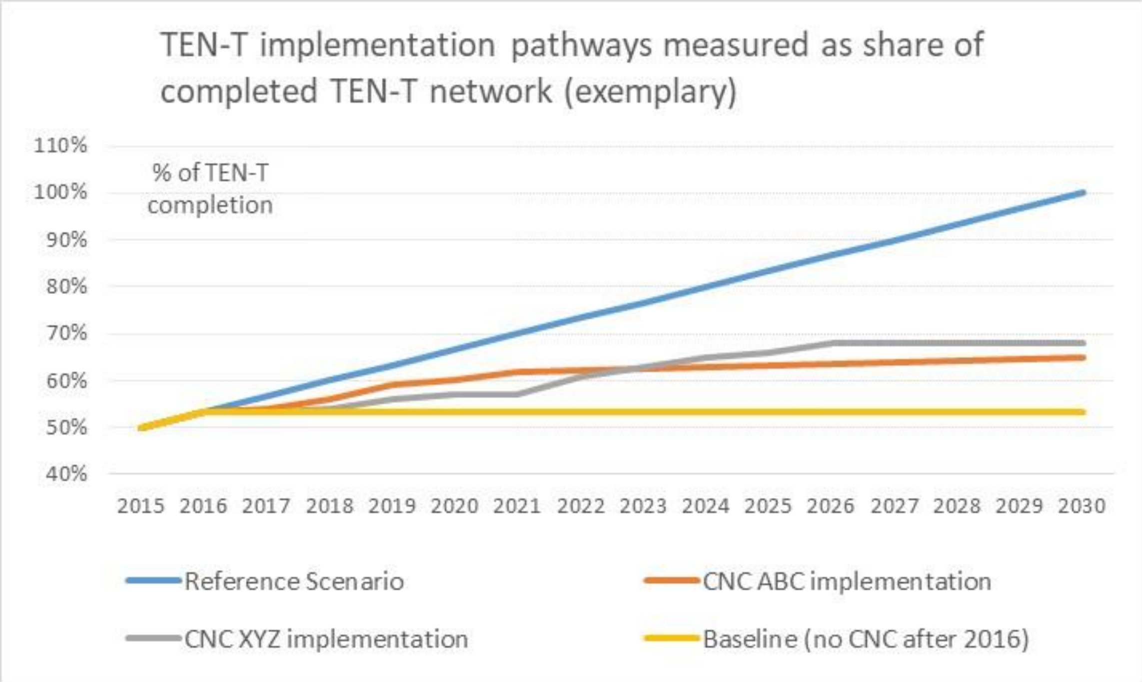
The Baseline Scenario assumes that no further TEN-T core network projects beyond 2016 are implemented. In the Reference scenario the core TEN-T network is assumed to be fully implemented by 2030. The modelling exercise has been designed in such way that the Reference Scenario in this study is consistent with the update of the EU Reference Scenario 2016[4], which 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 modeling 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, energy prices projections, etc., the Reference Scenario and the EU Reference Scenario 2016 are consistent. More detailed explanations are provided below.

The comparison of the Reference Scenario with the Baseline Scenario provides the impacts of the implementation of the full TEN-T core network.

Figure 11 presents different illustrative pathways on how the share of completed TEN-T core network is increasing over time. The starting point of completed share of TEN-T is fictitious as well as the linear trajectory representing the continuous TEN-T implementation in the Reference scenario until 2030. 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 (i.e. the share of already implemented TEN-T network remains constant between 2017 and 2030). Furthermore, two examples of possible CNC implementation scenarios (named ABC and XYZ) are provided in Figure 11. Completion of each CNC will increase the share of already

4 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.

implemented core network but 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 11: 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: higher speeds and lower levels of congestion than in the Baseline Scenario.

3.2 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 needed to comply with the EU Reference Scenario 2016.

3.3 Implementation of the core network corridors (CNC)

The impacts of the implementation of each core network corridor (CNC) has been assessed separately in relation to the Baseline Scenario (see also Figure 12):

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

[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 roughly account for 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 this part of the network as CNoCNC.

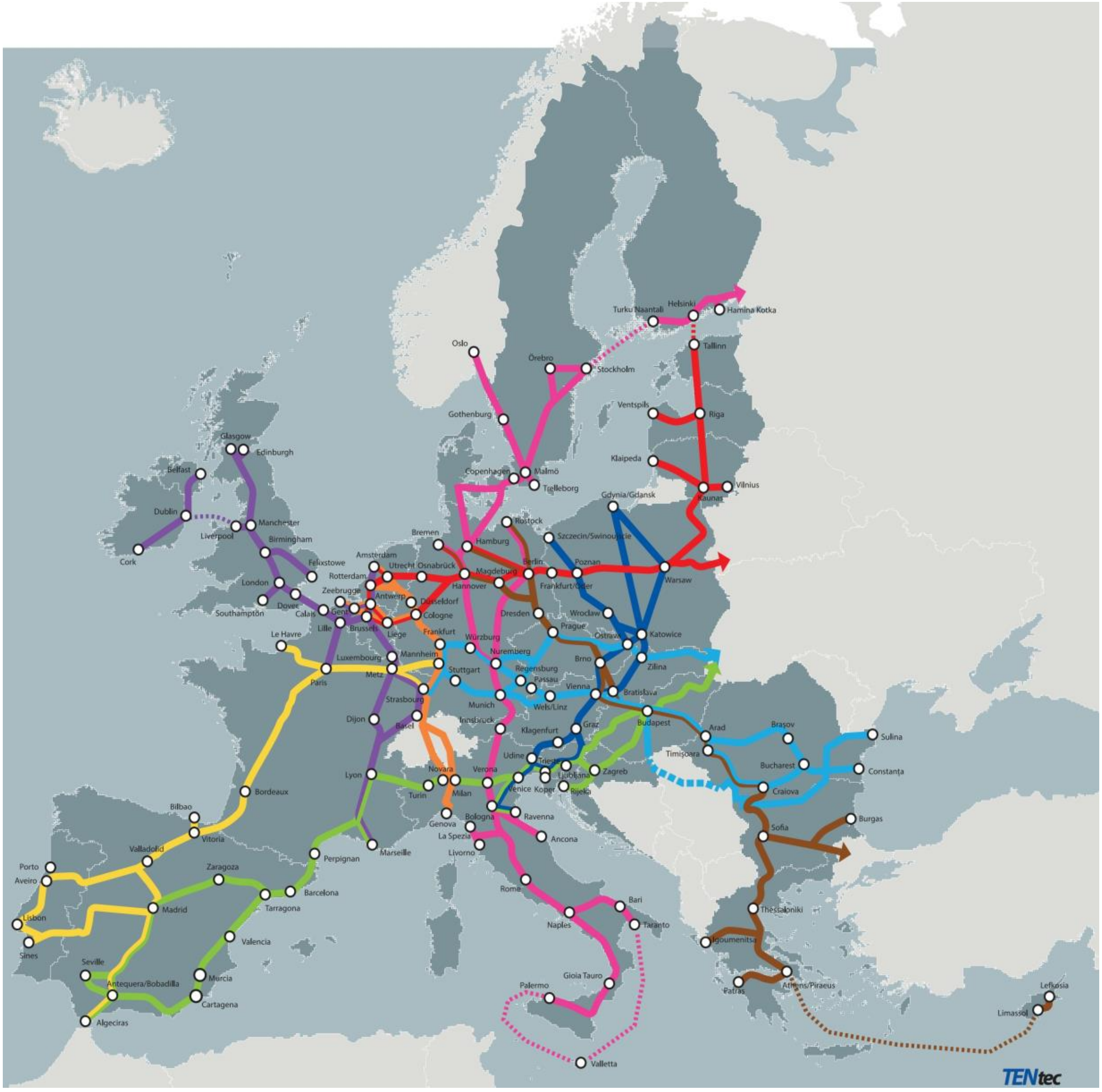


Figure 12: **Map of the nine CNC**

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

The TEN-T core network is composed by the nine TEN-T core network corridors (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.

3.5 Preparation of the TRUST model

3.5.1 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 by the EC. Other information sources provided by the Commission 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 into the CNC's projects' list revealed several data gaps, covering financial and technical aspects. To fill in the detected data gaps, a multi-step approach was followed. In a first step the project team derived technical information for the project's description. A second step required the involvement of the experts of all nine CNCs who were requested to fill in both 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 into 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 a faster identification of projects completed at different time horizons (i.e. 2020, 2025 and 2030) together with their technical characteristics and to speed up the implementation of TRUST model's network assumptions.

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 projects exist 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 reflect the assumptions implemented for taking 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.

3.5.2 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 6: Average changes in travel time on the upgraded part of the Core-non-CNCs 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

3.6 Preparation of the ASTRA model

3.6.1 Modelling the impact on transport

This study focuses on modelling the impact of the completion of the TEN-T core network as resulting from 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.

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

Besides the input deriving from TRUST, the modelling of transport impact within ASTRA encompassed the implementation of 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 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 7 assumptions on reduction of transport costs (-3% for unitised, bulk and general cargo commodities) and of travel time (-15%) have been implemented.

Table 7: 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 in terms of 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 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.

3.6.2 Modelling the economic impact

As a first step in the preparation of the economic modeling in ASTRA the Reference Scenario in ASTRA-EC was calibrated against the aggregated economic projections of the updated EU Reference Scenario 2016[6]. 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 13. 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, and (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.

6 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. 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 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 13: 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.

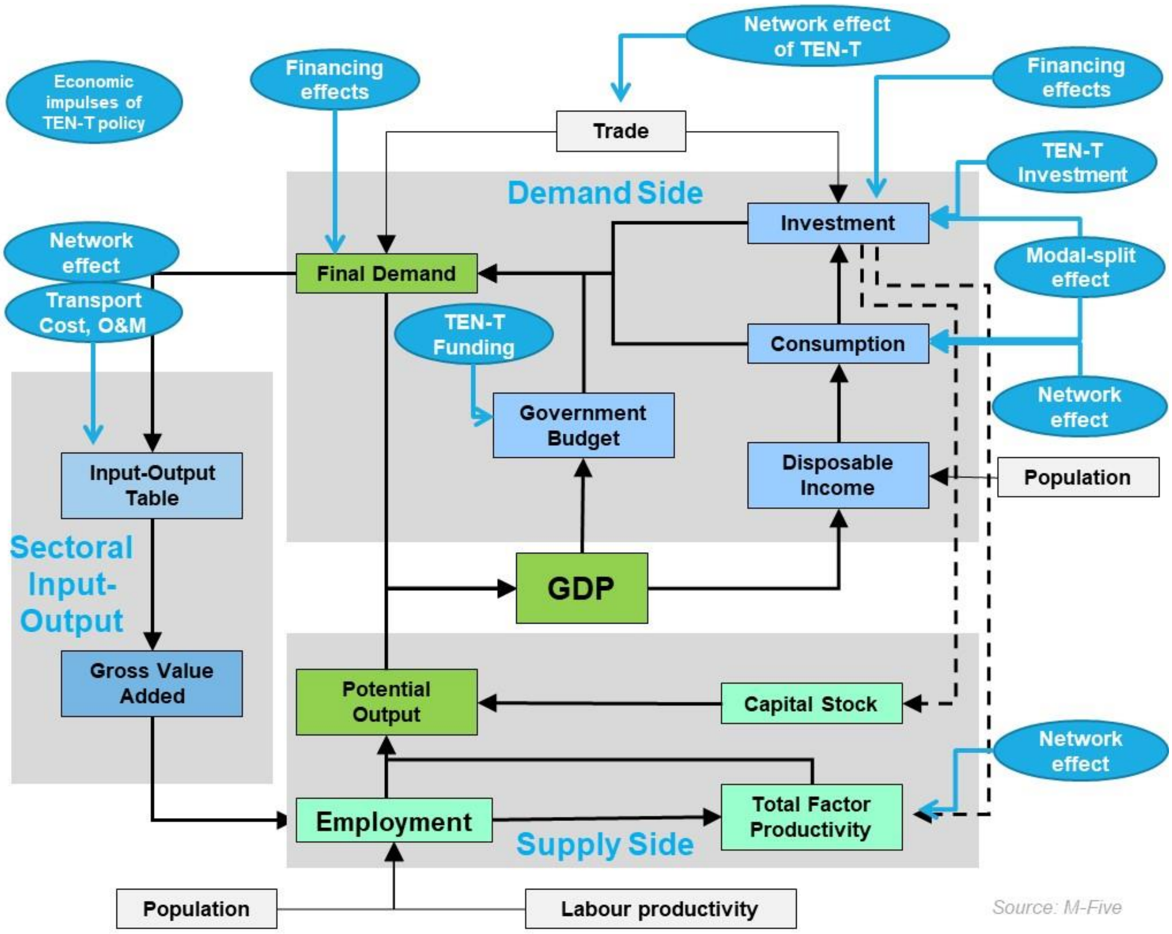


Figure 13: **Overview of the TEN-T impulses and the macroeconomic core of ASTRA**

3.6.3 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 € 603bn[7]. Of these investments € 438 bn are planned to be

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

spend in the period 2017 to 2030 (see Table 8). In the same period the TEN-T core network investments (i.e. the investments on the nine CNCs and the CNoCNC network account for € 556 bn).

In the database 1,363 projects resulting in an investment sum of € 169 bn. lie on more than one corridor. Analysing each corridor such projects are double counted as they are considered for each CNC. Hence, in Table 8 the sum over all nine individual CNC investment 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 8: 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 9). 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 9: 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 10. The largest TEN-T investments relatively 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 10: 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 bn. for 2017 to 2020 and € 203 bn for 2021 to 2026). ERTMS projects account for € 20 bn. between 2017 and 2030 with the largest share invested in the first three years.[8] ERTMS projects are divided in on board ERTMS projects and ERTMS track side projects. Overall, ERTMS track side projects are

8 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.

smaller than on board projects. The investments for the other project types *Study*, *Rolling Stock* and *Clean Fuel* are summarised in Table 11.

Table 11: TEN-T investments in the CNC by project type in Mio Euro$_{2005}$

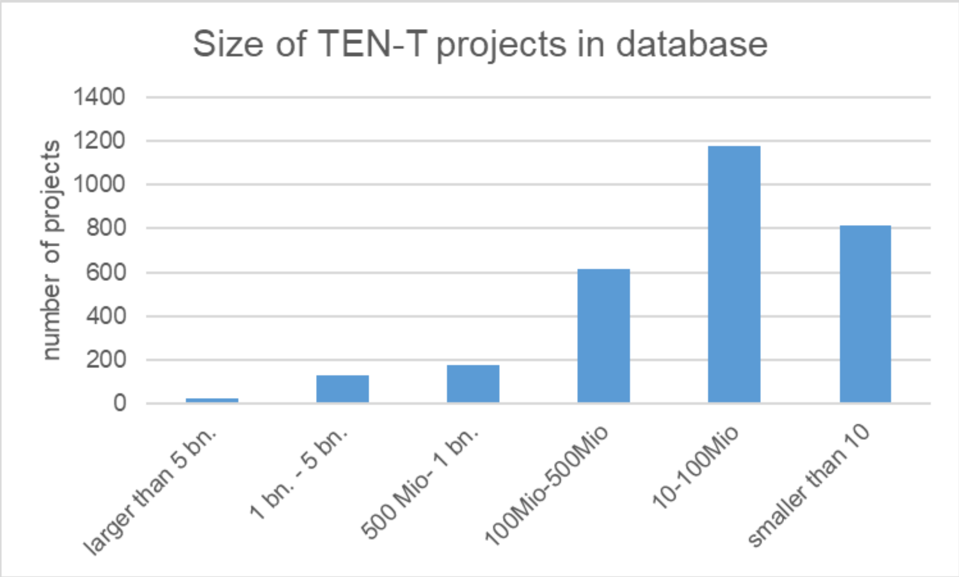
Investment type	2017-2020	2021-2026	2027-2030	2017-2030
ERTMS on board	8,853	7,023	1,388	17,263
ERTMS track side	1,499	1,190	235	2,924
Study	4,106	2,230	310	6,646
Construction	143,510	203,400	61,970	408,880
Rolling Stock	12	198	0	210
Clean Fuel	1,318	492	34	1,844
Total CNC	159,298	214,533	63,937	437,767

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. Depending on the sector where the investment is made, the multiplier differs causing different growth rates on a sectoral level as well as 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 MS. 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 Annex (see section 10).

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 some parts going to the construction sector. Investments in ERTMS have a high share in the electronics sector and influence also the computers sector and construction. Rolling stock impacts largely the vehicles sector.

The project size on the CNC differs significantly. The distribution of project size is shown in Figure 14. On the CNC there are 20 projects with a budget of more than € 5 bn. and 126 with a budget between € 1 bn. and € 5 bn. 1,181 projects, and thereby the largest number of projects, show investments of € 10 Mio to € 100 Mio. The biggest projects may even have a significant impact on the national economy, whereas the smaller projects 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 14: Distribution of investment volumes of TEN-T CNC projects in the project database in Euro$_{2005}$

Table 12 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 and Germany with 16%, followed by France with 12%, Poland with 6% and Spain with 5% of total TEN-T core network investments. Since the 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, additional checks on the level of debt of some of these countries and their 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 not to be critical.

Table 12: Distribution of TEN-T Investment per Country in Mio Euro$_{2005}$ and shares in total TEN-T investments

Country	2017-2020	2021-2025	2026-2030	2017-2030	Share per country
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 core network corridors (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 with planned or ongoing works on the networks have been identified. These network sections will contribute to the overall core network efficiency improvement but are not located on any of the 9 CNC. We call them the CNoCNC sections.

To assess the investment costs for those CNoCNC sections cost benchmarks are used building on the project database of the CNC. The existing project database is used to identify and cluster similar projects and match them with the categories of CNoCNC sections. The clustering follows in accordance with project characteristics like 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 estimated for HSR new construction, which was estimated to be in proportion to the cost benchmark for conventional railways. In complex landscape requiring larger numbers of tunnels and bridges cost per km of new construction of HSR can be substantially higher.

According to the available information on CNoCNC sections, they can be differentiated in 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 13.

Table 13: 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 reveal that it is relevant to distinguish projects in EU15 and in EU13. Such a distinction is made between the EU15 countries (+Norway) and the EU13, 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 14).

Table 14: 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.

3.6.4 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 (MS): 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 MS. Government spending in ASTRA is assumed to have a Keynesian multiplier effect. In the Reference scenario government expenditures are then higher.
2. EU funds: The effects are similar to those of the 'pure' MS financing as described in point 1. However, in the Reference Scenario a certain level of 'crowding out' is assumed.
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 MS increase the government expenditures. This results in higher budget deficits. However, this possibility might not be feasible for every MS. However, for simplicity we assume that there are no distorting effects on national budgets in the Reference scenario.

Table 15 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 around € 143 bn. Another large part of funding comes from other EU funds such as the Cohesion Fund and account to more than € 25 bn. of investment in the period 2017 to 2021. Also, the CEF fund contributes significantly, with more than € 16 bn. invested in the same period. Private funds account for another € 10 bn. and EIB funds for € 8 bn. 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 15: 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 also projects falling under the realm of PPPs are treated risk-wise like regular government bonds for the respective MS. 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.

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

Where

Exp^{Gov}	=	Government Expenditures
Con^{Gov}	=	Government Consumption
Inv^{Gov}	=	Government Investments
$Inv^{Networks}$	=	Investments transport infrastructure
$Transf^{Gov \rightarrow F}$	=	Transfer from Governments to private firms (e.g. subsidies)
$Transf^{Gov \rightarrow HH}$	=	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 be also 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)

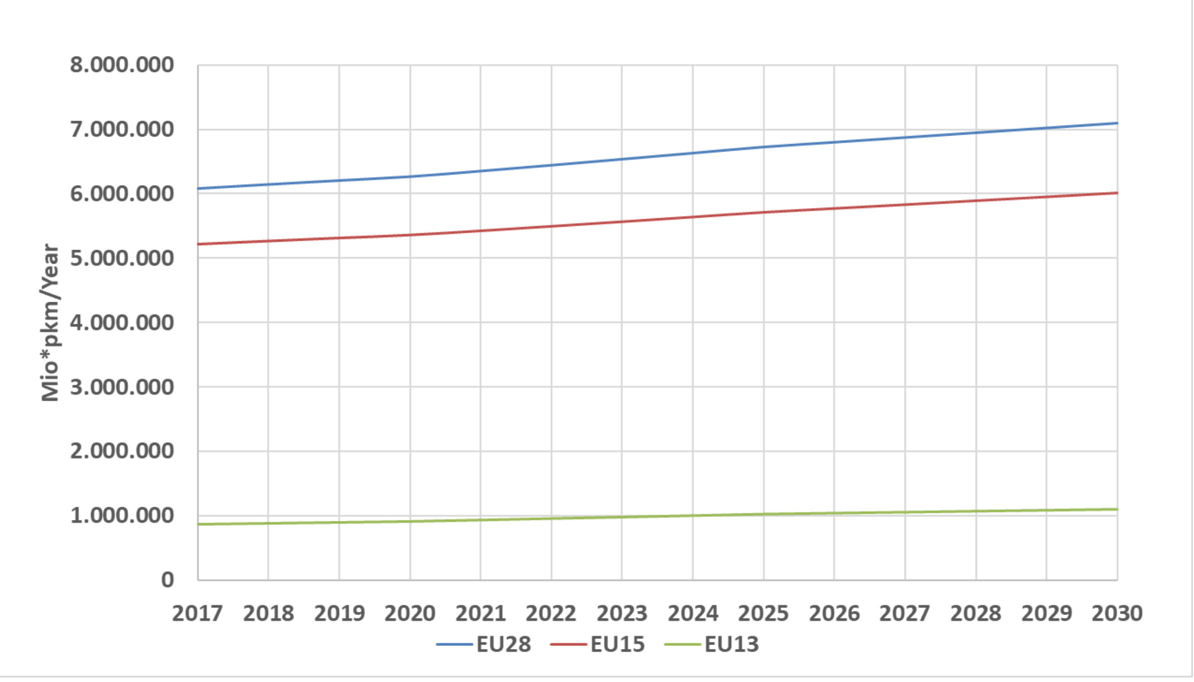
4 Baseline Scenario results

The Baseline Scenario results are described in the following two sections. The impact of the core network and the CNCs implementation is measured against this Baseline Scenario. 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 2020, 2025, 2030 through model runs performed with the network of the base year and demand matrices for 2020, 2025 and 2030.

4.1 Transport activity projections

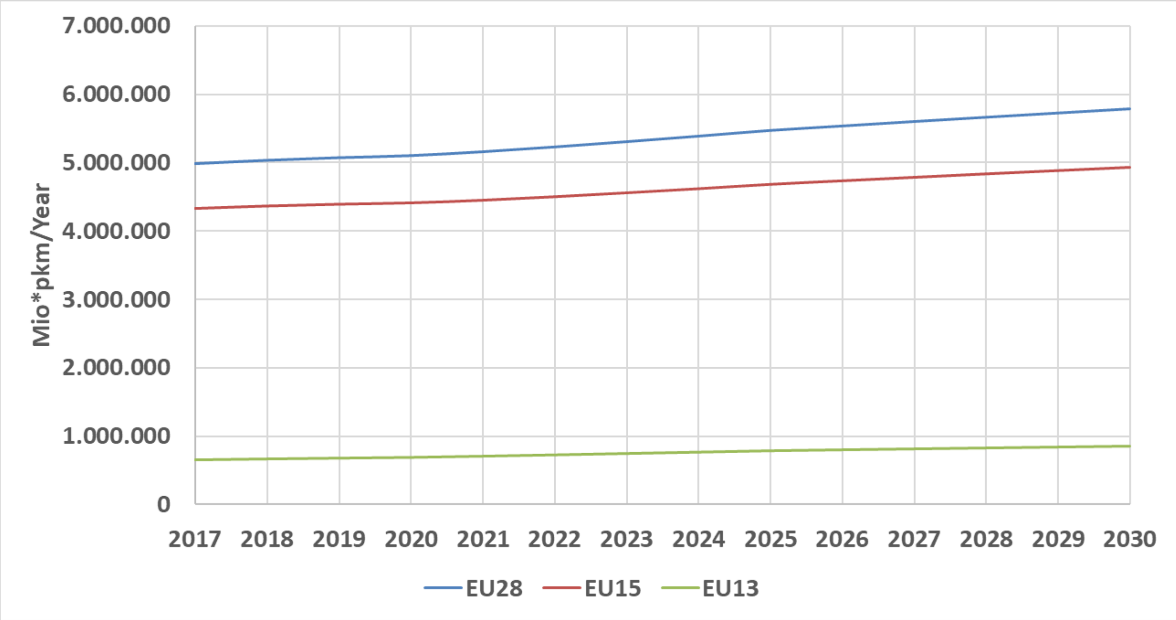
ASTRA model key transport activity results for the Baseline scenario for passengers and freight are given in the following figures. Total passenger transport activity (car, bus and rail) in the Baseline scenario is expected to increase by 17% between 2017 and 2030 at the EU28 level (15% for EU15 Member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

Similar results are shown for the transport activity by car (see Figure 16) which is expected to increase by 16% at the EU28 level (+14% in EU15; +30% in EU13).



Source: ASTRA model

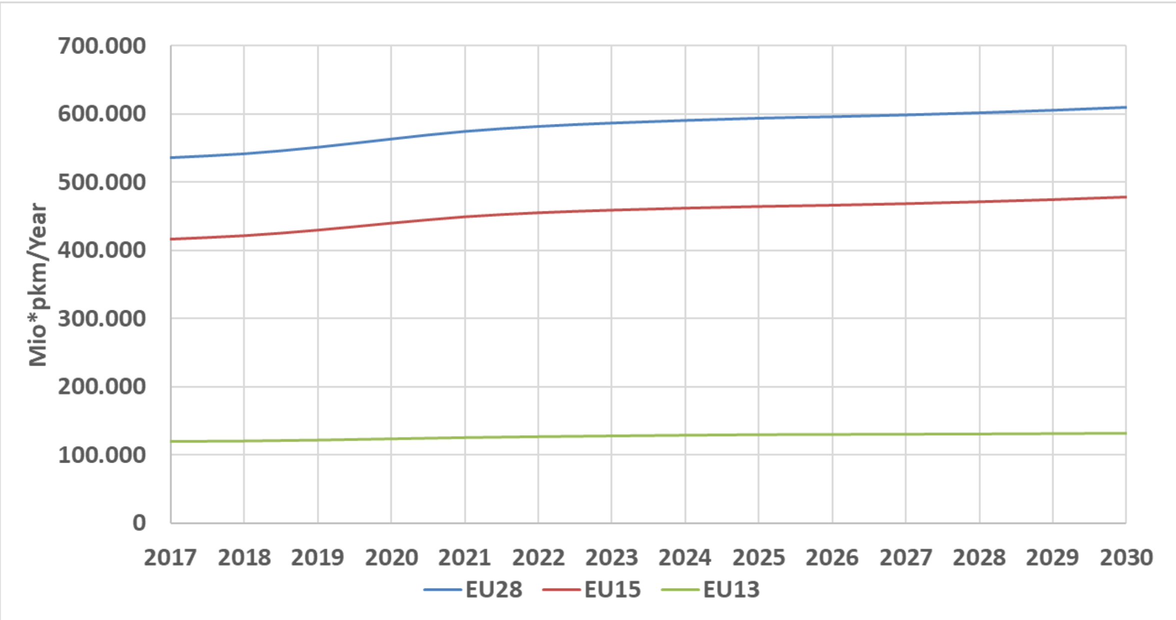
Figure 15: Total passenger transport activity (territoriality approach) in the Baseline scenario



Source: ASTRA model

Figure 16: **Passenger cars transport activity (territoriality approach) in the Baseline scenario**

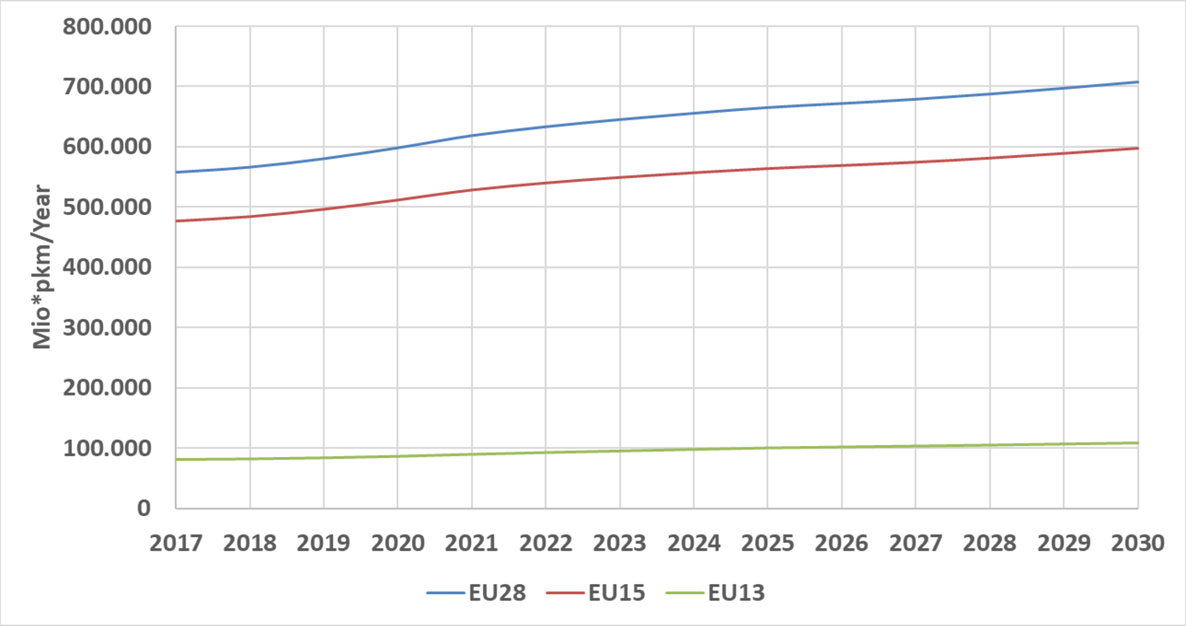
Transport activity by buses and coaches in the period 2017-2030 would go up by 10% at EU level (+15% for EU15 and +10% for EU13 countries) as shown in Figure 17.



Source: ASTRA model

Figure 17: **Buses and coaches transport activity (territoriality approach) in the Baseline scenario**

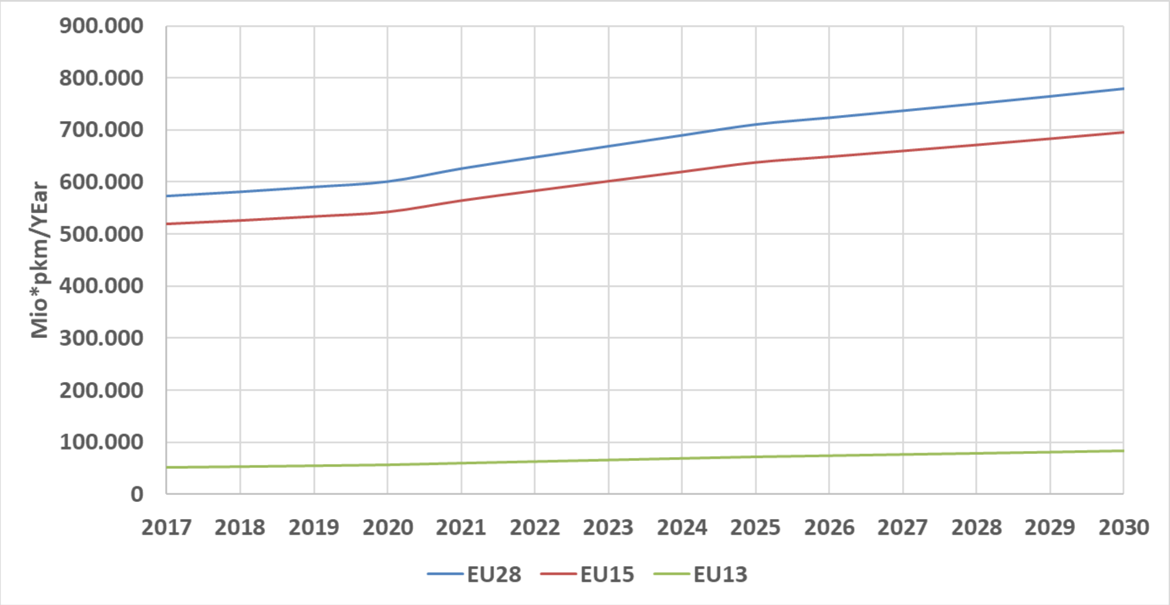
Rail passenger transport activity in the Baseline scenario is expected to increase faster relative to road, by 27% between 2017 and 2030 at the EU28 level (+25% for EU15 Member States and +34% for EU13).



Source: ASTRA model

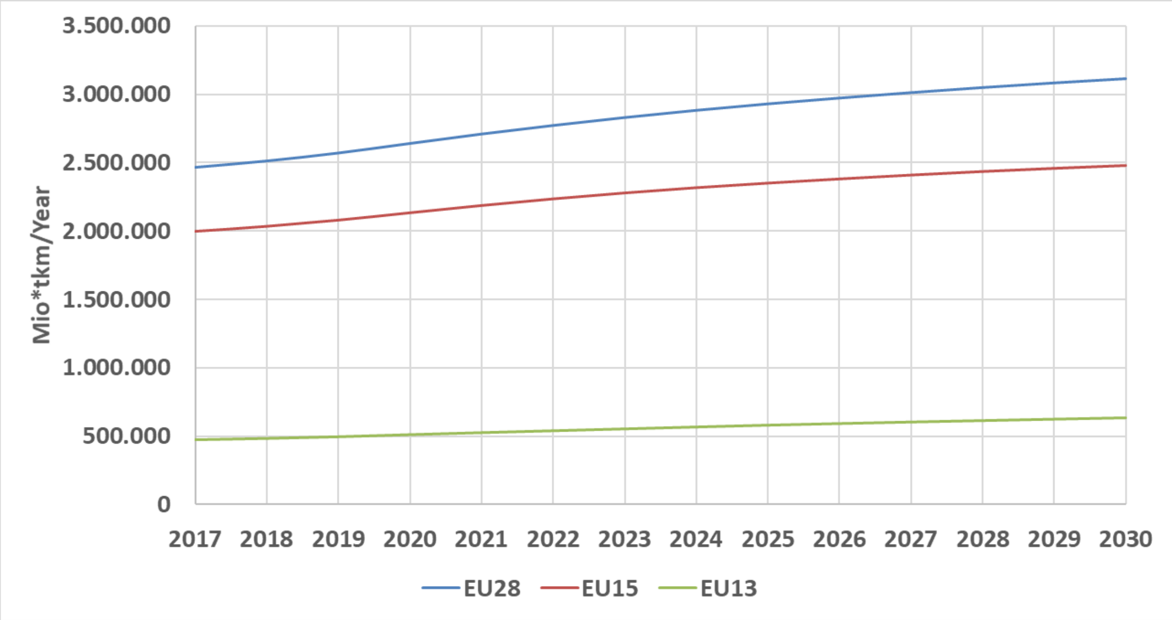
Figure 18: **Passenger rail transport activity (territoriality approach) in the Baseline scenario**

Air transport activity in the period 2017-2030, illustrated in Figure 19, shows an overall increase of 36% at the EU28 level (+36% for EU15 and +60% for EU13 countries).



Source: ASTRA model

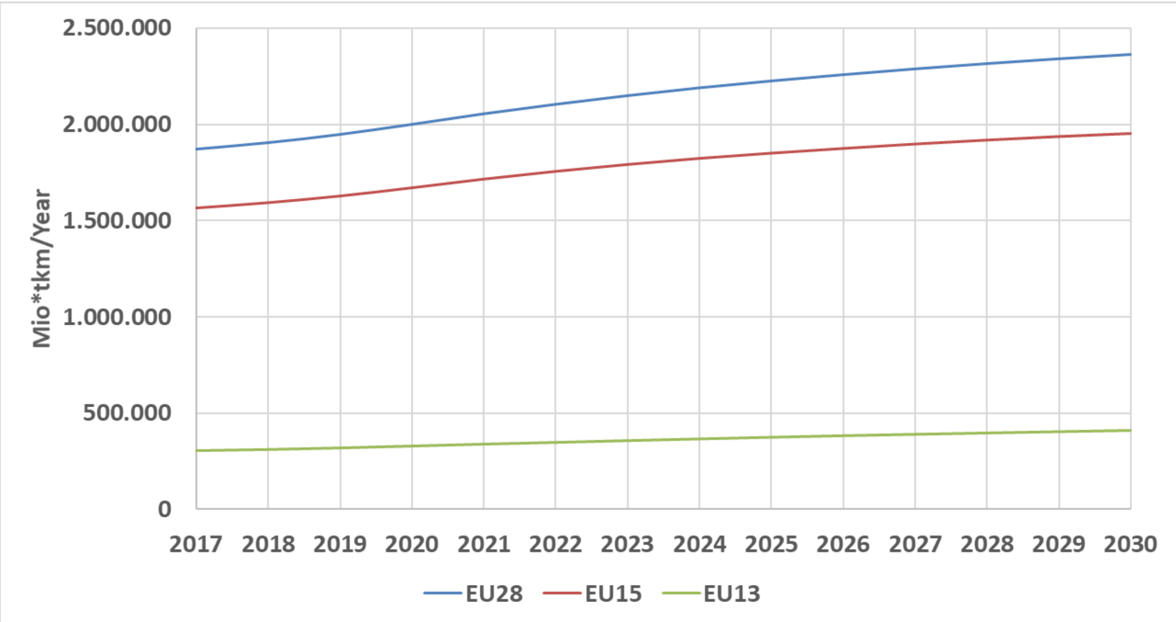
Figure 19: **Air passenger transport activity in the Baseline scenario**



Source: ASTRA model

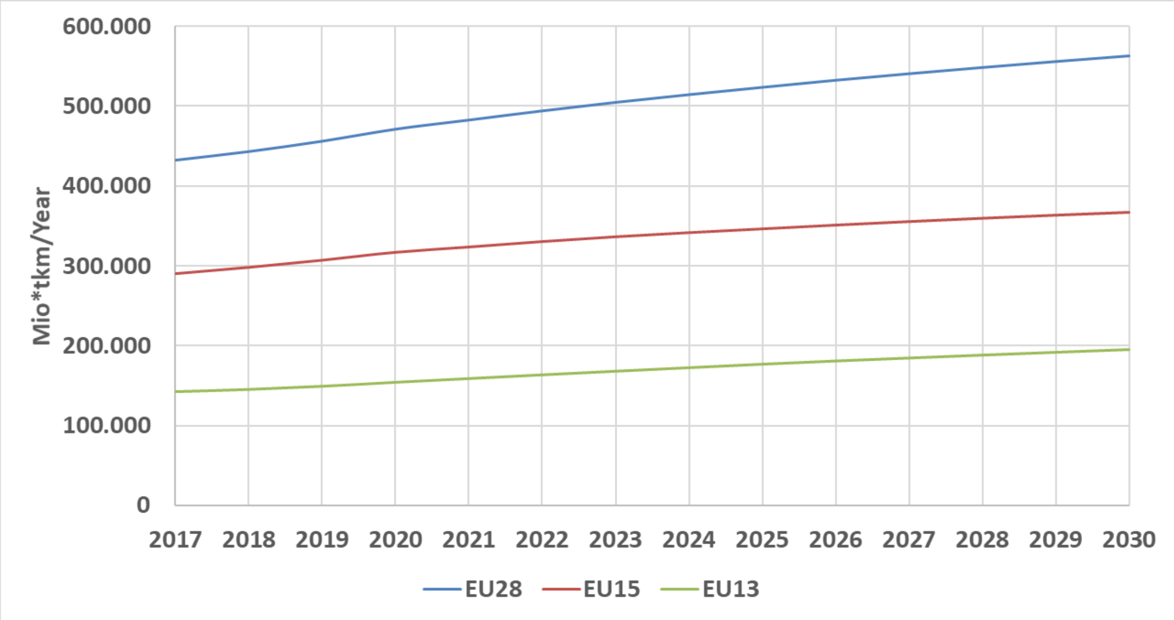
Figure 20: **Total freight transport activity (territoriality approach) in the Baseline scenario**

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

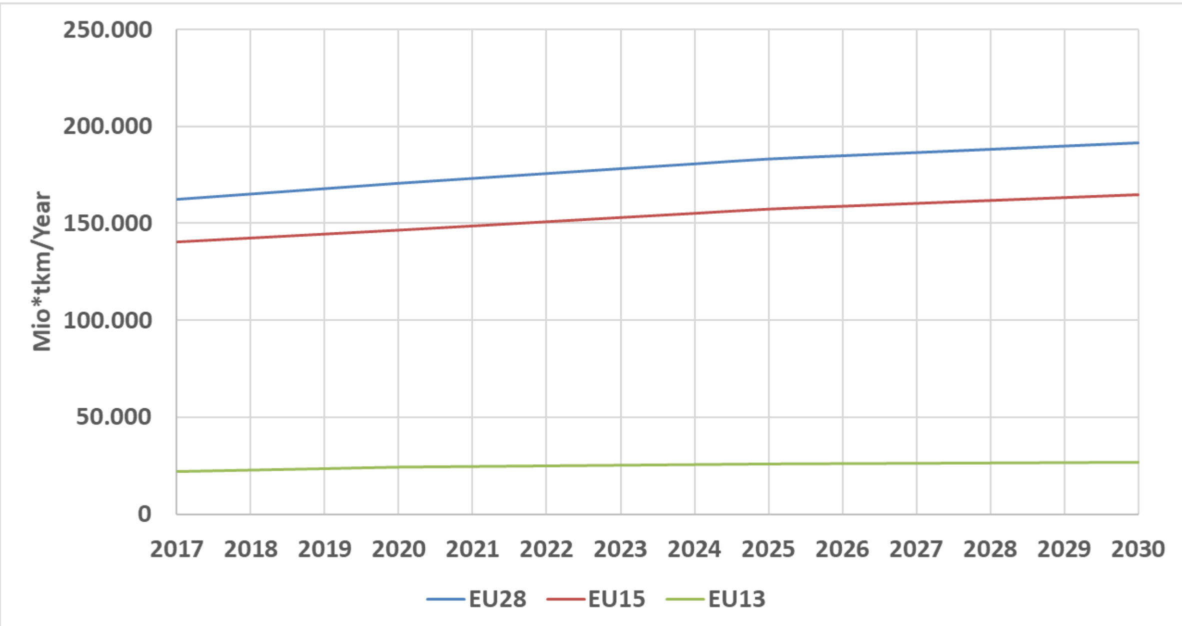
Figure 21: **Road freight transport activity (territoriality approach) in the Baseline scenario**



Source: ASTRA model

Figure 22: **Rail freight transport activity (territoriality approach) in the Baseline scenario**

Increase of rail freight activity in 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 22). Somewhat lower growth is projected for transport activity by inland waterways in the Baseline scenario (see Figure 23) which shows an overall increase of 18% at the EU28 level (+17% for EU15 and +20% for EU13 countries).

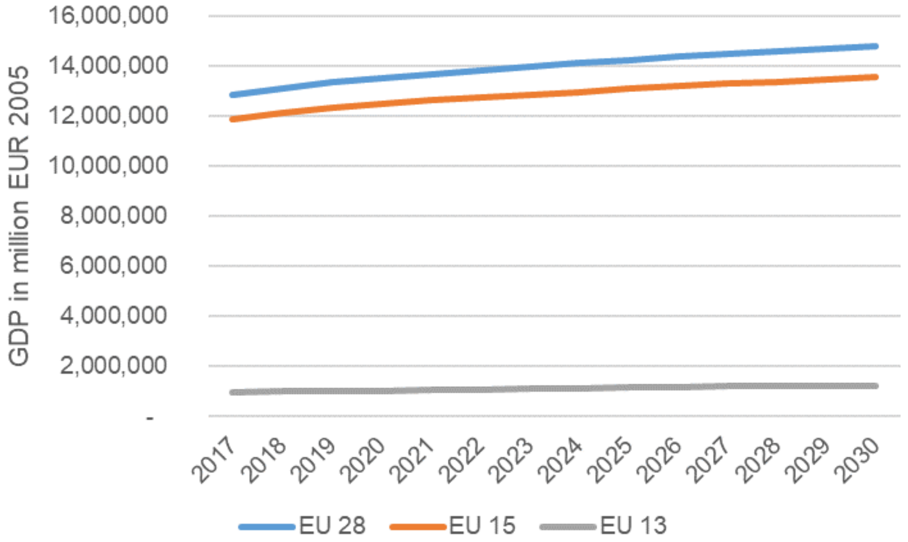


Source: ASTRA model

Figure 23: **Inland waterways freight transport activity (territoriality approach) in the Baseline scenario**

4.2 Macro-economic projections

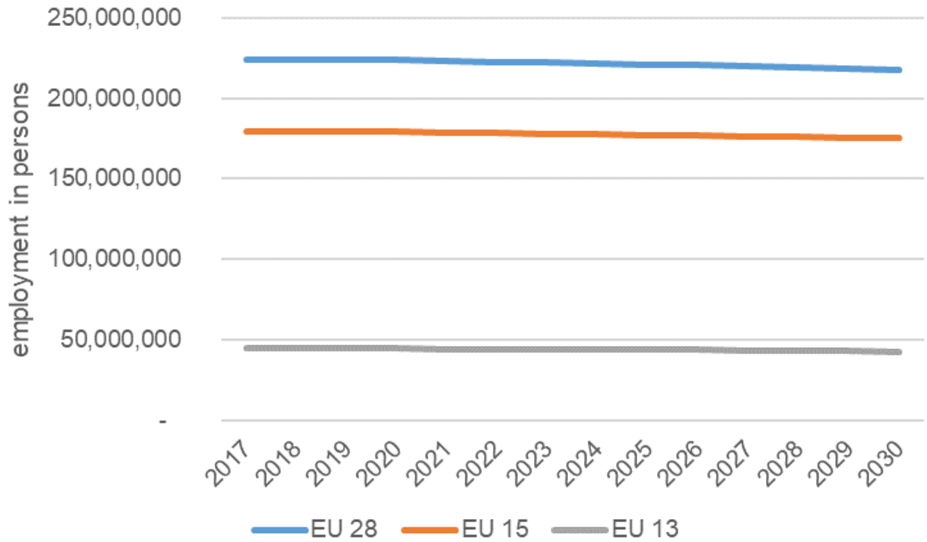
Figure 24 illustrates the GDP developments in the Baseline Scenario, without the impact of TEN-T investments beyond 2016. GDP is projected to grow by 1.1% per year during 2017-2030 (1.0% per year for EU15 and 1.9% per year for EU13).



Source: ASTRA model

Figure 24: **GDP projections in the Baseline Scenario**

Figure 25 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 25: **Trend of employment in Baseline Scenario**

5 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.

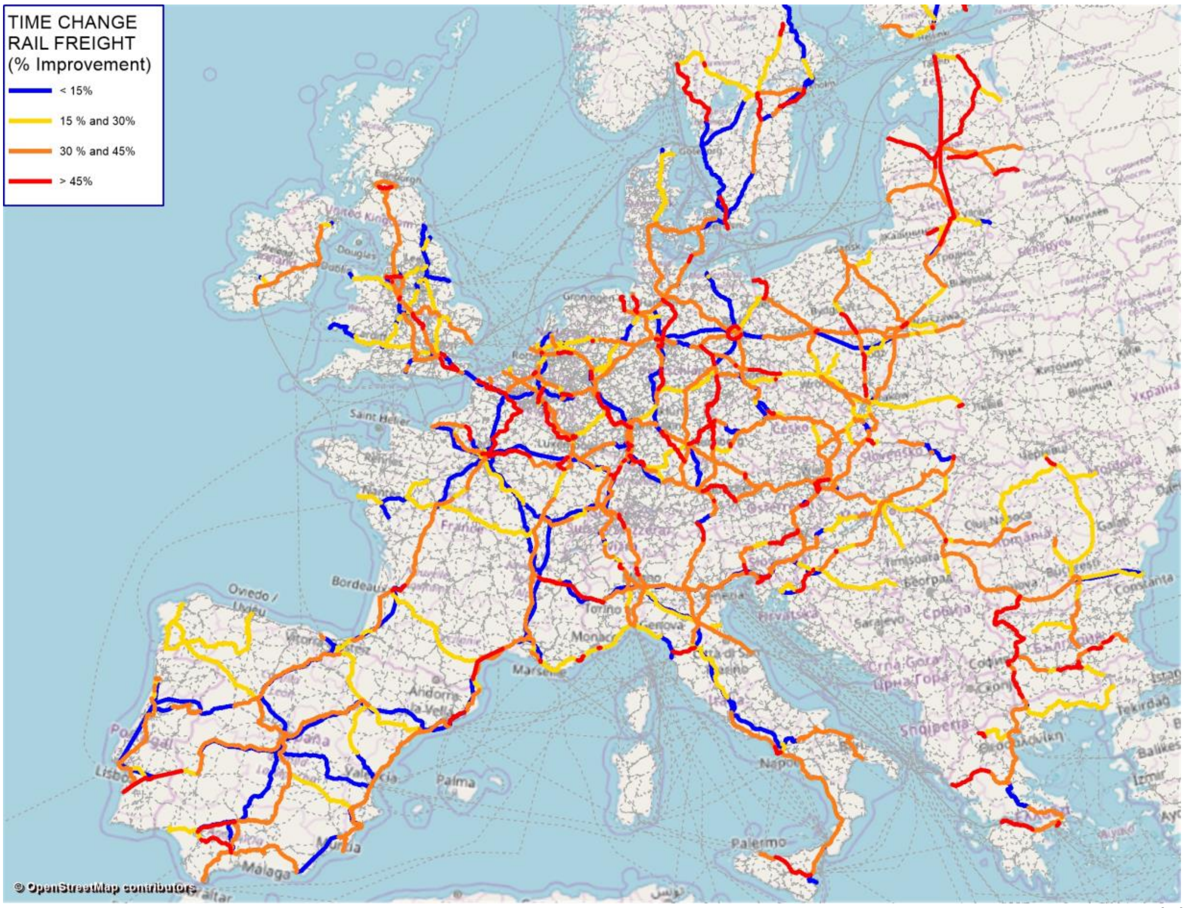
5.1 TEN-T impact at the network level

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 6.1.

Maps in Figure 26 and Figure 27 show the change of travel time in the TEN-T core rail network, respectively for freight and passengers, in the Reference scenario relative to Baseline in 2030.

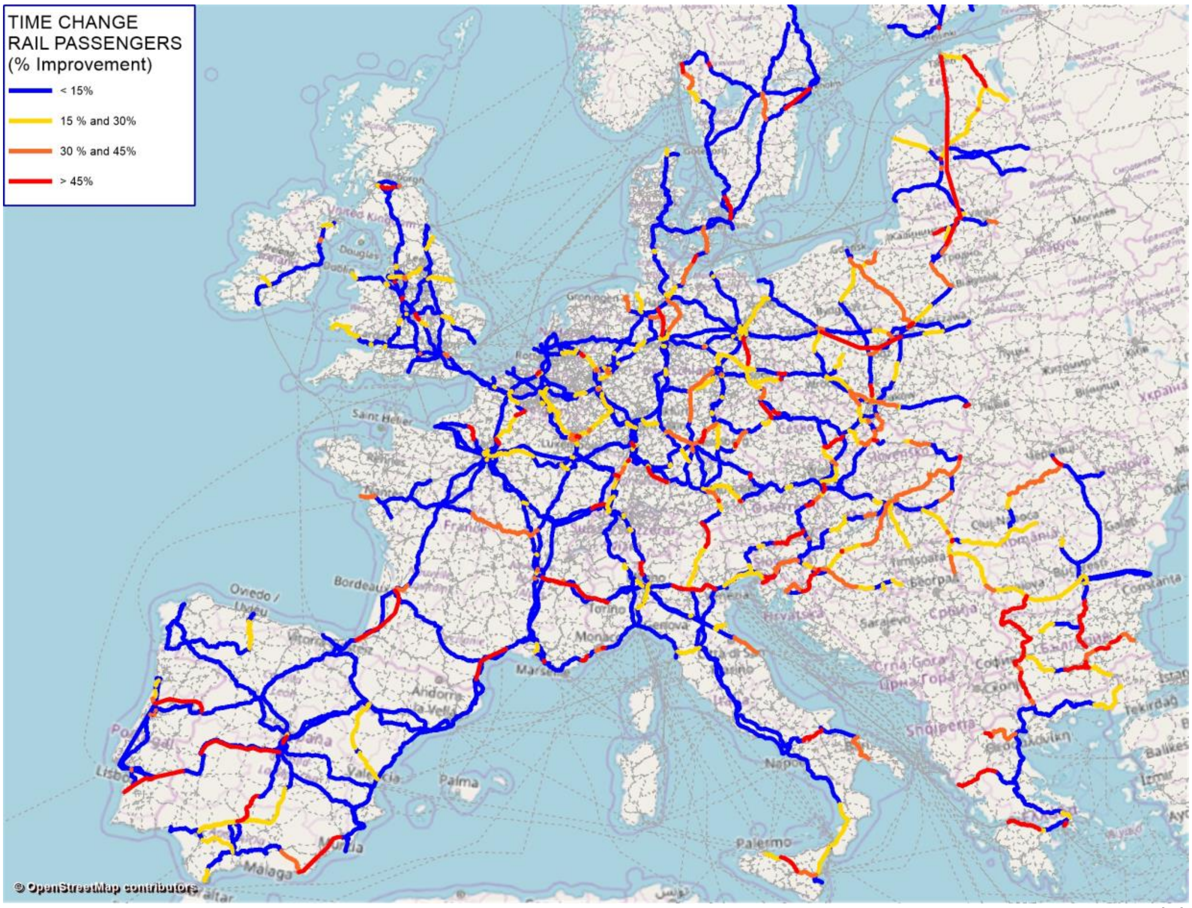
The comparison between the maps for passengers and freight clearly shows that the investments planned on the core network are expected to benefit more rail freight performance than passenger’s one. Figure 26 shows indeed a high proportion of the freight network whose travel time gains are expected to be over 30%, in contrast to Figure 27 which shows that a high proportion of the passenger network whose expected time gains are lower than 15%. This result reflects the evidence that the most of investments in the rail sector aim to increase rail performance, where several improvements are still possible, while the performance of the rail passenger network is generally already of high level.

Higher reduction of travel time for rail freight is the outcome of a combination of different factors. On one side there are the impacts of infrastructure investments which will allow for higher operational speeds on the corridor(s); on the other side there are the impacts of a general improvement of the efficiency of the rail freight system following the removal of several barriers to freight trains circulation among which: 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

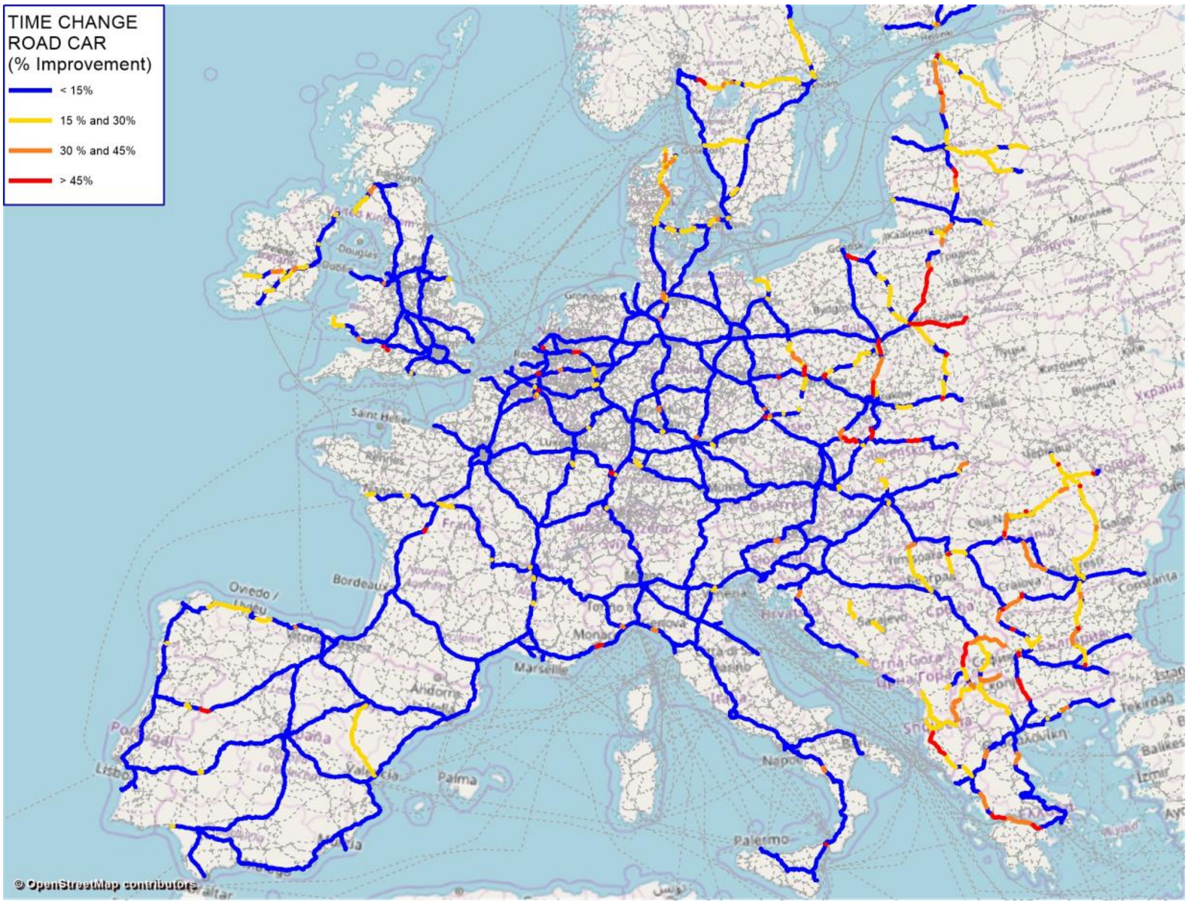
Figure 26: Changes of travel time for freight rail in the Reference Scenario relative to Baseline in 2030 (% change)



Source: TRUST model

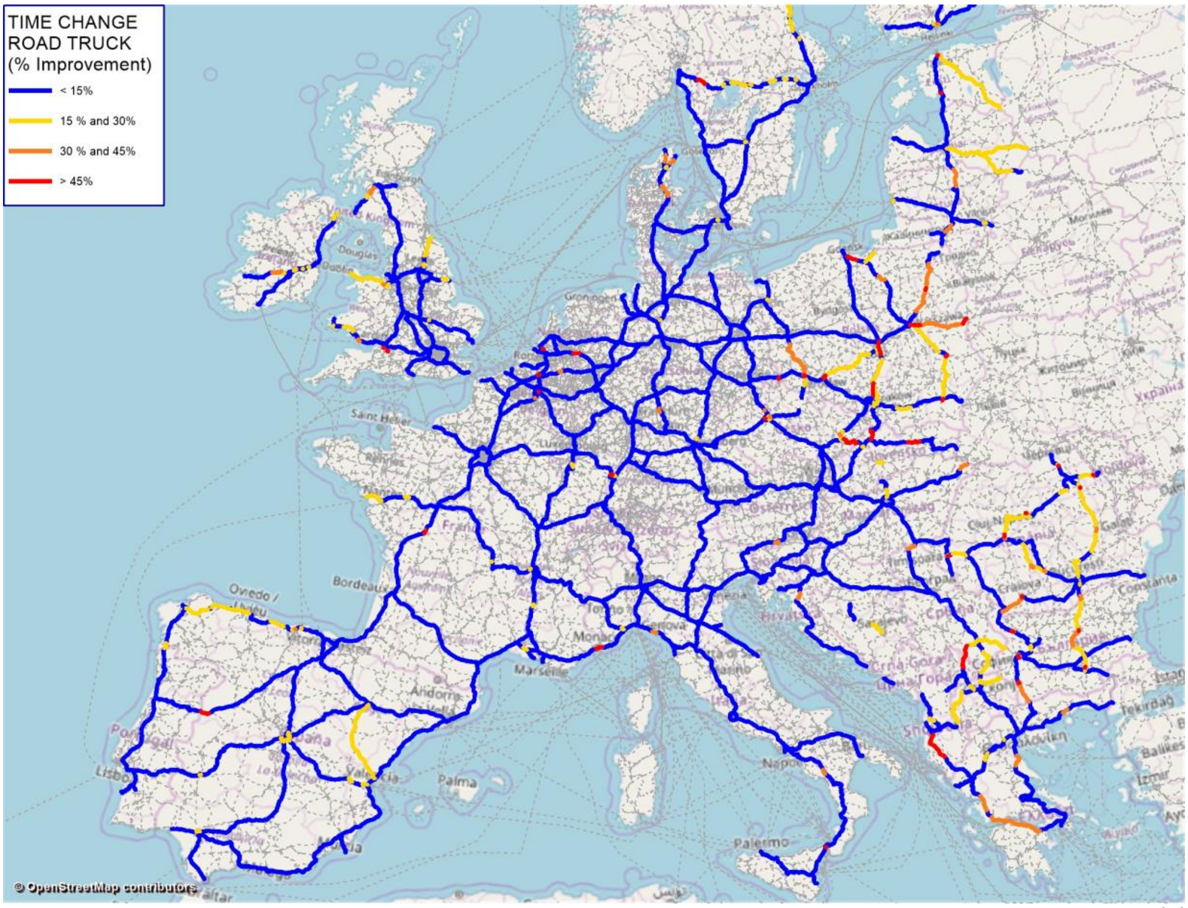
Figure 27: **Changes of travel time for passenger rail in the Reference Scenario relative to Baseline in 2030 (% change)**

Figure 28 and Figure 29 show the changes of travel time by road in the Reference Scenario relative to Baseline in 2030 respectively for cars and trucks. 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 at corridor level reported in section 8 show that the time gains on the road CNCs are mostly below 7%, partially also related to the already high performance of the road network.



Source: TRUST model

Figure 28: **Changes of travel time by road for passengers in the Reference Scenario relative to Baseline in 2030 (% change)**



Source: TRUST model

Figure 29: **Changes of travel time by road for freight in the Reference Scenario relative to Baseline in 2030 (% change)**

5.2 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 19. Maritime transport is not considered in the current study; 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..

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.

5.2.1 Passenger demand

By 2030 the overall passenger transport activity slightly increases (0.2%) in the Reference scenario relative to the Baseline (see Table 16). 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 16: 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%**

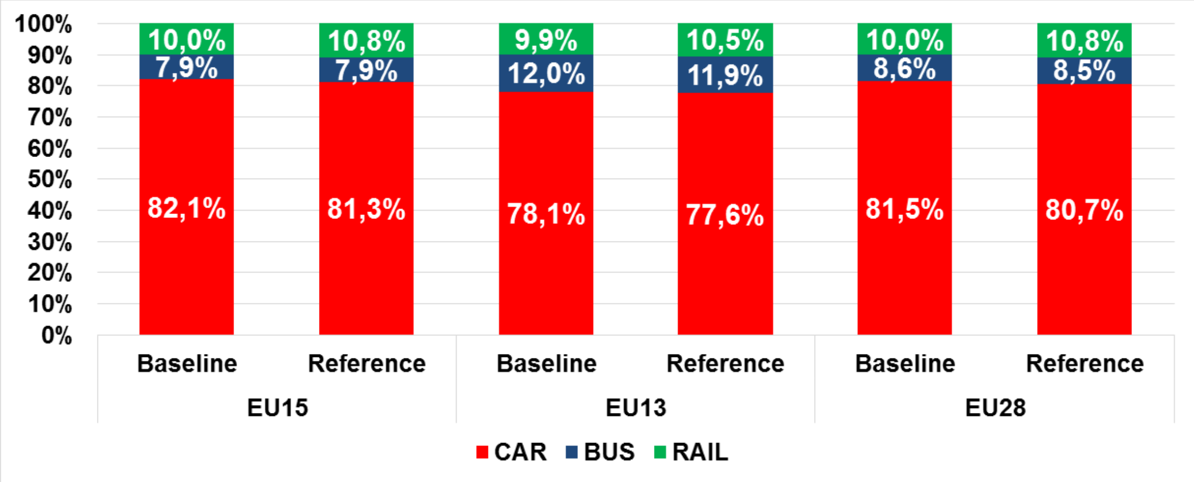
Source: ASTRA model; Note: Delta stands for the difference in tonne-kilometre per year while % change stands for the % difference between the Reference scenario and the Baseline scenario.

Passenger modal split in the Reference and Baseline scenarios in 2030 is shown in Table 17 and Figure 30. 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 17: Passenger Modal Split (territoriality approach) in the Reference scenario relative to Baseline in 2030

	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

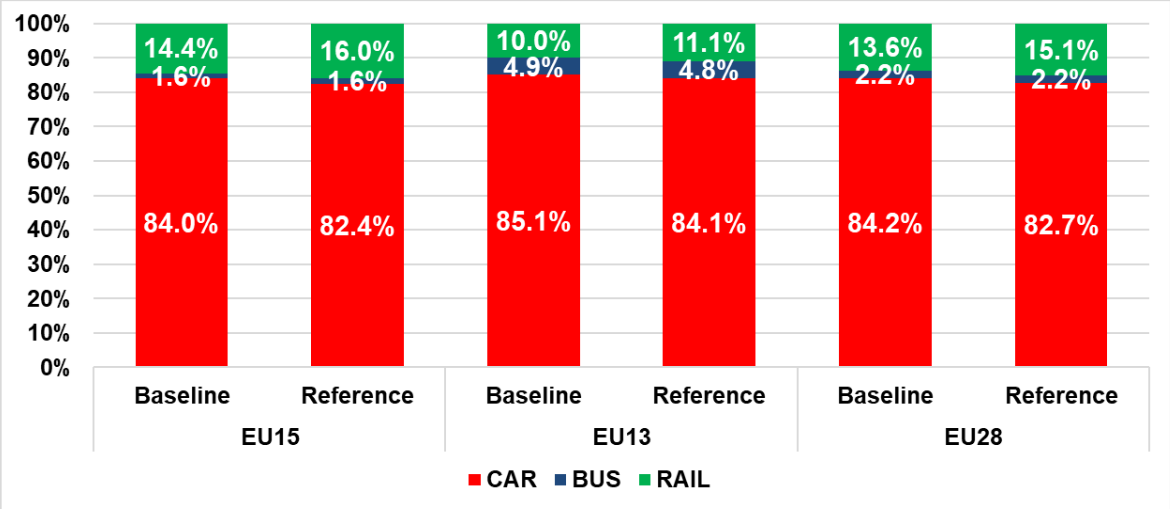
Figure 30: Passenger modal split (territoriality approach) in the Reference and the Baseline scenarios at 2030

More relevant changes can be observed for modal split of long distance passenger demand as reported in Table 18 and Figure 31. 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 18: Long distance passenger Modal Split (territoriality approach) in the Reference scenario relative to Baseline in 2030

	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



Source: ASTRA model

Figure 31: 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 19. 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 19: 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

5.2.1 Freight demand

Freight performance projections are shown in Table 20 and Figure 32. 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 21 and Figure 32 for total transport activity and in Table 22 and Figure 33 for long distance traffic. Overall, rail 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 20: Changes in freight transport activity (territoriality approach) for the Reference scenario relative to Baseline in 2030

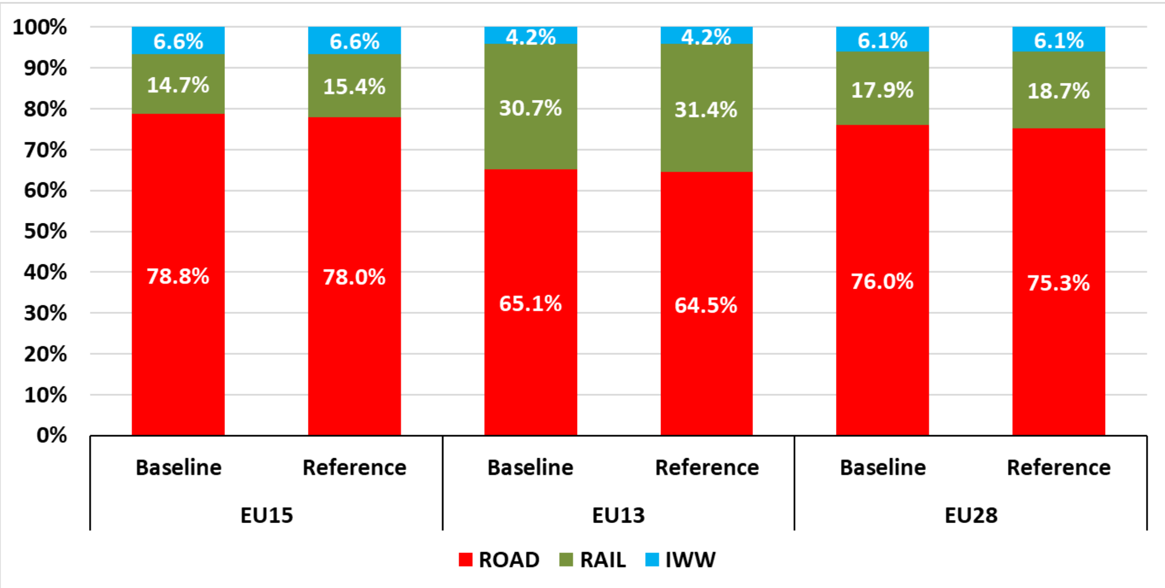
	ROAD		RAIL		IWW		TOTAL	
	Delta	% Change	Delta	% Change	Delta	% Change	Delta	% Change
EU15	-7 903	**-0.4%**	21 311	**5.8%**	1 108	**0.7%**	14 517	**0.6%**
EU13	-1 388	**-0.3%**	5 344	**2.7%**	70	**0.3%**	4 026	**0.6%**
EU28	-9 291	**-0.4%**	26 655	**4.7%**	1 178	**0.6%**	18 543	**0.6%**

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 21: 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



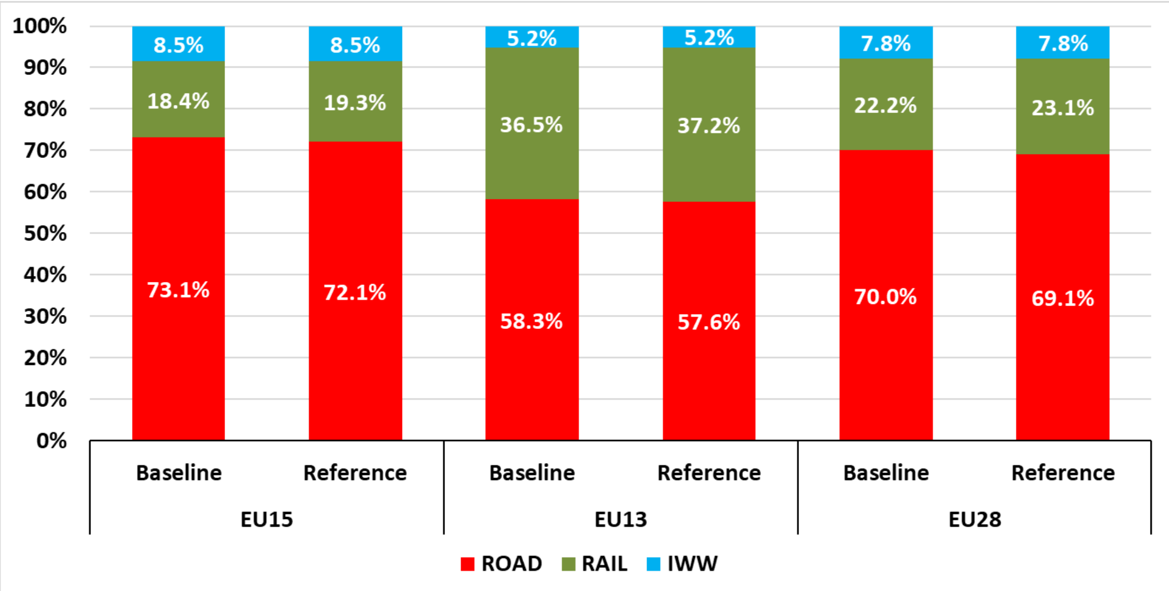
Source: ASTRA model

Figure 32: Freight modal split of total activity in tkm in the Reference and Baseline scenarios in 2030

Table 22: Change of freight modal split of long distance demand (territoriality approach) in the Reference scenario relative to Baseline in 2030

	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 33: Freight modal split of long distance traffic in the Reference and the Baseline scenarios in 2030

5.2.1 CO_2 emissions and transport external costs

The impacts on CO_2 emissions in the Reference scenario relative to the Baseline in 2030 are given in Table 23. 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 3.6.

Table 23: 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 71.6 million tonnes between 2017 and 2030, out of which 26 million tonnes are expected deriving from 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. Changes of CO_2 external transport costs given in Table 24 show a reduction of about 436.2 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 total transport sector in the Reference scenario relative to Baseline in 2030 are given in Table 25.

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). Taking these policies into account would lead to much higher CO2 emissions savings on the core TEN-T network.

Table 24: 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 25: 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 26. 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 27 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 26: 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 27: 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

5.3 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 13 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, in trade, intermediate inputs, total factor productivity, etc. 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 3.6.3).

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

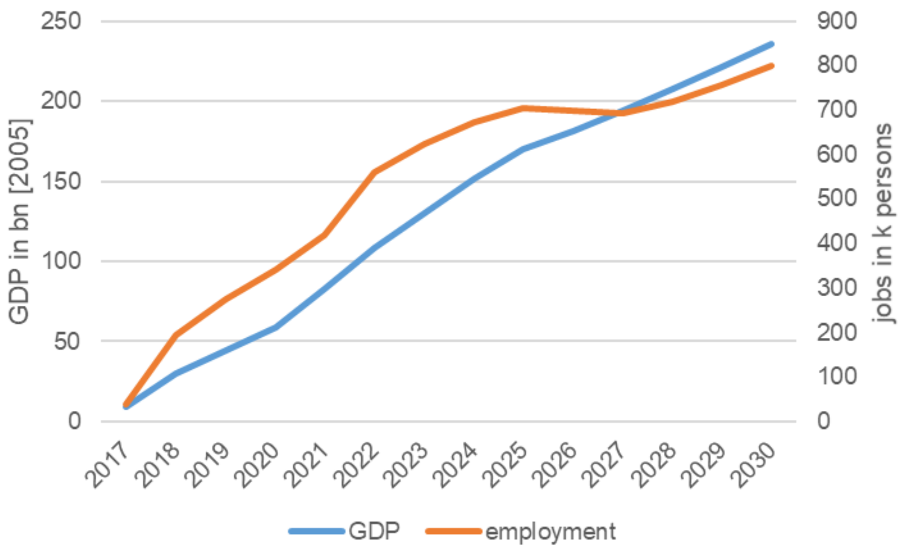
1. A transitional growth impact due to the demand shock associated with the direct demand impulses (additional investment in infrastructure), including the changes in demand by other sectors. Considering the discussion on terminology in the Annex

(section 10) 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 investments. This is part of the second-round effects fostered by productivity growth as discussed in the Annex (see section 10).
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 changed consumption and business outlook from 1 and 2. Changes of consumption also occur from increased income as element of the second-round effects as discussed in the Annex (see section 10).

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. Especially 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 34 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 34: Impact of TEN-T core network implementation on GDP and jobs between 2017 and 2030

Although GDP in Figure 34 grows steadily, the annual increase of GDP compared with the Baseline is higher during 2017-2025 relative to 2026-2030.

Table 28 shows the difference in GDP and employment between the Reference and the Baseline scenario for the years 2020 and 2030 for the EU15, EU13 and EU28.

In 2020 GDP for the EU13 is 1.9% higher in the reference scenario than in the baseline scenario. For the EU15 this difference is only 0.32% and for the whole EU28 thus 0.43%, as can be seen from Table 28.

The difference in employment in absolute numbers is reversed in 2020: As Table 28 shows for the EU13 that there are around 155 000 more full-time equivalent jobs in the reference scenario compared to the baseline scenario. This difference, however, translates in 0.4% more employment for the EU13 in 2020.

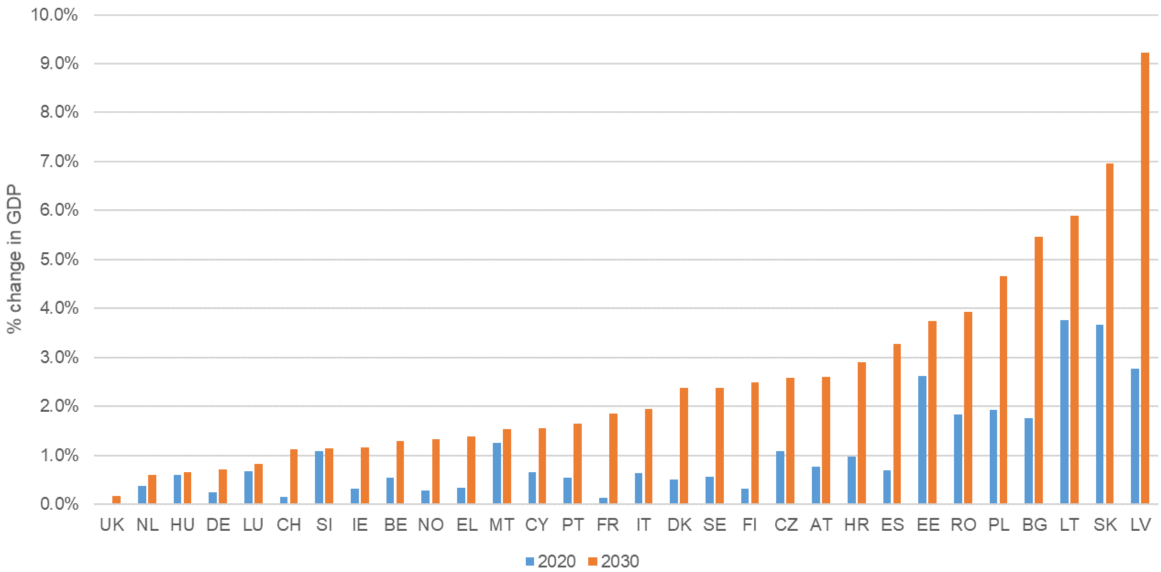
The EU15 in the reference scenario has around 185 000 more full-time equivalent jobs in 2020 than in the baseline scenario. In relative terms, this means 0.1% more employment for the EU15 in the reference scenario in 2020.

Table 28: Changes in the Reference scenario relative to the Baseline scenario for employment and GDP for EU15, EU13 and EU28

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

While in 2030 the difference in GDP for EU13 is 4.2% for the reference scenario compared to the baseline scenario and 1.4% for the EU15 (see Table 28), the growth path difference between the EU13 and the EU15 becomes smaller. That is to say, the MS of the EU15 seem to profit more from the impact types (2) and (3). Apparently, there is some convergence between the EU as a whole.



Source: ASTRA model

Figure 35: Changes in GDP due to additional TEN-T investments for each EU28 country

To reinforce this argument, one can draw on the breakdown of the country results as shown in Figure 35. The blue bars in the figure indicate the percentage changes in 2020 in the reference scenario compared to the baseline scenario and the orange bars show the changes for 2030. One can see that for many countries of the EU13 like Latvia, Slovakia, Lithuania, Bulgaria and Poland there are already significant GDP differences for 2020. For many of the EU15 like Italy, Denmark, Finland or Greece the changes in GDP from 2020 to 2030 are more substantial.

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 per MS. The share decreases for the next periods, but remains overall relatively high with an average of 2.0% for the whole period from 2017 to 2030. The data from this can be derived from Table 10.

Also, Slovakia has a high initial share of TEN-T investments of 2.4%, relative to GDP, for the period from 2017 to 2020. The share for the whole period from 2017 to 2030 for this country is as high as 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.

The same statement can be repeated for Poland: 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).

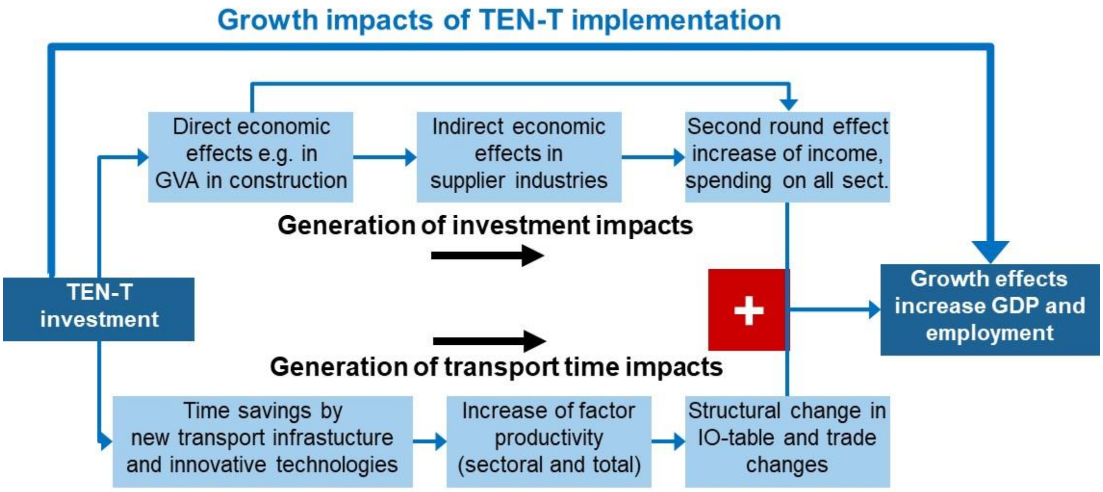
For two reasons it is important to report also the cumulated impacts of the TEN-T core network implementation over the period 2017 to 2030. First, the impacts of the TEN-T implementation occur over such a long period starting from the first additional investment in 2017 and ending at the time horizon of our analysis in 2030. In fact, the impacts even go beyond 2030, as is shown in section 5.4. Second, also the investment amount is quantified over the whole period and though it is distributed over 14 years the focus often is put on the total investment budget such that it is also strongly recommended to compare like-with-like to consider the total impacts of the investment. These are the cumulated impact of GDP and employment over 2017 to 2030. Table 29 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 the EU15 and 3 million job-years in the EU13.

Table 29: 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
EU 15	95,000	1,400,000	457,000	4,537,000
EU 13	47,000	426,000	394,000	2,963,000
EU 28	143,000	1,826,000	851,000	7,501,000

Source: ASTRA model

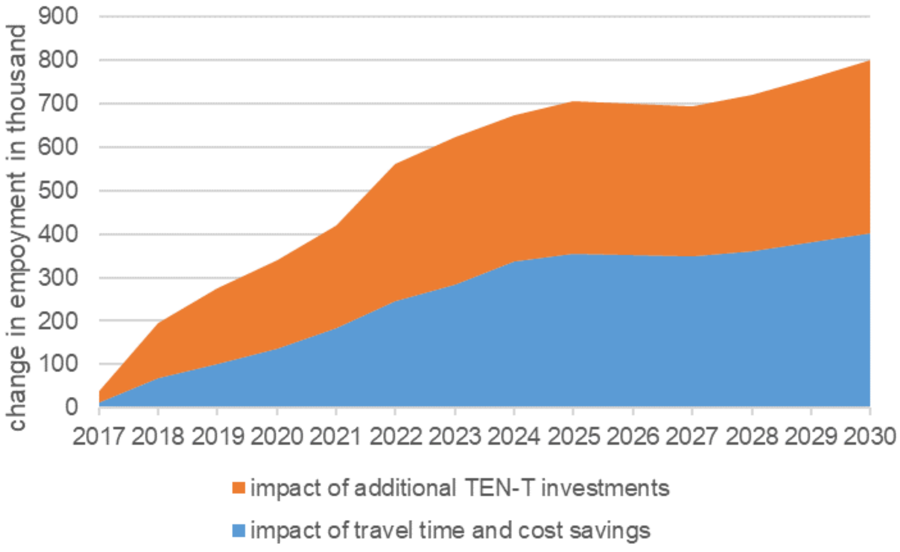
The analysis of economic impacts can be extended to capture impacts closer linked to the transport sector impacts. The impacts discussed so far comprise classical economic analyses of demand shocks, capital stock enhancement and total factor productivity growth (impact type 1, 2, 3 from above). The major impact of transport infrastructure improvement usually is reduction of travel times i.e. time savings. These travel time savings can be converted into (generalized) 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 36. Together the growth impacts of investment expenditures (upper chain of impacts) and the transport economic impacts (lower chain of impacts) generate the total impacts on GDP growth and jobs.



Source: M-Five

Figure 36: **Decomposition of growth impacts into impacts of investments and impacts of transport time and productivity**

In the real world the two impact chains can not be differentiated for several reasons. First, the two mechanisms are dependent on each other (i.e. no transport improvement 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 was implemented using the ASTRA model and the decomposition results are presented in Figure 37.



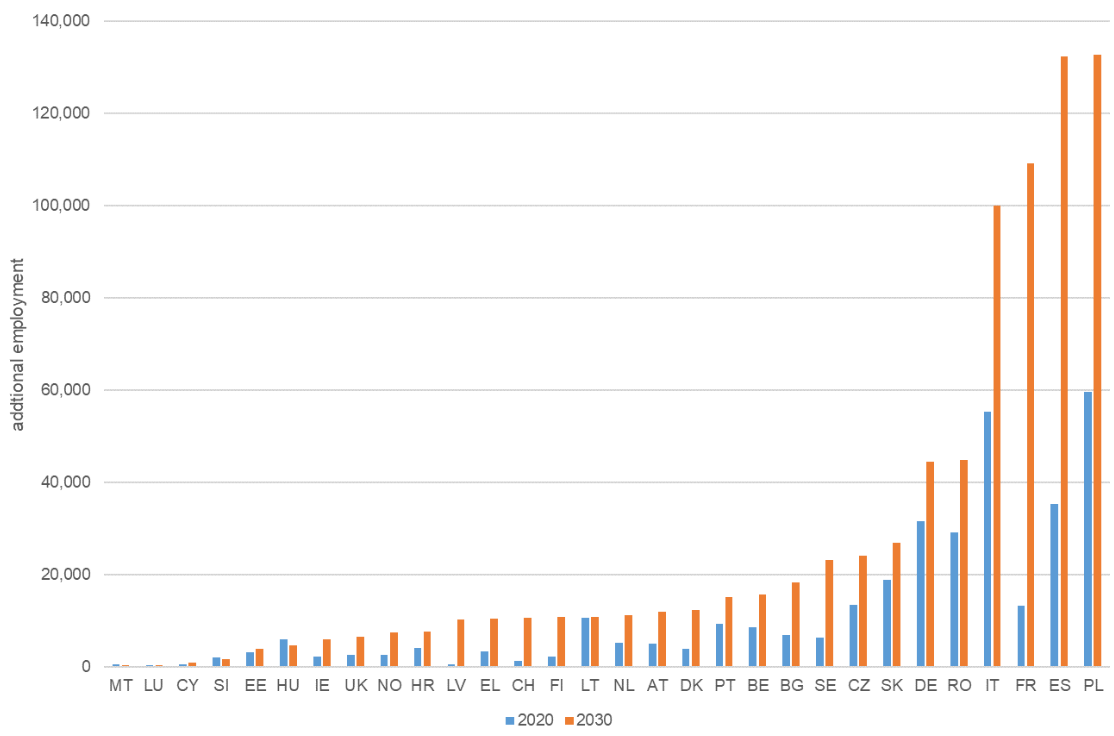
Source: ASTRA model

Figure 37: **Decomposition of investment and transport time/cost impacts on jobs in EU28**

Figure 37 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 lion 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 should overestimate the time improvements in the initial years of the 5-year interval as improvements in the networks enfold synergies when more links are improved following rather an exponential pattern than a linear pattern. This should then also hold for the impact curve of time&cost savings.

The same breakdown for the MS as in Figure 35 for GDP is done in Figure 38 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.

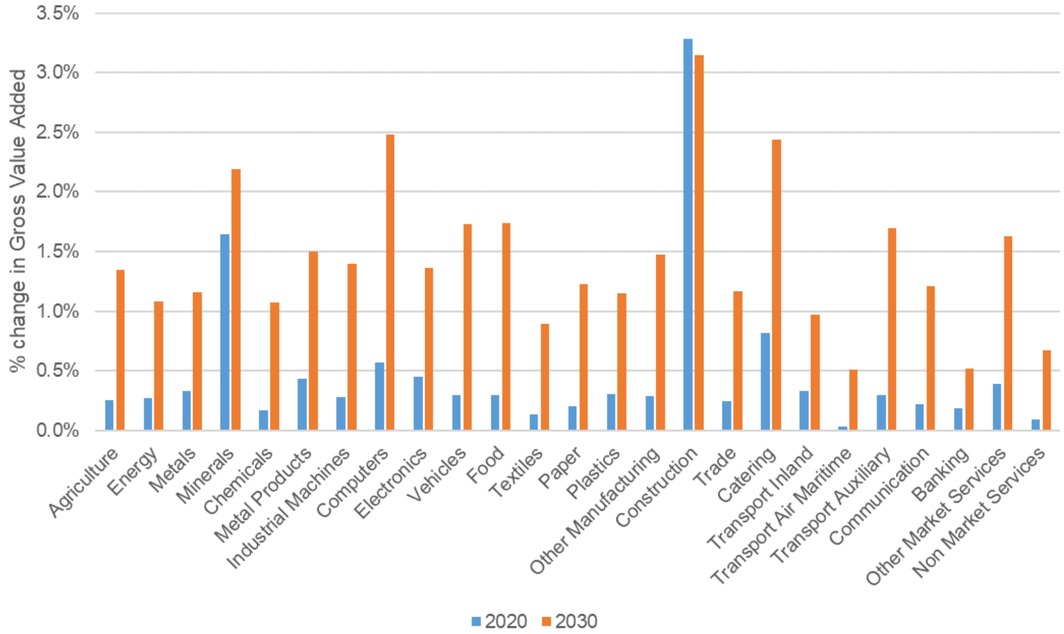


Source: ASTRA model

Figure 38: Jobs created due to additional TEN-T investments for each EU28 country

Figure 38 shows that in 2030 the bigger countries enjoy the largest employment gains. While the GDP difference with 4.7% in 2030 for Poland makes it the 5th biggest effect in this category, in absolute employment this translates to around 133 000 additional jobs in 2030. With 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 additional 3.3% GDP, which is the 8th biggest effect on relative GDP changes and this also results in around 133 000 additional jobs in 2030, which is due to the economy and working population in Spain being higher than that in Poland and that a larger number of jobs is needed to create GDP growth and a higher production.



Source: ASTRA model

Figure 39: **Changes in Gross Value Added for EU28 due to additional TEN-T investments**

Finally, Figure 39 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.

5.4 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 years period. The argument to carry out such an analysis is that by the TEN-T investment the economy is shifted on a higher long-term growth trajectory, which is actually confirmed by the following analysis.

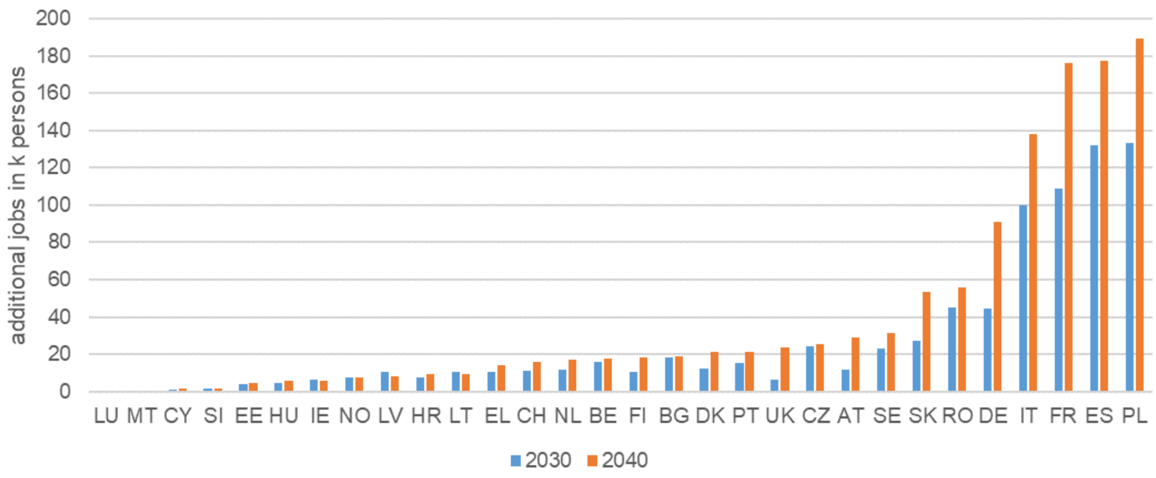
Table 30 provides an overview of the changes in employment and GDP in 2030 and 2040 in the EU13, EU15 and EU28. Overall GDP grows on average 2.6% in all MS by 2040. The relative GDP growth is in 2030 as well as in 2040 higher in the EU13 than the EU15. In the EU13 GDP is about 5.6% higher and in the EU15 2.3% higher in the reference scenario than in the baseline scenario in 2040. Due to the TEN-T investments there are close to 1.2 million additional jobs in the EU28 in 2040 of which 383 000 are located in the EU13 and 783 000 in the EU15.

Table 30: Overview of TEN-T core network impacts on GDP and employment for 2030 and 2040

	GDP		Employment	
	2030	2040	2030	2040
EU15	1.38%	2.27%	509 600	782 700
EU13	4.17%	5.61%	287 500	382 900
EU28	1.59%	2.56%	797 000	1 165 600

Source: ASTRA model

The analysis of the long-term growth trajectory can also be undertaken at the level of the MS. This is shown for the impact on employment. The impact of the TEN-T investments for the years 2030 and 2040 on employment for each MS are summarised in Figure 40. There are significant job increases in nearly all European countries in the period from 2030 to 2040. Especially in Germany, Italy, France, Spain and Poland there accrue large absolute employment effects in this period.



Source: ASTRA model

Figure 40: Impact of TEN-T investment on employment in 2030 and 2040

6 Findings on the core network corridors (CNC)

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

6.1 Transport impacts of CNC

The sections below provide transport results for the Core Network Corridor Scenarios. In these scenarios only the implementation of individual corridors are simulated, meaning that each scenario does not include the other 8 CNCs and the completion of the Core-Non-CNCs network.

Results are provided both at the network level from the TRUST model and at an aggregate level from 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 some key corridors sections identified on the basis of representative Origin-Destinations (OD) pairs along the corridors covering the whole corridors length and connecting major network nodes and/or country borders.

TRUST model output in terms of variation of OD travel costs and time by road and rail modes were used as input for the ASTRA model to compute modal split changes determined by infrastructure improvement. ASTRA model works with a NUTS1 zoning system and therefore the most detailed results that can be provided by ASTRA are at NUTS 1 level.

ASTRA model results for the CNCs scenarios are provided at three different 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 (i.e. EU15, EU13 and EU28).
- 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 NUTS 1 level results, which show the impact of the scenario by summing up only the results for the NUTS 1 zones crossed by the corridor.

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

Passenger (car, bus, rail) and freight (road, rail and inland waterways) transport activities are computed according to the territoriality approach. As the territoriality approach considers all the traffic running on the territory of a country, results for air and maritime modes are not computable under this approach. Results for these modes are provided at the European level in the next Section.

6.1.1 Transport impacts at the network level

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

Data on travel time variations reported in Table 31 show that in the investments planned on CNCs are expected to benefit more rail freight performance than passengers' one with the Mediterranean corridor (-44.4%) benefiting more than the others for the reduction of freight travel time at 2030 followed by the Rhine-Alpine (-38.9%) and Atlantic (-36.7%). Other CNCs show a reduction of travel time ranging from -35.7% (Baltic-Adriatic) to -23.3% (North Sea-Baltic). The improvement for passengers' 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. Lower time gains in the range of -15.4% (Scan-Med) to -6.8% (Atlantic) apply to the other corridors.

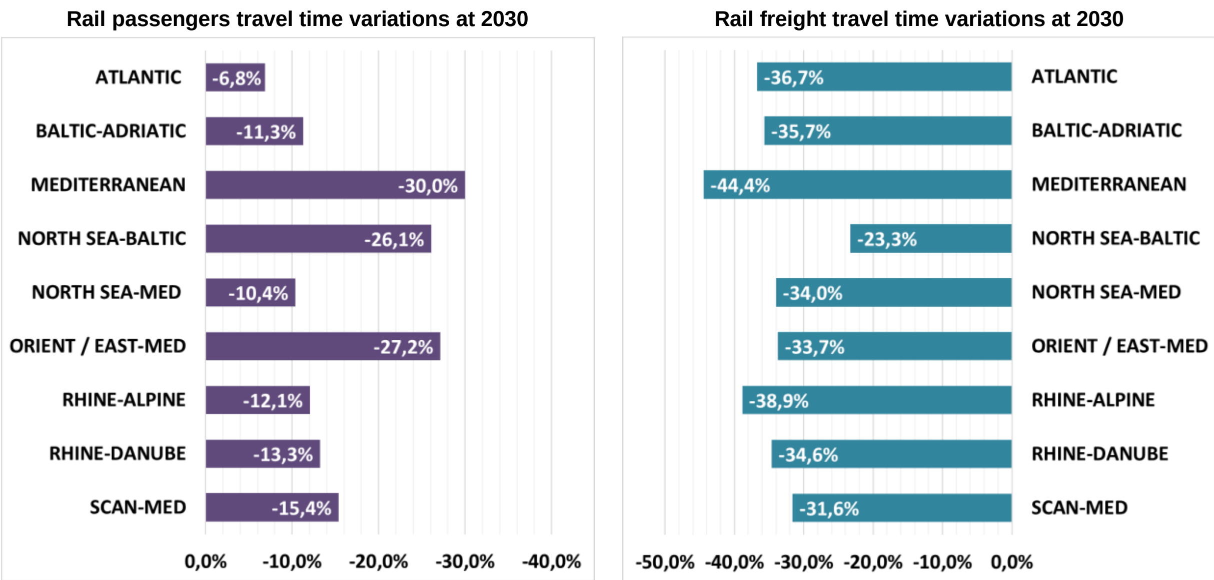
As already mentioned above, higher reduction of travel time for rail freight is the outcome of a combination of the impacts of infrastructure investments which increase operational speeds on the corridor(s) and of the impacts of a general improvement of the efficiency of the rail freight system following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

Table 31: Changes of travel time by rail for both passengers and freight in the CNCs scenarios relative to Baseline in 2030 – (% change to the Baseline)

	RAIL TRAVEL TIME % CHANGE	
CORRIDOR	Passengers	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

Variation on rail operational costs along the CNCs reported in Table 32 mirror the assumptions implemented for taking into account the ERTMS deployment over time.



Source: TRUST model

Figure 41: **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 32: **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 of travel time along the **road** CNCs for passengers and freight are presented in Table 33. It can be noted that road changes are less relevant than those observed for the rail network.

Table 33: Changes of travel time by road for passengers and freight in the CNCs scenarios relative to 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 of travel time at 2030 is higher on the North Sea – Baltic (-16.9% for passengers and -11.4% for freight, given the infrastructure investments on road connections between Warsaw and Baltic states capital cities) followed by the Rhine-Danube (-8.1% for passengers and freight) and the Orient-East-Med (-6.1% for passengers and -4.2% for freight). Other CNCs show smaller impact. Road operational costs remain substantially unchanged.

6.1.2 Transport impacts at the aggregate level

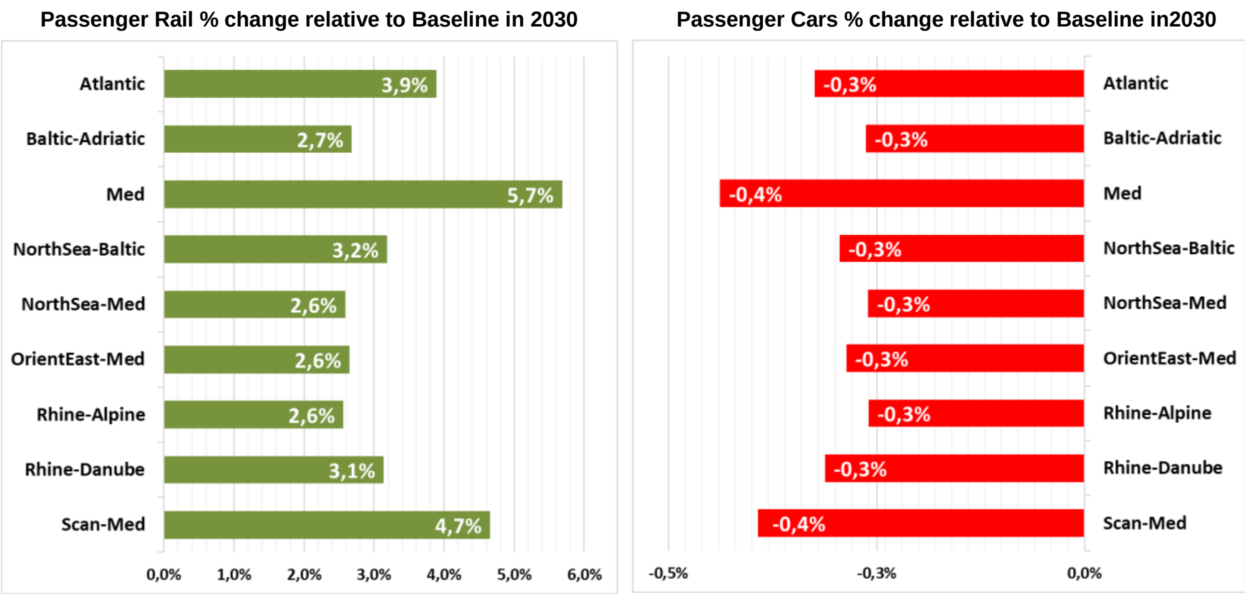
Change of passenger transport activity by car and rail (territoriality approach) in the NUTS1 regions crossed by the corridors for all CNCs scenarios relative to Baseline at 2030 are given in Table 34 and Figure 42.

Table 34: Change of passenger transport activity (territoriality approach) in the NUTS1 regions crossed by the corridors for all CNCs 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 ranges 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 of passenger car activity in the NUTS1 regions resulting as a consequence of increased rail performances are in the range -0.3% to -0.4% for all the corridors.



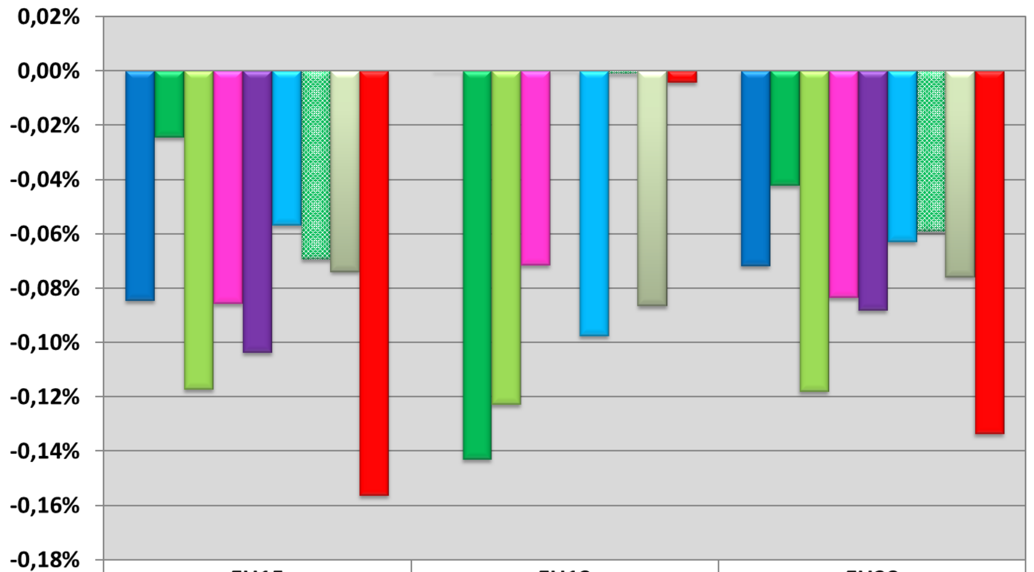
Source: ASTRA model

Figure 42: 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 of passenger transport activity (territoriality approach) at the European level for all CNC scenarios relative to Baseline in 2030 are given in Figure 43 and Figure 44 respectively for passenger cars and rail.

Small reductions in car passenger activity can generally be noted as a consequence of increased rail performance. Reductions at the EU28 level are in the range -0.04% for the Baltic-Adriatic corridor to -0.13% for the Scan-Med corridor (Figure 43).

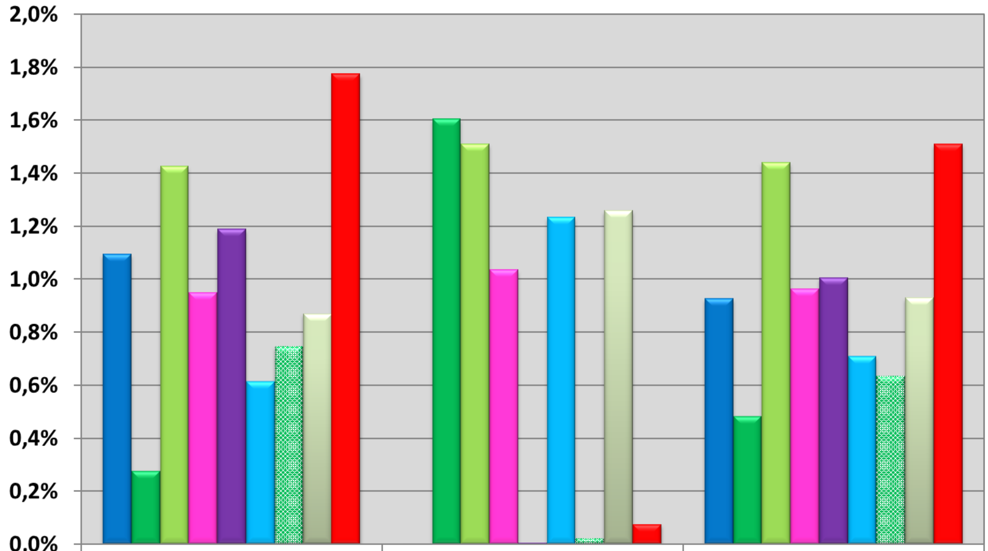
As expected changes of rail activity shown in Figure 44 are generally higher than those observed for road and in the range of 1.5% for the Scan-Med corridor to 0.5% for the Baltic Adriatic corridor.



	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 43: Change of passenger cars activity (territoriality approach) at the EU level for all CNCs scenarios relative to 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 44: **Change of rail passenger activity (territoriality approach) at the EU level for all CNCs scenarios relative to Baseline in 2030 – (% change to the Baseline)**

Change of road and rail freight transport activity (territoriality approach) in the NUTS1 regions crossed by the corridors for all CNCs scenarios relative to Baseline in 2030 are given in Table 35 and Figure 45.

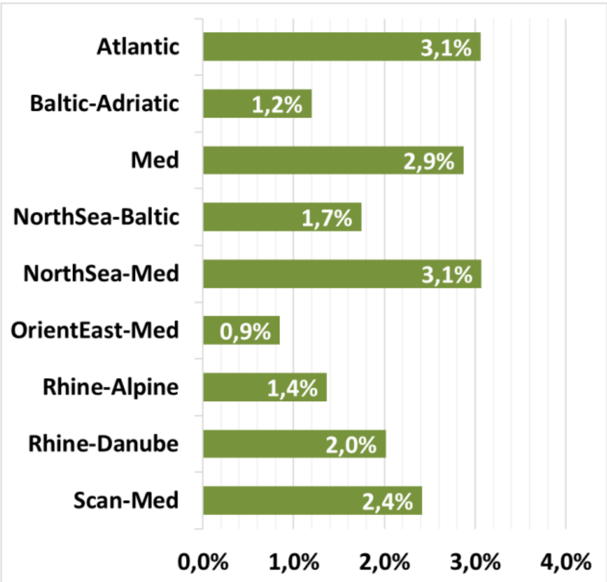
Rail freight variations are in the range 3.1% for the NUTS1 regions crossed by the North Sea-Med corridor to 0.9% for those crossed by the Orient-East-Med corridor. Road freight reductions following the increased rail performance range from 0.1% in the NUTS1 regions crossed by the Orient-East-Med and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

Table 35: 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 - (million tkm/year; % change to the Baseline)

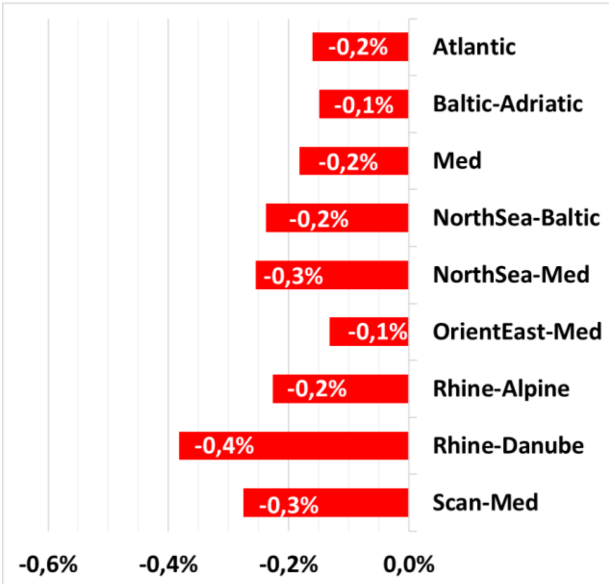
	ROAD		RAIL	
	Delta	% Change	Delta	% Change
Atlantic	-788	-0.2%	1 716	3.1%
Baltic-Adriatic	-578	-0.1%	1 503	1.2%
Mediterranean	-889	-0.2%	1 873	2.9%
North Sea-Baltic	-1 373	-0.2%	3 728	1.7%
North Sea-Med	-1 616	-0.3%	2 477	3.0%
Orient-East-Med	-478	-0.1%	1 165	0.8%
Rhine-Alpine	-1 088	-0.2%	1 298	1.3%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

Source: ASTRA model

Freight Rail change relative to Baseline in 2030



Freight Road change relative to Baseline in 2030

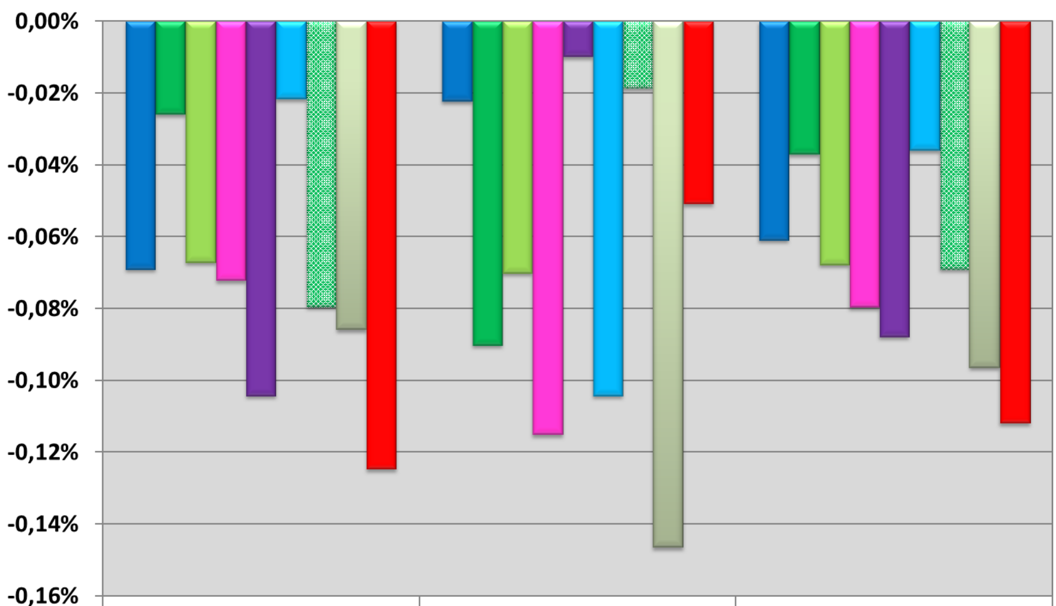


Source: ASTRA model

Figure 45: 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 of freight transport activity by road, rail and inland waterways (territoriality approach) at the European level for all CNC scenarios relative to Baseline at 2030 are given respectively in Figure 46, Figure 47 and Figure 48.

Small reductions in road freight activity can generally be noted as a consequence 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 46). These small reductions also reflect the improvement of the road network in some countries which smooths the competition with the rail mode.

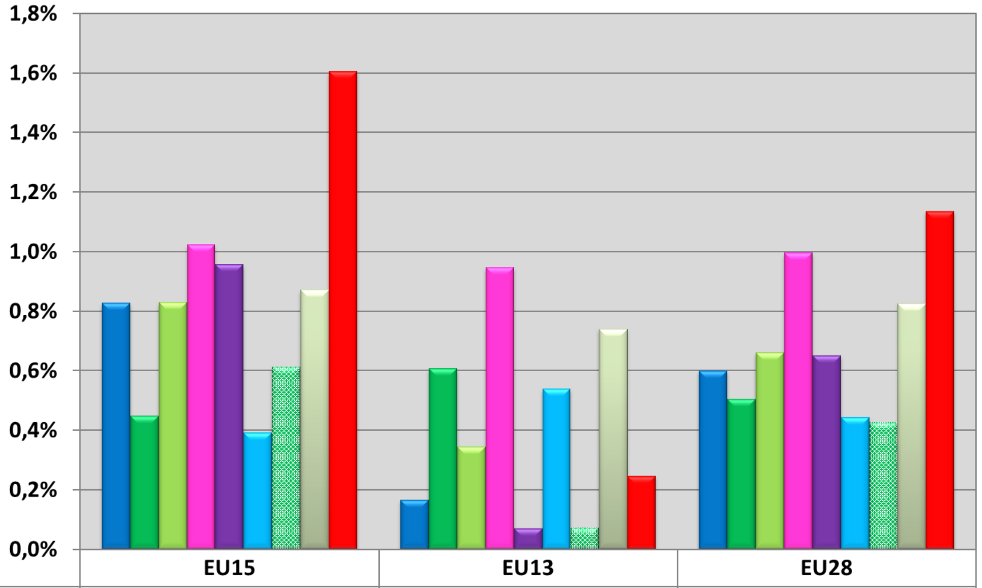


	EU15	EU13	EU28
Atlantic	-0,07%	-0,02%	-0,06%
Baltic-Adriatic	-0,03%	-0,09%	-0,04%
Med	-0,07%	-0,07%	-0,07%
NorthSea-Baltic	-0,07%	-0,12%	-0,08%
NorthSea-Med	-0,10%	-0,01%	-0,09%
OrientEast-Med	-0,02%	-0,10%	-0,04%
Rhine-Alpine	-0,08%	-0,02%	-0,07%
Rhine-Danube	-0,09%	-0,15%	-0,10%
Scan-Med	-0,12%	-0,05%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

Source: ASTRA model

Figure 46: Change of road freight activity (territoriality approach) at the EU level for all CNCs scenarios relative to Baseline in 2030 – (% change to the Baseline)

As has been seen for passenger changes, rail freight changes, as shown in Figure 47, 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.’

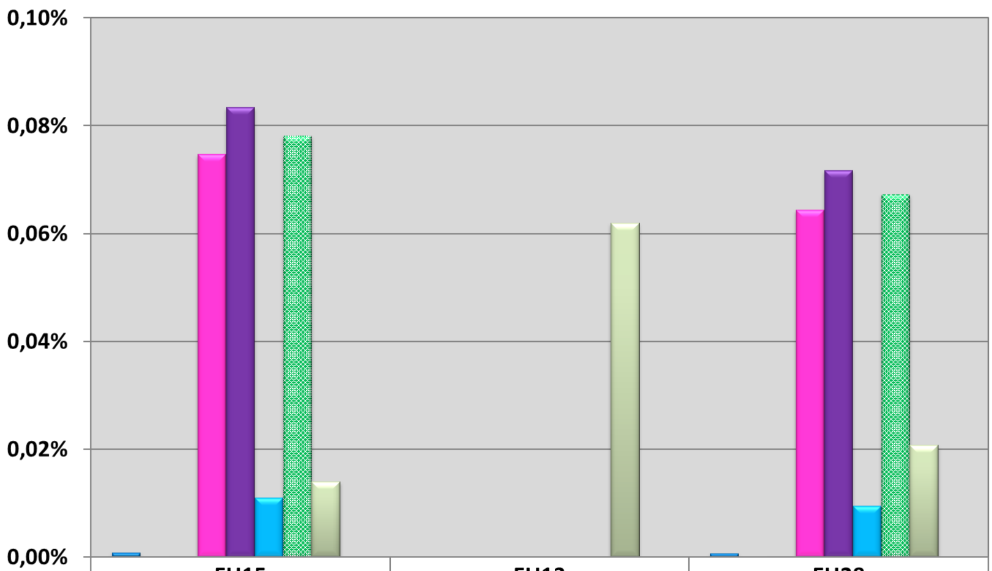


	EU15	EU13	EU28
Atlantic	0,8%	0,2%	0,6%
Baltic-Adriatic	0,4%	0,6%	0,5%
Med	0,8%	0,3%	0,7%
NorthSea-Baltic	1,0%	0,9%	1,0%
NorthSea-Med	1,0%	0,1%	0,6%
OrientEast-Med	0,4%	0,5%	0,4%
Rhine-Alpine	0,6%	0,1%	0,4%
Rhine-Danube	0,9%	0,7%	0,8%
Scan-Med	1,6%	0,2%	1,1%

Source: ASTRA model

Figure 47: Change of rail freight activity (territoriality approach) at the EU level for

Change of inland waterways activity at the European level is shown in Figure 48. Traffic increases for the Rhine-Danube are about 0.6% for EU13 in the Reference scenario relative to the Baseline. For EU15, traffic on Rhine-Alpine and NorthSea-Med goes up by 0.8% in the Reference scenario relative to the Baseline.



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

6.2 Economic impacts of CNC

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

6.2.1 Comparison of economic impacts of CNC

Table 36 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 a bit nuanced: This stems from the fact that the MS are very diverse in their respective labour productivity. While some countries with a high labour productivity do not profit that much in the creation of new jobs by the completion of the corridors, some countries with a lower labour productivity experience more gains in jobs created. The difference can stem from the average labour productivity differences between two countries, but as well from differences of particular sectors (i.e. 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 Euro over one year. In a country with a labour productivity of 100 000 Euro the investment would generate 10 job-years. In a country with labour productivity of 20 000 Euro it would be 50 job-years.

Table 36: Changes in GDP and employment for the nine CNC relative to the Baseline

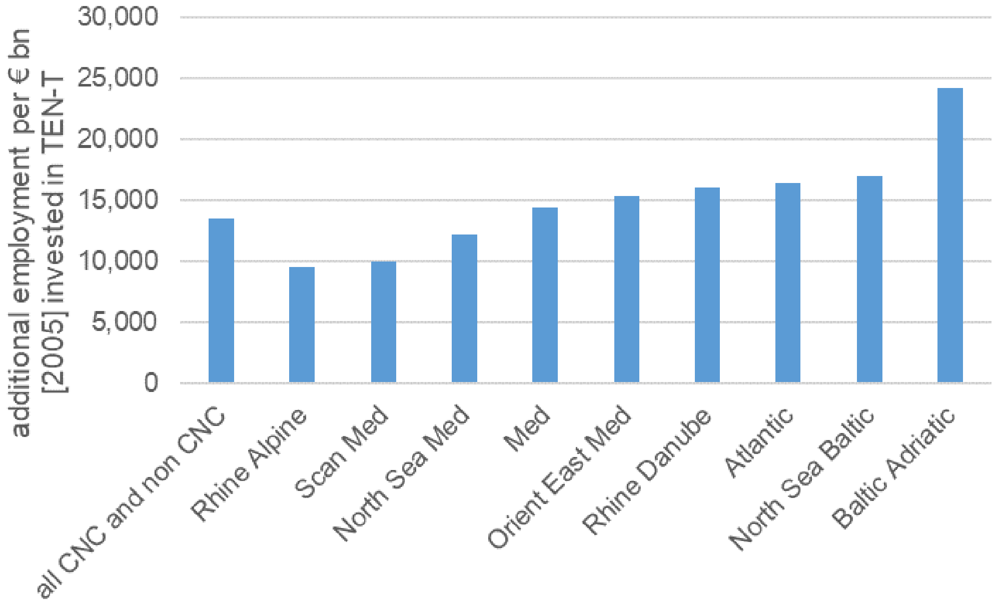
	∆GDP in 2030	∆Employment in 2030
Scan-Med	0.33%	142 000
Med	0.29%	153 000
Atlantic	0.12%	62 000
Rhine-Danube	0.14%	93 000
Rhine-Alpine	0.15%	69 000
Baltic-Adriatic	0.17%	122 000
Orient-East-Med	0.10%	76 000
NorthSea-Baltic	0.18%	115 000
NorthSea-Med	0.23%	94 000
Total of nine CNC and CNoCNC	**1.59%**	**797 000**

Source: ASTRA model

In Table 36 it is important to note that the total of the nine CNC is not the aggregation of the single numbers (which would be 926 000 additional employment), but 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 of the CNC.

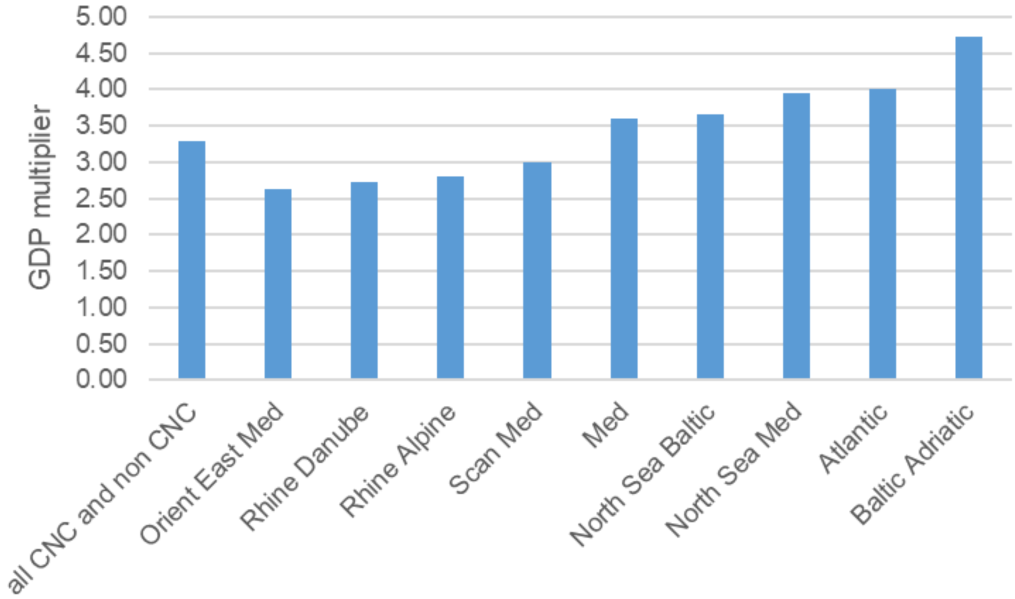
Figure 49 and Figure 50 show the multipliers for the jobs and additional GDP for each of the nine CNC as well as the TEN-T core network including the CNoCNC projects in comparison. The multipliers were calculated by taking the integral of the changes between 2017 and 2030 and dividing them by the integral 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 as well as the TEN-T core network. The multipliers for employment differ more, which can be accrued to the different labour productivity in the respective countries. We therefore conclude that it is beneficial to have both indicators as evaluation criteria in place, as they are able to convey divergent information.



Source: ASTRA model

Figure 49: Employment multiplier for EU28 – 2017 to 2030



Source: ASTRA model

Figure 50: GDP multiplier for TEN-T core network investments – 2017 to 2030

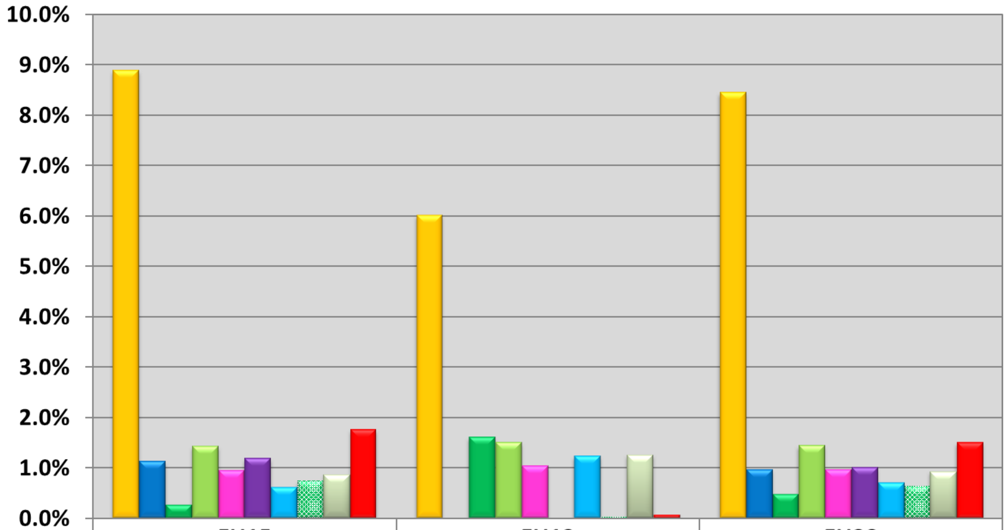
6.3 Impact of TEN-T at corridor level

The transport results at 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: the length of the corridor, the volume and the type of the investments, and their time profile, the performance of the networks in the Baseline which varies corridor by corridor, the structure and the elasticities of the demand only to mention the most important ones.

Considering the rail transport activity at NUTS1 level 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%, for freight 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 that shows higher impact in terms of change in rail transport activity for passengers and freight, this group includes the Mediterranean, the Scan-Med, the Atlantic, 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). Other corridors, North Sea-Baltic and Rhine-Danube show average impacts, around 3% change in transport activity for passengers and 1.7%/2% for freight. The impacts on the Orient-East-Med, Rhine-Alpine and the Baltic-Adriatic is below the 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.

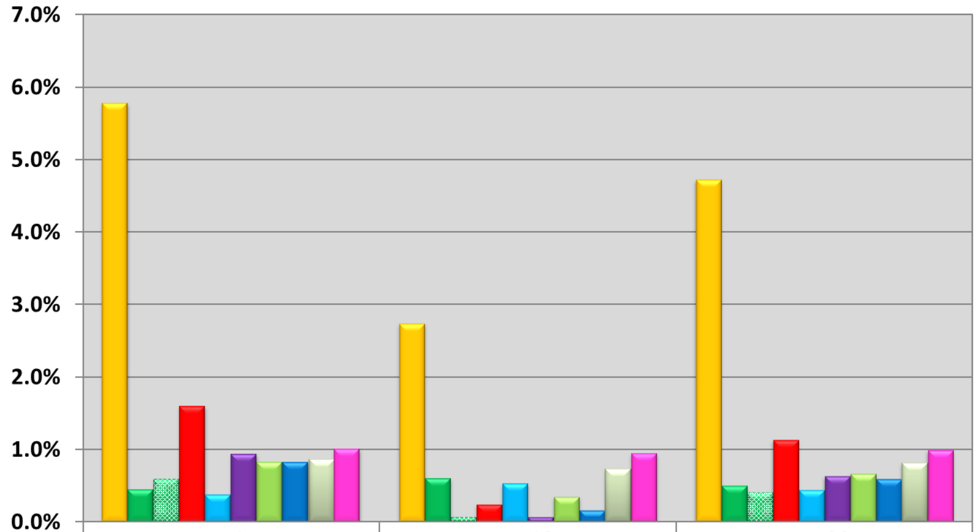
The following graphs are an attempt to highlight the contribution of the single corridors to the overall results coming out from the Reference. Note that the table should be considered an exercise because the two results, the Reference and the aggregation of the Corridor results, are not fully comparable as on the one hand side the Reference includes not only the Corridors but also the completion of the core non Corridor networks, and on the other side the Corridors have many overlapping sections which impact on the changes in transport demand. It should also be noted that the core non Corridor network is more balanced between road and rail than the Corridors, and has not the same impact on freight and passengers, benefitting more passengers as it affects more medium distance travel. The Scandinavia-Mediterranean Corridor is the CNC that contributes most, at the EU28, followed by the Mediterranean CNC in the case of passengers, and by the North Sea Baltic for freight. The other Corridors are contributing 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 51: **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 52: **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 at the European level of the Corridors 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 as shown in Table 37 and Table 38 below.

While for passengers the impact 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, for freight the impact at the EU28 level is always higher and, in some corridors like the Atlantic, is more than double the impact on passenger activity. Freight demand along the corridor is mainly long distance, therefore the increased performance on the corridor affects more visibly the demand on other parts of the European core network; this effect is less evident for passengers whose demand 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 37: 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 38: 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

Economic stimulus of TEN-T investments are highest by the Scandinavian Mediterranean Corridor measured as GDP change in 2030. The Scan Med is actually also the corridor where the largest investment sum is placed revealing a correlation between investment and additional GDP. The same is revealed by the Mediterranean Corridor which is the second largest in terms of investment. It also reveals the second largest influence on GDP in 2030 via the TEN-T investments. Figure 53 gives an overview of the impact of TEN-T investments on GDP for each CNC and all CNCs and CNoCNC.

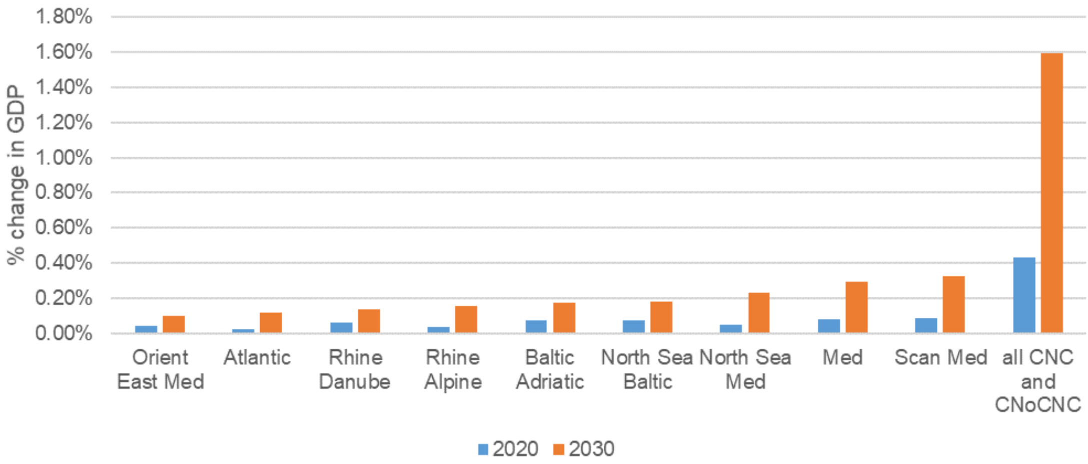
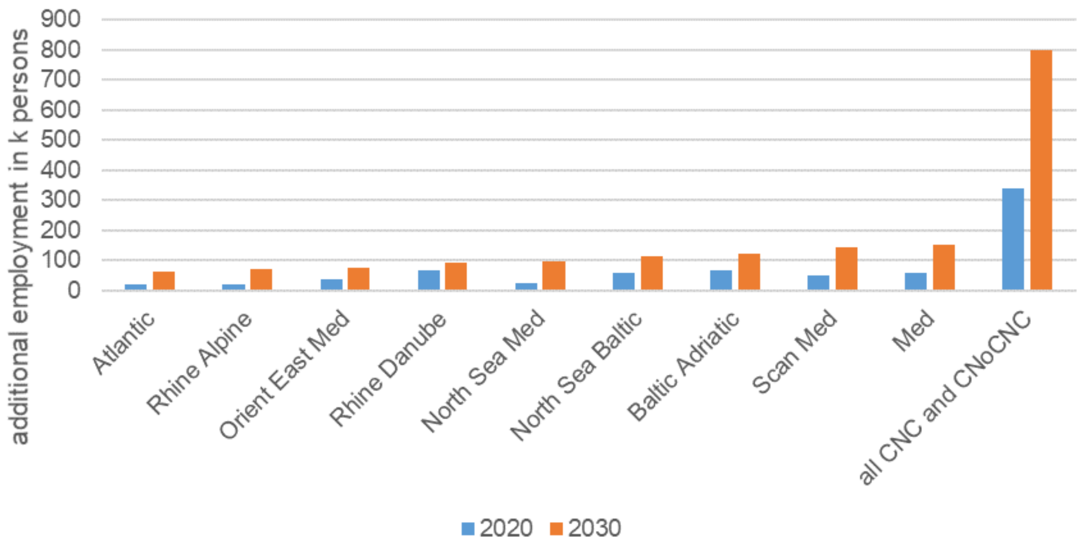


Figure 53: **Impact of TEN-T investments in EU28 on GDP**

Similarly to GDP changes, the two CNCs that gain the highest additional employment are the Scandinavian Mediterranean and the Mediterranean CNC. Overall in 2030, there are about 797 000 people additionally employed in the EU28 due to the TEN-T investments.



Source: ASTRA model

Figure 54: **Impact of TEN-T investments in EU28 on employment**

However, as the economic multipliers have shown (Figure 49, Figure 50), the efficiency of investments is highest for the Baltic-Adriatic Corridor, while Scan-Med and Med corridors providing absolutely for the highest gain in GDP and employment they belong to the medium efficient CNCs as their multipliers are estimated in the middle of the range of multipliers. In other words, highest absolute economic gains and most efficient gains belong to different CNCs.

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

7 Conclusions and Recommendations

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

Looking at the whole transport system of which the core network is an important element of, 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 MS like Spain or Poland just two corridors pass through the countries, in many MS even only one CNC is established. Thus the economic impacts delivering an increase of 1,6% of European GDP reveals the benefit of the TEN-T policy to focus on a core network that eliminates gaps and connects European regions. The concept of the core network corridors can be extended in a fruitful manner by connecting the CNC with regional networks, which can be done in several ways:

- via multi-modal terminals enabling the use of other modes for the regional distribution.
- via upgrading selected links of the comprehensive network closing 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 for the environmental friendly modes.

The next decade still requires a focus on the completion of the CNC to reap the benefits of a strong and integrated network covering Europe in the future, which over time is getting seamlessly integrated with the regional networks. Taking this approach fits better to the vision of a European integration that benefits people and the economy compared with an approach that would seek first the full implementation of regional networks and as a last step would link the various national regional networks across the borders with each other.

Complementary and of equal importance is to achieve the objective of transport decarbonisation. TEN-T core network implementation is contributing to decarbonisation by fostering modal-shift towards environmental friendly 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. This has been acknowledged in the 2016 EU strategy on low-emission mobility.

8 Lists of figures and tables

The following list of figures and list of tables include both the figures and tables that are part of the main report and those that are included in the Annex. The latter are reported starting with page 124.

List of figures

List of tables

9 References

Abiad, A., Furceri, D., Topalova, P. (2015): *The Macroeconomic Effects of Public Investment: Evidence from Advanced Economies*. IMF Working Paper WP/15/95, International Monetary Fund, Washington.

Bivens J. (2014). *The Short- and Long-Term Impact of Infrastructure Investment on Employment and Economic Activity in the US Economy*. EPI Briefing Paper #374. Economic Policy Institute, July 2014.

Bom, PRD., Ligthart, JE. (2009): *How Productive is Public Capital? A Meta-Regression Analysis*. Working Paper 09-12, Andrew Young School of Policy Studies, Georgia State University.

Buffie, E., Berg, A., Pattillo, C., Portillo, R., Zanna, LP. (2012): *Public Investment, Growth and Debt Sustainability: Putting Together the Pieces*. IMF Working Paper WP/12/144, International Monetary Fund, Washington.

Bröcker, J., Korzhenevych, A., & Schürmann, C. (2010). *Assessing spatial equity and efficiency impacts of transport infrastructure projects*. Transportation Research Part B: Meth-odological, 44(7), 795-811.

Bröcker, J. and J. Mercenier (2011) '*General Equilibrium Models for Transportation Economics',* in: Palma, A.de, Lindsey, R, Quinet, E. and R. Vickerman (eds.): *Handbook of Transport Economics*. Cheltenham. 21-46.

Capros, P., De Vita, A., Tasios, N., Siskos, P., Kannavou, M., Petropoulos, A., ... & Paroussos, L. (2016). *EU Reference Scenario 2016 - Energy, transport and GHG emissions Trends to 2050*.

Christophersen, H., Bodewig, K., Secchi, C. (2015): *Making the best use of new financial schemes for European transport infrastructure projects*. Brussels.

Combes, P. P., Duranton, G., Gobillon, L., Puga, D., & Roux, S. (2012). *The productivity advantages of large cities: Distinguishing agglomeration from firm selection*. Econometrica, 80(6), 2543-2594.

Di Cataldo M., Rodríguez-Pose A. (2017): *What drives employment growth and social inclusion in the regions of the European Union?,* Regional Studies, DOI: 10.1080/00343404.2016.1255320

Doll C., Rothengatter W., Schade W. (2015): *The results and efficiency of railway infrastructure financing within the European Union*. European Parlament, Policy Department D, ISBN 978-92-823-8245-5, Brüssel.

EC/SDG – European Commission/Steer Davies Gleeve (2017): Clean Power for Transport Infrastructure Deployment – FINAL REPORT. Study on behalf of the European Commission, London/Brussels.

Ehlers, T. (2014): *Understanding the challenges for infrastructure finance*. BIS Working Papers No. 454. Bank for International Settlements, Basel.

EIB – European Investment Bank (2013): *The Economic Appraisal of Investment Projects at the EIB*. Report by the EIB, Luxembourg.

EIB – European Investment Bank (2016): *EIB operations inside the EU 2016*. Report by the EIB, Luxembourg.

EIOPA (2013): *Discussion Paper on Standard Formula Design and Calibration for Certain Long-Term Investments*. EIOPA, Frankfurt.

Engel, E., Fischer, R., Galetovic, A. (2010): *The economics of infrastructure finance: Public-Private-Partnerships versus public provision*. EIB Papers 15(1):40-69

Engel, E., Fischer, R., Galetovic, A. (2014): *The economics of public-private partnerships: A basic guide*. Cambridge University Press.

European Commission (2013): *EU Energy, Transport and GHG Emissions. Trends to 2050 – Reference Scenario 2013.* European Commission Directorate-General for Climate Action and Directorate-General for Mobility and Transport. Brussels, Belgium.

European Commission (2015): *The 2015 Ageing Report. Economic and budgetary projections for the 28 EU member states*. European Economy 3/2015, DG ECFIN.

European Commission (2016): *Impact Assessment accompanying the Proposal for a Directive of the European Parliament and of the Council amending Directive 2012/27/EU on Energy Efficiency*. Commission Staff Working Document, COM(2016) 761 final, Brussels.

European Commission (2017): *The 2018 Ageing Report. Underlying Assumptions & Projections Methodologies*. European Economy Institutional Papers 65, DG ECFIN.

European PPP Expertise Centre - EPEC (2017): *Market Update Review of the European PPP Market in 2016.* European Investment Bank.

European Central Bank (2017). *Asset Purchase Programmes*. Retrieved in October from: https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html#abspp

Exel J., Rienstra S., Gommers M., Pearman A., Tsamboulas D. (2002): *EU involvement in TEN development: network effects and European value added*. In: Transport Policy, 9, p. 299-311.

Ferrari, M., Giovannini, A., Pompei, M. (2016): *The challenge of infrastructure financing*. Oxford Review of Economic Policy, Vol. 32(3):446-474.

Fratzscher, M. (2015): *Der Bericht der Expertenkommission zur „Stärkung von Investitionen in Deutschland“*. Wirtschaftsdienst, Vol. 95(7).

Fermi F., Fiorello D., Krail M., Schade W. (2014): *Description of the ASTRA model and of the user interface*. Deliverable D4.2 of ASSIST (Assessing the social and economic impacts of past and future sustainable transport policy in Europe). Project co-funded by European Commission 7th RTD Programme. Fraunhofer-ISI, Karlsruhe, Germany

Graham, D.J. (2006) *Wider Economic Benefits of Transport Improvements: Link Between City Size & Productivity.* Study on behalf of the DfT. London.

Group of Thirty (G30) Working Group (2013): *Long-Term Finance and Economic Growth*. Group of Thirty, Washington.

Gutiérrez, J., Condeço-Melhorado, A., López, E., & Monzón, A. (2011). *Evaluating the European added value of TEN-T projects: a methodological proposal based on spatial spillovers, accessibility and GIS*. Journal of Transport Geography, 19(4), 840-850.

Haider M., Crowley D., DiFrancesco R. (2013*). Investing in Ontario´s Infrastructure for Economic Growth and Prosperity.* Commissioned by the Residential and Civil Construction Alliance of Ontario.

Hartwig J., Kockat J., Schade W., Braungardt B. (2017): *The macroeconomic effects of ambitious energy efficiency policy in Germany – Combining bottom-up energy modelling with a non-equilibrium macroeconomic model*. Energy 124, pp. 510-520.

Heintz, J., Pollin, R., Garrett-Peltier, H. (2009): *How Infrastructure Investments Supports the US Economy: Employment, Productivity and Growth*. Political Economy Research Institute, University of Massachusetts Amherst, January 2009.

ITF – International Transport Forum (2013): *Understanding the value of transport infrastructure - Guidelines for macro-level measurement of spending and assets*. OECD/ITF task force report, Paris Krail M. (2009): *System-Based Analysis of Income Distribution Impacts on Mobility Behaviour*. Nomos-Verlag, Baden-Baden, Germany.

Krail M. (2009): *System-Based Analysis of Income Distribution Impacts on Mobility Behaviour*. Nomos-Verlag, Baden-Baden, Germany.

Mercenier J., Álvarez-Martínez M., Brandsma A., Di Comite F., Diukanova O., Kancs d'A., Lecca P., López-Cobo M., Monfort P., Persyn D., Rillaers A., Thissen M., Torfs W. (2016): *RHOMOLO-v2 Model Description: A spatial computable general equilibrium model for EU regions and sectors*. JRC Technical Reports JRC100011, European Commission, DG Joint Research Centre, EUR 27728 EN, doi:10.2791/18446.

Metsäranta H., Törmä H., Kinnunen J., Laakso S., Zimoch U. et al. (2013). *The wider economic impacts of transport. Bothnian Green Logistic Corridor*. Project part financed by the European Regional Development Fund and European Neighbourhood and Partnership Instrument.

Mohring H. (1993): *Maximizing, measuring, and not double counting transportation-improvement benefits: a primer on closed- and open-economy cost-benefit analysis*. In: Transportation Research - Part B, vol. 27B, no. 6, pp. 413-424.

OECD (2016): *Annual Survey of Large Pension Funds and Public Pension Reserve Funds*. OECD Publishing, Paris.

OECD (2017): *Investing in Climate, Investing in Growth*. OECD Publishing, Paris.

Preqin (2017a): *Preqin Global Infrastructure Report.* Preqin Ltd.

Preqin (2017b): *Preqin Quarterly Infrastructure Update Q1 2017.* Preqin Ltd.

Rothengatter, W. (2017) *Wider Economic Impacts of Transport Infrastructure Investments: Relevant or Negligible?* To appear in: Transport Policy.

Schade W. (2005): *Strategic Sustainability Analysis: Concept and application for the assessment of European Transport Policy*. NOMOS-Verlag, ISBN 3-8329-1248-7, Baden-Baden.

Schade W., Meija-Dorantes L., Rothengatter W., Meyer-Rühle O., Kritzinger-S. (2014): *Update on Investments in Large TEN-T Projects*. Report published by the European Par-liament Policy Department B, Brussels.

Schade W., Krail M., Hartwig J., Walther C., Sutter D., Killer M., Maibach M., Gomez-Sanchez J., Hitscherich K. (2015): *Cost of non-completion of the TEN-T*. ISI, PTV, Infras, M-Five, Study on behalf of the European Commission DG MOVE, Karlsruhe, Germany.

Schade, W., Hartwig, J., Maffii, S., Martino, A., de Stasio, C., Welter, S. (2017a): *The impact of TEN-T completion on growth, jobs and the environment – INCEPTION REPORT.* Report on behalf of the European Commission. Karlsruhe, Milan.

Schade, W., Hartwig, J., Rothengatter, W., Welter, S. (2017b): *Explanation and clarification of economic terminology in the TEN-T growth debate.* Working Paper, M-Five, Karlsruhe.

Schade W., Bellodi L., Hartwig J., Maffii S., Martino A., de Stasio C., Welter S. (2019*) The impact of TEN-T completion on growth, jobs and the environment – First INTERMEDIATE REPORT.* Report on behalf of the European Commission. Karlsruhe, Milan.

Sterman, J. D. (2000): *Business Dynamics. Systems Thinking and Modeling for a Complex World*. McGraw-Hill.

Sichelschmidt, H. (1999). *The EU programme "trans-European networks"—a critical as-sessment*. Transport Policy, 6(3), 169-181.

Spiekermann, K., & Wegener, M. (1996). *Trans-European networks and unequal accessibility in Europe*. European journal of regional development, 4(96), 35-42

Venables, A. (2007) *Evaluating urban improvements. Cost-benefit analysis in the presence of agglomeration and income taxation*, Journal of Transport Economics and Policy, 41.173-186.

Venables A. J. (2016). *Incorporating wider economic impacts within cost-benefit appraisal*. Discussion paper for International Transport Forum.

Wangsness, P. B., Rødseth, K. L., & Hansen, W. (2017). *A review of guidelines for including wider economic impacts in transport appraisal*. Transport Reviews, 37(1), 94-115.

Weisbrod, G., Reno, A. (2014): *Economic Impact of Public Transportation Investment*. Prepared for the American Public Transportation Association. May 2014